This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

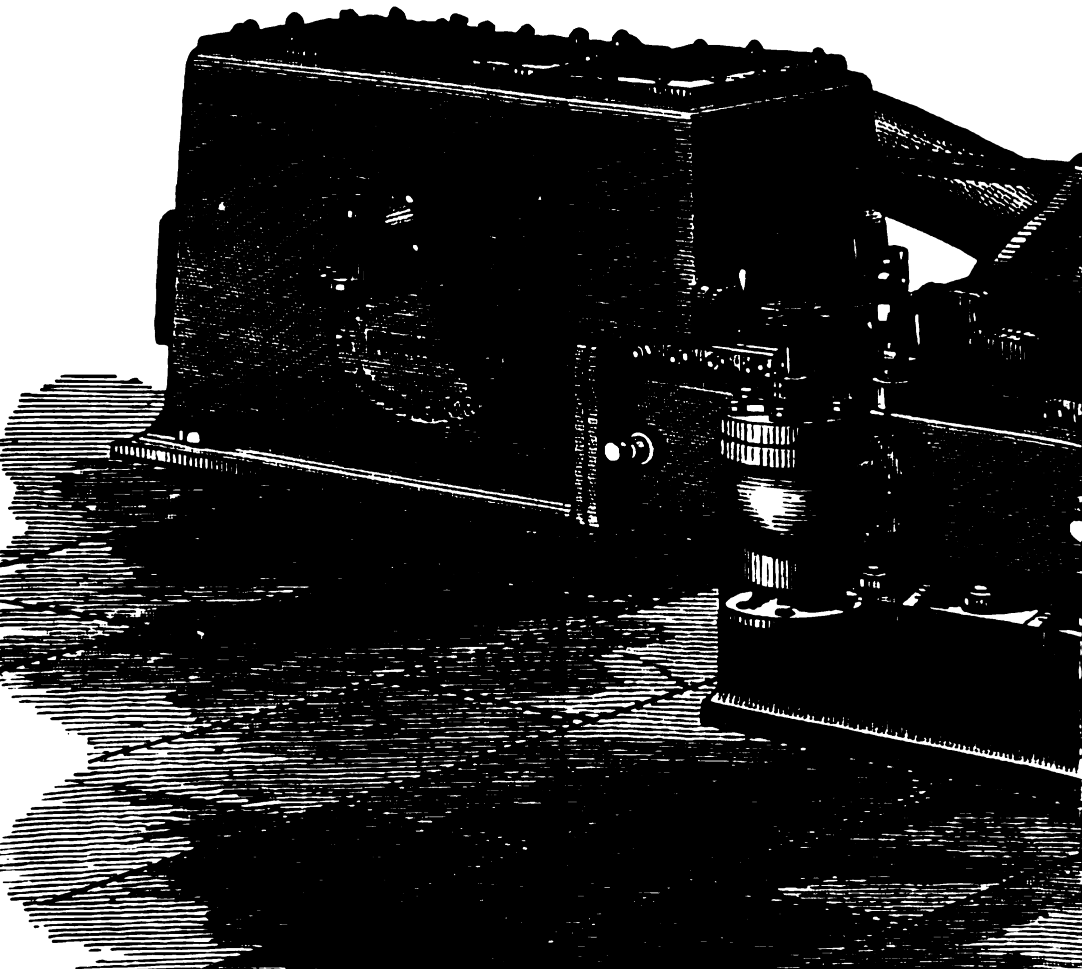
Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at http://books.google.com/



Report on machinery and manufactures, with an account of ...

Digitized by Google

1837
ARTES VERITAS SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
TUEBOR
SI QUAERIS PENINSULAM AMOENAM CIRCUMSPICE
DEPARTMENT
OF
ENGINEERING

Digitized by Google

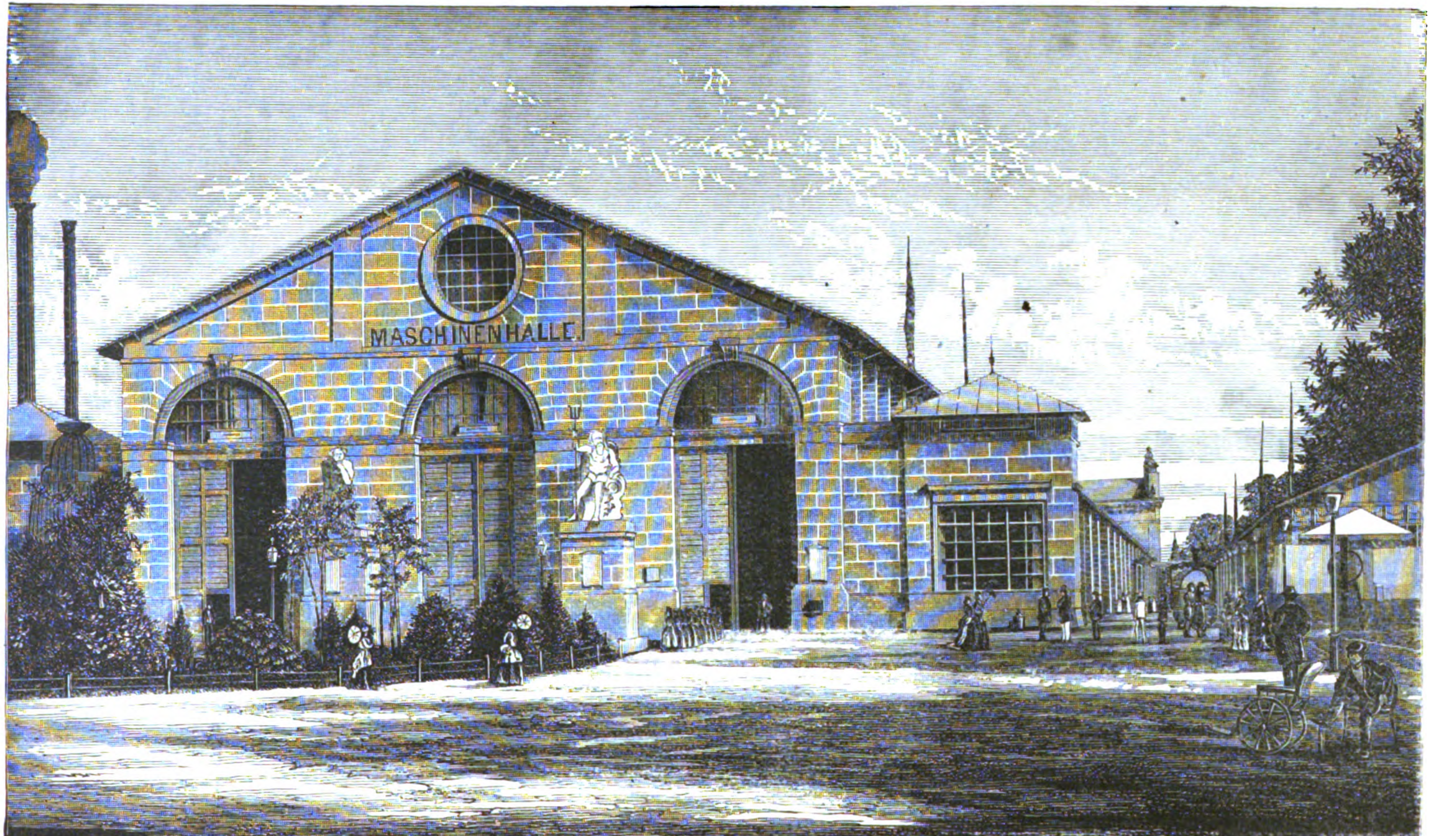
Engin. Library
TJ
6
.T55

Digitized by Google

Digitized by Google

Digitized by Google

FRONTISPIECE.



Machinery Hall.

Digitized by Google

VIENNA INTERNATIONAL EXHIBITION, 1873.

GENERAL LIBRARY UNIVERSITY OF MICHIGAN

REPORT

ON

MACHINERY AND MANUFACTURES,

WITH

AN ACCOUNT OF EUROPEAN MANUFACTURING DISTRICTS.

BY

ROBERT H. THURSTON, A. M., C. E.,

PROFESSOR OF MECHANICAL ENGINEERING; STEVENS INSTITUTE OF TECHNOLOGY; MEMBER OF THE SCIENTIFIC COMMISSION OF THE UNITED STATES.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1875.

Digitized by Google

TABLE OF CONTENTS.

PART I.

MACHINERY AT VIENNA, 1873.

INTRODUCTION.

MACHINERY AND TOOLS.

INTRODUCTION.

CHAPTER I.

STATIONARY STEAM-ENGINES.

Digitized by Google

CHAPTER II.

MARINE STEAM-ENGINES.

CHAPTER III.

LOCOMOTIVE-ENGINES.

Digitized by Google

CHAPTER IV.

ROAD-LOCOMOTIVES OR TRACTION-ENGINES.

CHAPTER V.

PORTABLE ENGINES; STEAM FIRE-ENGINES.

CHAPTER VI.

STEAM-BOILERS AND ATTACHMENTS.

Digitized by Google

CHAPTER VII.

AIR AND GAS ENGINES.

Digitized by Google

CHAPTER VIII.

HYDRAULIC MOTORS.

CHAPTER IX.

PUMPS.

CHAPTER X.

METAL-WORKING AND WOOD-WORKING MACHINERY.

Digitized by Google

Digitized by Google

CHAPTER XI.

TEXTILE AND MISCELLANEOUS MACHINERY.

CHAPTER XII.

GENERAL REVIEW.

Digitized by Google

PART II.

EUROPEAN MANUFACTURING DISTRICTS.

CHAPTER I.

SWITZERLAND AND ITS MANUFACTURES.

CHAPTER II.

MANUFACTURING IN GERMANY.

CHAPTER III.

GERMAN MANUFACTURING ESTABLISHMENTS AND TECHNICAL SCHOOLS.

Digitized by Google

CHAPTER IV.

BELGIAN AND FRENCH MANUFACTURING ESTABLISHMENTS AND TECHNICAL SCHOOLS.

CHAPTER V.

MANUFACTURING IN GREAT BRITAIN.

Digitized by Google

Digitized by Google

LIST OF ILLUSTRATIONS.

[Full-page illustrations are indicated by an *.]

Digitized by Google

Digitized by Google

Digitized by Google

TABLES.

Digitized by Google

REPORT

ON

MACHINERY AND MANUFACTURES.

PART I.

MACHINERY EXHIBITED AT VIENNA, 1873.

1 MA

Digitized by Google

[If the history of the progress of the mechanical arts be interesting, still more so, doubtless, would be the exhibition of their present state and a full display of the extent to which they are now carried. The slightest glance must convince us that mechanical power and mechanical skill, as they are now exhibited in Europe and America, mark an epoch in human history worthy of all admiration. Machinery has been made to perform what has formerly been the toil of human hands to an extent that astonishes the most sanguine, with a degree of power to which no number of human arms is equal, and with such precision and exactness as almost to suggest the notion of reason and intelligence in the machines themselves. Every natural agency is put unrelentingly to the task. The winds work, the waters work, the elasticity of metals works; gravity is solicited into a thousand new forms of action; levers are multiplied upon levers; wheels revolve on the periphery of other wheels; the saw and the plane are tortured into an accommodation to new uses; and, last of all, with inimitable power, and "with whirlwind sound," comes the potent agency of steam. In comparison with the past, what centuries of improvement has this single agent comprised in the short compass of fifty years! Everywhere practicable, everywhere efficient, it has an arm a thousand times stronger than that of Hercules, and to which human ingenuity is capable of fitting a thousand times as many hands as belonged to Briareus. Steam is found in triumphant operation on the seas; and, under the influence of its strong propulsion, the gallant ship,

> Against the wind, against the tide,
> Still steadies with an upright keel.

It is on the rivers, and the boatman may repose on his oars; it is on highways, and exerts itself along the courses of land-conveyance; it is at the bottom of mines, a thousand feet below the earth's surface; it is in the mill, and in the workshops of the trades. It rows, it pumps, it excavates, it carries, it draws, it lifts, it hammers, it spins, it weaves, it prints. It seems to say to men, at least to the class of artisans, "Leave off your manual labor; give over your bodily toil; bestow but your skill and reason to the directing of my power, and I will bear the toil, with no muscle to grow weary, no nerve to relax, no breast to feel faintness!" What further improvement may still be made in the use of this astonishing power it is impossible to know, and it were vain to conjecture. What we do know is, that it has most essentially altered the face of affairs, and that no visible limit yet appears beyond which its progress is seen to be impossible.—DANIEL WEBSTER.]

Digitized by Google

REPORT ON MACHINERY AND MANUFACTURES.

PART I.

REPORT ON MACHINERY EXHIBITED AT VIENNA, 1873.

INTRODUCTION.

SUCCESS OF THE EXHIBITION; MACHINERY-HALL; SCOPE OF THE REPORT; CHARACTER OF THE EXHIBIT AS A WHOLE; THE INTERNATIONAL JURY; DEFECTS OF THE JURY-SYSTEM; ORGANIZATION OF THE JURY; METHODS OF JURY-WORK; ASSIGNMENT OF JURORS FROM THE UNITED STATES; DISTRIBUTION OF AWARDS; PERIODS OF SESSION; STATISTICS OF AWARDS; FAULTS OF MANAGEMENT ON THE PART OF EXHIBITORS; CAUSES OF SUCCESS OF EXHIBITORS FROM THE UNITED STATES; THE UNITED STATES SECTION; THE EXHIBITION AS A WHOLE; CONTINENTAL NATIONS AS COPYISTS.

1. The Vienna International Exhibition of 1873 was probably the most completely satisfactory exhibition of industrial processes, apparatus, and products that has yet been attempted.

The general administration, the organization of the Exhibition, and the manner in which it was conducted throughout the period of its existence were admirable. The defects of arrangement and errors in management and the accidents which sometimes occurred to break in upon the absolute smoothness with which the machinery of administration and management usually ran were much fewer and less important than might have been expected in such a gigantic and unexampled enterprise.

2. Among the many interesting departments of the Exhibition, none were more interesting to the general public and none assumed greater importance in the eye of the political economist and the statesman than that contained within the "*Maschinen Halle.*" (Frontispiece.)

Within this great building (which had a floor-space of 40,000 square meters, or nearly ten acres) were collected many thousands of exhibits, embracing every known variety of machinery. The building was traversed, as shown in the engravings illustrating this report, from end to end by two aisles, dividing the machinery in motion, which was distributed along the middle line of the building, from that which did not require motive-power, and which was arranged on either side.

The visitor walking through the building found on either side, for a distance of a half-mile, an unbroken mass of machinery, of every class,

Digitized by Google

of all degrees of magnitude, and of every conceivable variety of style, material, workmanship, and finish. The difficulty of making a complete and satisfactory examination of all of these devices, many of which would demand the attention for hours, or even days, if the visitor were attempting to acquire a thorough knowledge of details, may readily be conceived. The utmost patience, the most complete knowledge of engineering, and steady application throughout the whole period of the exhibition would scarcely suffice. To examine the 5,000 exhibits of Group XIII alone, giving five minutes to each, would require more than forty days' work of ten hours each. But a single "exhibit" was frequently composed of several, or even of many, separate machines, either of which would afford full compensation for hours expended in study. This was the case with the majority of the exhibits in the United States section, and with many others in every department.

It would, therefore, be quite hopeless to attempt to make a report upon this class of exhibits absolutely complete; and if it can be made even tolerably satisfactory, the reporter may consider himself fortunate.

3. The report here given is confined to the department to which the writer was assigned, as a member of the International Jury—to Group XIII, Machinery.

In this group are comprehended many classes of machinery with which, either in consequence of their infrequent use in America or of a complexity which demanded such study as time did not permit, the writer was not sufficiently familiar to criticise confidently. Other classes are of little interest to the manufacturers and the workingmen of the United States, in consequence of the fact that they have already learned to excel foreign makers to such a degree that to describe them would be a simple repetition of a story long ago familiar.

The endeavor has been to condense within the following pages as much information as could properly be gathered into such a report, omitting as little as possible that might be expected to prove useful to its readers, and accepting information, supplementary of the observation of the writer, from whatever source it could be obtained.

Such a report must necessarily partake somewhat both of the character of a treatise upon industrial materials, apparatus, and processes, and of that of a descriptive catalogue of exhibits. It has been the intention of the writer to criticise impartially and to suggest, where it appeared proper, directions in which to look for further progress. The work has been one of difficulty, but of exceeding interest; arduous, but very instructive.

4. The collection of machinery, as a whole, was somewhat unsymmetrical and incomplete. Many classes of machines were entirely unrepresented, and others were exhibited in numbers quite disproportionate to their importance.

The unfortunate patent-systems of Europe prevented many foreign makers from appearing where they considered themselves liable to the

Digitized by Google

piracy of their most valuable devices. The somewhat illiberal spirit which prevails to a greater extent in Europe than in the United States, and which induces manufacturers to avoid giving more publicity than they are compelled to less important matters of detail, also had the effect of keeping away many well-known European manufacturers. But, in spite of this, the collection formed a magnificent encyclopedia of mechanism.

The official examination and the award of prizes throughout the exhibition were intrusted to an International Jury.

5. THE INTERNATIONAL JURY consisted of over six hundred members, selected by the governments of the countries exhibiting at Vienna. It was divided into twenty-six "groups," to each of which was assigned a department of the Exhibition for examination.

The members of the jury were appointed to those groups in which they were supposed to be fitted to act most intelligently.

6. Group XIII comprehended all machinery and means of transport. The exhibits in this group were 4,694 in number, and were distributed in four sections, exclusive of agricultural machinery, which was assigned to Group-jury II. It was to this group that the writer was assigned.

These exhibits were classified as follows:

Number of exhibits in Group XIII, exclusive of agricultural machinery.

Sections.	Russia.	Hungary.	Austria.	Germany.	France.	Switzerland.	England.	United States.	Belgium.	Italy.	Sweden and Norway.	Denmark.	Holland.	Totals.	
I.															
Prime movers	14	7	98	210	55	34	20	5	6	2	8	1	7		467
II.															
Metal-working machinery	6	3	61	180	30	17	39	34	21	12	....	....	....	403	3,432
Wood-working machinery	1	3	83	50	26	....	60	24	....	...	31	....	...	278	
Textile machinery	....	3	293	300	54	65	65	3	45	...	....	....	...	828	
Various kinds, unclassified	18	64	518	330	83	38	266	450	97	8	....	40	11	1,923	
III.															
Means of transport	58	75	152	60	18	4	22	22	120	3	3	1	1		539
IV.															
Street-railroads	23	43	92	52	10	6	24	1	...	....	1	4	....		526
Totals	120	198	1,297	1,182	276	164	496	539	289	25	43	46	19		4,694

7. The great defect of the jury-system of examination and report, as adopted at these international exhibitions, is one which is evidently inherent, and one which it is probably impossible to completely remedy.

The large number of exhibits, the comparatively small number of jurors, and the limited time allowed, forbid that thorough examination and careful comparison which should always precede the formation of an opinion and the framing of a report. In many cases only an actual

Digitized by Google

and careful test of the competing apparatus can give a really reliable basis for discrimination. The steam-engine which received the highest honor at Vienna was quite well designed and very well constructed; yet there were many others, apparently at least, equally as well designed and quite as well built. The jury could not, however, find time to make a test-trial of each, but were compelled to rely upon appearances, and, perhaps, to give some weight to the reputation of the firm. There seems to be no remedy for this defect; it is, however, a very serious one.

8. The jury to which was assigned the examination of Group XIII was composed as follows:

GROUP XIII.

PRESIDENT.

Herr Wilhelm Ritter von Engerth, of Vienna, Austria.

VICE-PRESIDENTS.

Herr Dr. C. Karzmarsch, director of the Polytechnic School of Hanover, German Empire.

Dr. J. Anderson, machinery department, Woolwich, Great Britain.

JURORS.

Herr C. A. Angström, professor in Technical School at Stockholm, Sweden.

M. Belpaire, inspector-general of railways, Belgium.

Herr Dr. Böttcher, director of the Industrial School of Chemnitz, German Empire.

Signor Colombo Cavaliere, professor, Giuseppe, Italy.

Herr Professor G. Delabar, of St. Gallen, Switzerland.

M. Ehrler, France.

Herr Rudolph Grimus, Ritter von Grimburg, professor in the Technical Academy, Vienna, Austria.

Herr Dr. E. Hartig, professor at Dresden Polytechnic School, German Empire.

Herr Gustav Herrmann, professor in Technical School at Aachen, German Empire.

G. V. Holmes, esq., Great Britain.

Joseph E. Holmes, esq., New York, United States of America.

Herr Carl Jenny, professor in Technical School at Vienna, Austria.

Herr von Kessler, director of the *Maschinenfabrik Esslingen*, German Empire.

Herr Johann Lindemann, captain, Denmark.

Herr Jacob Lohner, of Vienna, Austria.

Signor Padula, professor in Engineering School of Naples, Italy.

Herr Emerich Pekar, Hungary.

Herr Carl Pfaff, of Ottakring, Vienna, Austria.

Digitized by Google

Herr F. Reuleaux, director of the Polytechnic School at Berlin, German Empire.
Mon. H. Schneider, of Creuzot, France.
C. W. Siemens, esq., F. R. S., London, Great Britain.
Herr G. Sigl, of Vienna, Austria.
Prof. R. H. Thurston, of the Stevens Institute of Technology, New Jersey, United States of America.
Mon. H. Tresca, subdirector of the *Conservatoire des Arts et Métiers*, Paris, France.
Herr Stephan Verderber, chief engineer in the Hungarian board of trade, Pesth, Hungary.
M. J. Vichnegradski, professor in Industrial Academy, St. Petersburg, Russia.
Herr A. Wöhler, of Berlin, German Empire.

SUPPLEMENTARY JURORS.

Herr Professor Autenheimer, of Basel, Switzerland.
M. J. Beco, ingénieur, Belgium.
Herr Max Bielek, professor in Pesth, Hungary.
Signor Chizzolini, Italy.
M. Desouches, France.
Herr Emil Herrmann, Hungary.
M. V. Kirpitscheff, professor in Technical School of St. Petersburg, Russia.
M. Henri Mathieu, France.

EXPERT.

M. Kindt, Belgium.

9. The majority of these names are familiar to engineers as those of men who are distinguished either in the practice of the profession or for their scientific attainments. The working of the jury, as a whole, indicated a fortunate combination of the two classes which composed it.

The jury assembled on Saturday, June 14, and, after organization, several days were occupied in the arrangement of the plan of operations and in discussing the general methods to be pursued.

10. The group-jury was finally divided into sections as follows:

SECTION 1.—Prime movers.

SECTION 2.—Machines for working metal, wood, and textile materials.

SECTION 3.—Means of transport in general.

SECTION 4.—Street-transportation.

Section 2, containing nearly three-fourths of all the exhibits in Group XIII, was further separated into two subdivisions:

Class 1.—Wood and metal working machinery.

Class 2.—Textile machinery, including sewing-machinery.

11. In the absence of his colleague on Group XIII, who had not then reported, the writer attached himself to Class 1, Section 2, in which

Digitized by Google

were interested the larger number of exhibitors from the United States, and which included our most important interests. The second member was assigned to Class 2 of the same section, as that was considered next in importance. The remaining sections were unavoidably left without representatives from the United States. On the whole, this fact probably did not injuriously affect the standing of the comparatively small number of exhibitors interested in those sections.

12. In some instance the awards proposed for our exhibitors were evidently not such as were deserved; but a simple representation of the case at a session of the group-jury was usually sufficient to secure reconsideration. Awards that were deemed satisfactory were, in most instances, allowed after a more complete investigation had been made.

We have to regret that in two or three cases the lack of familiarity of members of the jury with the conditions under which our industrial enterprises are conducted, or their peculiar views of business principles, or of manufacturing processes as derived from an experience differing vastly from that of the American mechanic, prevented exhibitors from obtaining the high awards to which they were properly entitled. It is fortunate, however, that in these cases the exhibitors had already attained a reputation at home which rendered them perfectly safe against the false inference which might have been based upon their non-success had they been less well known.

13. The sessions of the sectional juries were held daily, and occupied all available time up to July 18. During this period, the jury met every morning at 9 o'clock, and spent the day examining exhibited machinery and in comparing their claims to distinction. As awards were determined upon, they were reported to the group-jury for confirmation.

14. On the 9th day of July the writer was detailed by the Commissioner-general to represent the executive commission at the international field-trial of agricultural implements and machinery at Sieb-nbrunn. A detailed account of this trial, which resulted in securing an *Ehren Diplom* for one American machine, and medals for several other mowers and reapers from the United States, will properly be given in the report of the jury. The trial occupied the entire day, and was very satisfactory, so far as it went. The competition was, in fact, one between exhibitors from the United States. The English exhibitors had withdrawn entirely, and the only foreign-built machines which entered the field were too heavy and too inconveniently arranged to have a chance of success.

The best of the European machines was that of Hofherr, of Vienna, a substantial and well-built machine, which did good work.

The trial was very incomplete, as no dynamometric determinations of direct traction or side-draught were made. No special examination was made of the condition of machines before and after their work was done, and no means were adopted to ascertain whether heated journals or choked knives and machinery were more difficult of prevention in one

Digitized by Google

machine than in another. The character of the work done, the time occupied, and the general construction of each machine were the bases of awards.

15. The result of the work of the jury of Group XIII will be seen on examining the report of the Commissioner-general and the official list of awards published by the Austrian authorities. Awards were distributed amongst various countries as follows:

Country.	Diplomas of honor.	Medals of progress.	Medals of merit.	Diplomas.	Total.
America	2	30	23	18	73
England	5	39	43	41	128
France	6	41	37	42	126
Switzerland	3	14	19	12	48
Denmark	1	2	4	5	12
Sweden	1	2	3	1	7
Belgium	2	9	11	15	37
Germany	10	83	169	79	341
Austria	8	49	84	104	245
Hungary	1	10	10	24	45
Russia	1	7	16	13	37
Total	40	286	419	354	1,099

16. Comparing the awards made to the exhibitors from the United States with those accorded to those from other countries, there will be noticed a marked difference between the proportions of the number of medals of progress to that of medals of merit in Group XIII.

There were a larger number of the former given to the United States in this group than of the latter. This proportion was reversed with all other nations. American exhibitors received thirty medals of progress and twenty-three medals of merit. The former award was intended to be given to exhibitors who had given evidence of marked improvement, effected since the year 1867, the date of the last international exhibition. It is to be taken as a reward, not only of intrinsic merit, but of an actual advance, within this period, effected in a device which was then considered particularly meritorious.

17. Of the total of nine diplomas of honor granted in all groups to exhibitors from the United States, five were awarded to national, state, or municipal institutions and four to individual exhibitors.

The diploma of honor was the highest honor given at Vienna. It was intended to confer peculiar distinction upon those who had aided most effectively by intellectual, industrial, or material contributions, the advancement of civilization. This highest award was made only by the council of presidents of juries, on the recommendation of a group-jury. Of the four diplomas of honor accorded to private exhibitors from the United States, three were given to exhibitors of important classes of machinery, viz: To George H. Corliss, for the Corliss steam-engine; to William Sellers & Co., for machine-tools and metallurgical machinery, and to W. A. Wood, for mowing-machines.

Digitized by Google

There was no opposition to the proposal to confer this high honor upon these exhibitors, and the recommendation was made unanimously. An apparent legal impediment in the case of the first-named was found in the fact that the recipient of the award did not formally exhibit his machine. This difficulty was met by the statement that, notwithstanding the fact that he did not appear as exhibitor, a large proportion of the steam-engines entered having been copied from his designs, he was really represented in every section of the Exhibition and by the engine-builders of every manufacturing nation. His name was familiar to every member of the jury, and, with the majority, his was the only name which had become known in connection with the recent improvement of the steam-engine in the United States. No real opposition appeared to this nomination, which was actively sustained by the ablest members of the jury.

18. On the whole, the awards made to the exhibitors in the United States section were very judiciously distributed, and the few errors which an inspection of the official list may reveal are due principally to the unfamliarity of the majority of members of the jury with the advanced methods and the fine distinctions to which the American mechanic is accustomed. Consequently, the difficulties met by our exhibitors in the endeavor to present fully the merits of their devices were sometimes serious.

American exhibitors were extremely careless, also, in preparing proper circulars for the use of the jury. Exhibitors of other nations usually had circulars printed in the English, French, and German languages, in which their exhibits were carefully described, and, when necessary, the descriptive text was illustrated by neatly-made engravings, showing every important detail plainly, and in which all points of difference between it and other devices of the same class were distinctly pointed out, and the consequent advantages stated, the points taken being sustained by evidence. Some of these exhibitors even published books of considerable size, and of great intrinsic value.

In many cases, the exhibits in the United States section were unaccompanied by even an ordinary business circular. It was very generally the fact that no representative of the exhibitor had accompanied them to Vienna, and it became necessary for the members of the executive commission and its employés, and for members of the jury, to devote an amount of time and attention to these matters which could with difficulty be given them at a time when the pressure of official duties was in itself a serious burden upon both the physical and the mental powers.

19. The success of exhibitors in the United States section is, therefore, all things considered, somewhat remarkable, and it is an evidence of the high reputation acquired by American mechanics abroad, as well as of the actual merit of their productions. It could hardly have been possible for them, in the absence of proper representatives, to have

Digitized by Google

secured so careful an examination of their contributions as was given them by the overworked jury, solicited as its members were, on all sides, by the active agents of competitors, had not the members already learned to look to the United States for very much of all that is novel and ingenious in modern mechanism.

20. During the attendance of the writer at the Exhibition, his time was too closely occupied with jury-work to permit as complete an examination as it was desired to make of the specimens of engineering skill there shown outside of the group to which his attention was officially called.

Of the section assigned to the United States, an account has already been given in a report made while in Vienna, and which was forwarded by the United States minister. It is only necessary here to repeat that that department was sadly deficient in the variety of its exhibits and in the extent of its display. The most creditable portion of the section was that in the machinery-hall, where a larger number of original inventions, ingenious machines, and "new and useful" devices were exhibited than could be found elsewhere.

The accompanying plan and the illustrations distributed through this report, which were made from photographs, exhibit better than could any verbal description the arrangement and appearance of the United States section, and of other parts of Machinery-Hall.

21. The exhibition, as a whole, was remarkably deficient in novelties n apparatus or in processes, and an American mechanic could not fail to be surprised by the evident lack of originality among European constructors, and to be disappointed in his expectation of finding, at an "international exhibition," in which the whole civilized world was represented, so little that was new and such slight evidence of progress in the industrial arts since the Paris Exposition of 1867.

In comparing the sections assigned to the various nations which were represented in Machinery-Hall, it became evident on the most cursory examination that the truly novel was almost invariably found in the sections of Great Britain and the United States.

Great Britain greatly excelled all other nations in the variety of machinery exhibited, in substantial construction, and in the effectiveness of her standard machinery. The display made by citizens of the United States was, though limited in extent, the richest in new forms of apparatus, and contained by far the most striking examples of the special adaptation of machines to peculiar varieties of work, and of what is commonly designated as "labor-saving" machinery.

22. All other nations, as a rule, simply presented copies of British and American machines. These were frequently announced as such, seemingly to secure confidence in their value. Corliss engines, and tools marked "*Système Sellers*," or copied from Browne & Sharpe, Pratt & Whitney, and others of our well-known mechanics, were frequently met with.

Digitized by Google

When a deviation from standards had been attempted, it was very commonly unsuccessful, both in design and execution. The French firms of Ducommun & Co., of Mulhouse, and Schneider, of Creuzot, were marked exceptions to this rule, as were also the Cockerill Iron Works, of Seraing, Belgium, and Krupp, of Essen, Prussia. All of these establishments

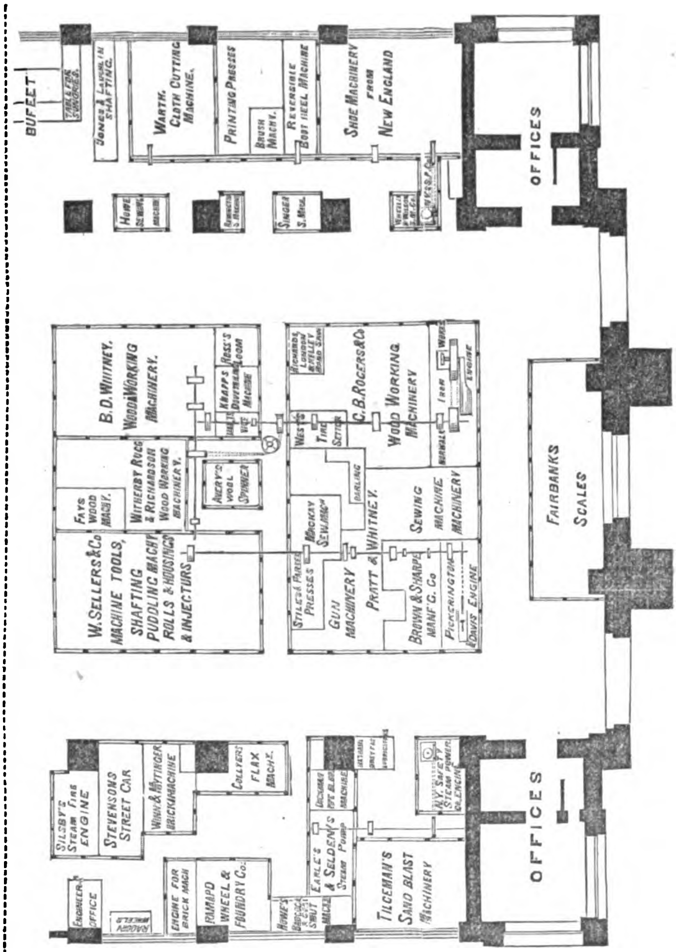


FIG. 1.—United States Section, Machinery-Hall. (Plan.)

turned out work that was remarkable for its excellence of material and finish. They exhibited less originality in design than their British and American competitors, but in standard designs they were almost unexcelled.

Several Austrian firms, notably that of Pfaff, Fernau & Co., of Vienna, in the manufacture of machinery, and George Sigl, in locomotive-building, did excellent work.

Borsig, of Berlin; Schmaltz of Saxony, and Zimmermann, exhibited well-made machines.

Digitized by Google

The Zurich builders attracted attention as the exhibitors of work of more than usual excellence, and also as having produced some excellent and partly original designs. They were evidently far in advance of average European practice.

The observations made by the writer when studying in detail the class of exhibits with which he was particularly conversant, and in which he was, by habits and pursuits, most interested, are given in the succeeding Report on Special Exhibits; while those made upon the general tour of Europe, after the completion of the work at Vienna, follow in a section devoted to European manufacturing establishments and technical schools.

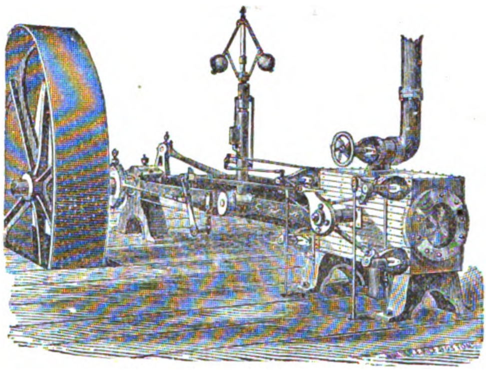


FIG. 2.—The Corliss engine.

Digitized by Google

Digitized by Google

Vienna Exhibition 1873. Machinery etc.

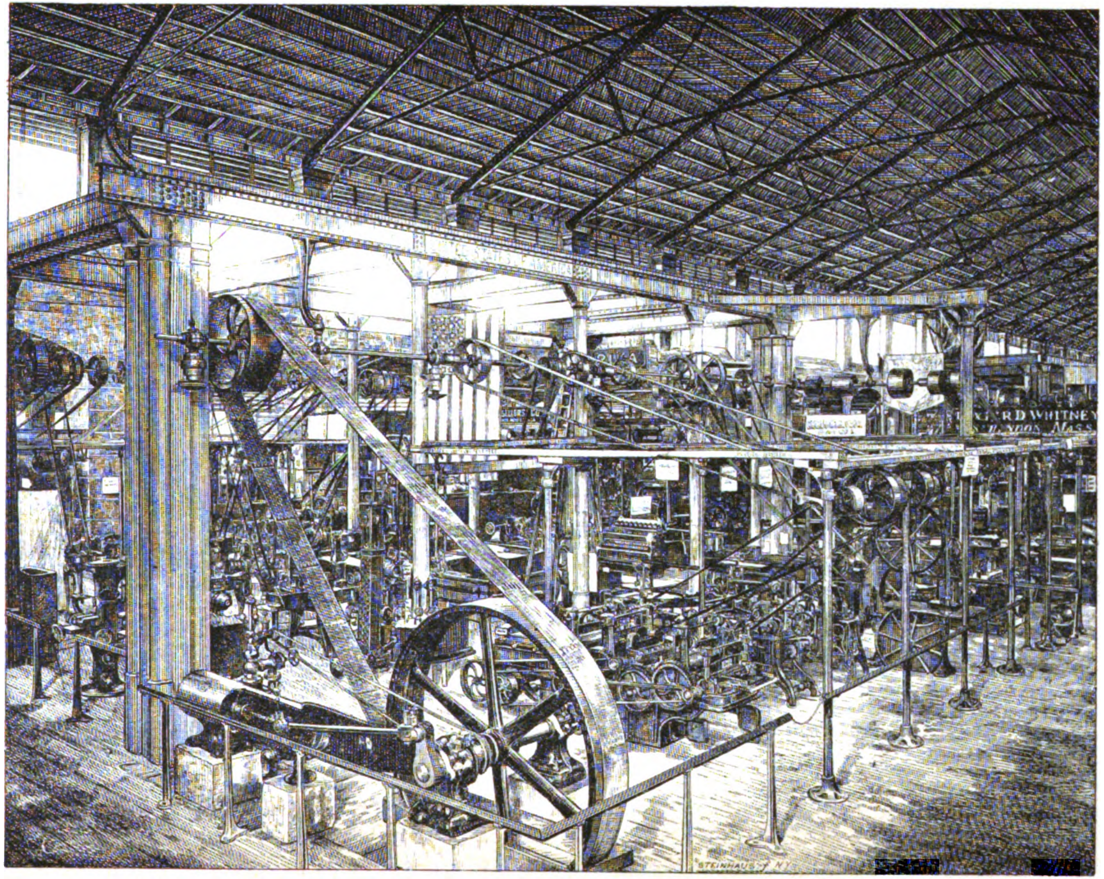


Fig. 3.

Digitized by Google

MACHINERY AND TOOLS.

INTRODUCTION.

METHOD OF STUDY; CHARACTERISTICS OF NATIONAL EXHIBITS.

23. In so vast a collection as that which crowded the great "*Maschinen Halle*," and its several annexes, the visitor could only thoroughly inspect and critically compare the exhibits by an expenditure of time and labor which was commensurate with its extent.

In making this examination during the several weeks given to it, the plan was adopted of taking up one class after another, and seeking out the representative exhibits in each section, studying their general plans of construction, peculiarities of design, and the arrangement and proportions of details, and after completing this work in the collection contributed by one nation, passing on to the next, and finally making a general comparison of the distinguishing features of each and of the character of material and workmanship.

24. Each nation was usually found to excel in some special department of industry, but the difference between the several continental nations, and between them all and their Anglo-Saxon competitors was, as will be seen, always plainly observable, and sometimes very striking. The usual characteristics of the South Europeans were elegance and lightness of form, with beauty of external finish. The North Europeans appeared to best advantage where simplicity of form, strength of parts, and general adaptation to useful purposes, demanding no display of fine art, were requisites.

The British and Americans both excelled in originality, the former displaying the highest excellence of workmanship and promise of greatest durability, and the latter the most remarkable ingenuity and capacity for making the most of their resources.

Digitized by Google

CHAPTER I.

STATIONARY STEAM-ENGINES.

STATE OF EUROPEAN PRACTICE; HISTORICAL OUTLINE OF MODERN PROGRESS; LIMITS OF ECONOMIC GAIN BY EXPANSION; PRESENT POSITION OF EUROPEAN BUILDERS; COMPARISON OF PRACTICE OF VARIOUS NATIONS; CONDITIONS OF EFFICIENCY; DIRECTIONS FOR THE ATTAINMENT OF ECONOMY; ENGINE OF SOCIN & WICK; ENGINE OF SULZER FRÈRES; TRIAL OF THE SULZER ENGINE; PLAIN SLIDE-VALVE ENGINES; ENGINE OF THE NORWALK IRON COMPANY; NORWALK SAFETY STEAM-POWER COMPANY; TANGYE BROTHERS' ENGINE; COMPOUND ENGINES OF W. & J. GALLOWAY, OF SCHNEIDER & CO.; THE EHRHARDT-DINGLER ENGINE; THE PORTER-ALLEN ENGINE; THE PICKERING ENGINE; BROTHERHOOD & HARDINGHAM'S THREE-CYLINDER ENGINES; SIEMENS'S ENGINE; REVIEW OF THE WHOLE FIELD; DIMENSIONS OF EXHIBITED ENGINES; INFLUENCE OF AMERICAN DESIGNS ON EUROPEAN PRACTICE.

25. **RECENT PROGRESS.**—The ninety stationary steam-engines of the Exhibition were carefully examined; but the writer regrets to be compelled to state that there was very little to be found at Vienna in this class that was really new and valuable.

European practice is evidently passing through very nearly such a series of changes as have been noted in our own country by every engineer who can trace them back twenty years.

26. The value of high pressures and considerable expansion was recognized as long ago as in the early part of the present century, and Watt, by combining skilfully the several principal organs of the steam-engine, gave it very nearly the shape which it has to-day. The compound engine, even, was invented by contemporaries of Watt, and the only important modifications since his time have occurred in details. The introduction of the "drop cut-off," the attachment of the governor to the expansion-apparatus in such a manner as to determine the degree of expansion, the improvement of proportions, the introduction of higher steam and greater expansion, the improvement of the marine engine by the adoption of surface-condensation, in addition to these other changes, and the introduction of the double-cylinder engine, after the elevation of steam-pressure and increase of expansion had gone so far as to justify its use, are the changes which have taken place during this century. A quarter of a century ago it began to be generally understood that expansion of steam produced an economical effect, and mechanics and inventors vied with each other in the effort to obtain a form of valve-gear which should secure the immense economy which an abstract consideration of the expansion of gases according to Marriotte's law would seem to promise. The counteracting phenomena of internal condensation and re-evaporation, ot the losses of heat externally and internally,

Digitized by Google

and of the effect of defective vacuum, defective distribution of steam, and of back pressure, were either unobserved or were entirely overlooked.

27. It was many years, therefore, before our engine-builders became convinced that no improvement upon existing forms of expansion-gear could secure even an approximation to theoretical efficiency. Occasionally an engineer of unusual intelligence and of exceptional power of observation found this to be the fact.

Mr. Francis B. Stevens, by a careful collation of indicator-cards, constructed more than twenty years ago the formula

$$p = P\frac{1 + A \text{ hyp} \log e}{e} - B - CP^*$$

in which p represented the mean pressure, P the boiler-pressure, e the expansion, A, B, C, constants determined by observation of actual performance of engines. This formula is made the basis of another, which gives the probable consumption of fuel at any degree of expansion and at any given pressure. By this latter equation a series of minimum rules was worked out by its author, which gave what would now be recognized by an experienced engineer as very correctly representing the limit of economical expansive working. The available energy of steam rises as pressure and temperature increase, in consequence of the widening of the range of temperature through which expansion occurs, to an extent which somewhat increases the economical range of expansion beyond the limit as thus deduced from extra-thermal considerations. This rise is not rapid, however, and Mr. Stevens's figures are very probably closely accurate.

28. The fact thus learned, that the benefit of expansive working has a limit which is very soon reached in ordinary practice, was not then, and has only recently become, generally known among our steam-engine builders, and for many years there continued the keenest competition between makers of rival forms of expansion-gear, and inventors were continually endeavoring to produce something which should far excel any previously-existing device.

This phase of the process of steam-engine improvement seems to have been just reached in Europe, and the general recognition of the value of a good detachable valve-gear, with the governor so attached as to determine the point of cut-off, has caused a rivalry among European builders, in the effort to produce the best valve-motion, which has led to the introduction of just such a variety of devices—usually crude, unmechanical, and complicated—as we have been so familiar with in the United States. In Europe, as in the United States, efforts to "improve" standard devices have usually resulted in injuring their efficiency and in simply adding to the first cost and running expense of the engines, without securing a marked increase in economy in the consumption of steam.

Since European practice may be regarded as having grown out of,

* $A = 2.3$; $B = 5$; $C = 0.06$.

Digitized by Google

and as having progressed during late years by imitation of, American practice in the manufacture of first-class stationary engines, it is unnecessary to give here further description of any of this class of machinery.

29. In the production of the best engines, several nations have exhibited great skill in workmanship, and have made use of excellent material. The British stand at the head of European nations, and side by side with the manufacturers of the United States. The Belgians, the French, and the Swiss are following the English-speaking nations very closely, and the Germans and Austrians are rapidly closing up the wide space which so recently separated them from the former.

In one form of stationary steam-engines the English excel all countries, not excepting the United States. This is the small horizontal slide-valve engine, with independent slide cut-off riding on the back of the main valve—a combination generally known among engineers as the Meyer system of valve-gear. This form of steam-engine is a very excellent and effective machine, and does excellent work when properly proportioned to yield the required amount of power. It is well adapted to an expansion of from four to five times. Its disadvantages are the difficulty which it presents in the attachment of the regulator to determine the point of cut-off by the heavy work which it throws upon the governor when attached, and the rather inflexible character of the device as an expansive valve-gear. The best example of this class of engine had neat heavy bed-plates, well-designed cylinders and details, smooth-working valve-gear, the expansion-valve adjusting by a right and left hand screw, and regulation secured by the attachment of the governor to the throttle-valve.

A considerable number of compound stationary engines were exhibited in various departments. The larger proportion were neither neat in design nor well proportioned. The valve-gear was frequently very awkward in general arrangement, and not at all satisfactory in any respect.

30. Conditions of efficiency.—The principles and the practice of good engineering are precisely the same, whether applied in the designing of the compound or of the ordinary type of steam-engine. The proportioning of the two machines to each other in such manner as to form an effective whole, by procuring approximately equal amounts of work from both, is the only essential peculiarity of compound-engine design which calls for especial care, and the method of securing success in practice may be stated to be, for both forms of engines, as follows:

1st. A good design, by which is meant—

(*a*) Correct proportions, both in general dimensions and in arrangement of parts, and proper forms and sizes of details to withstand safely the forces which may be expected to come upon them.

(*b*) A general plan which embodies the recognized practice of good engineering.

Digitized by Google

(*c*) Adaptation to the specific work which it is intended to perform, in size and in efficiency. It sometimes happens that good practice dictates the use of a comparatively uneconomical design.

2d. Good construction, by which is meant—

(*a*) The use of good material.

(*b*) Accurate workmanship.

(*c*) Skilful fitting and a proper "assemblage" of parts.

3d. Proper connection with its work, that it may do its work under the conditions assumed in its design.

4th. Skilful management by those in whose hands it is placed.

31. In general, it may be stated that, to secure maximum economical efficiency, steam should be worked at as high a pressure as possible, and the expansion should be fixed as nearly as possible at the point of maximum economy for that pressure. It is even more disadvantageous to cut off too short than to "'follow' too far." With considerable expansion, steam-jacketing and moderate superheating should be adopted, to prevent excessive losses by internal condensation and re-evaporation, and expansion should take place in double cylinders, to avoid excessive weight of parts, irregularity of motion, and great loss by friction.

External surfaces should be carefully covered by non-conductors and non-radiators, to prevent losses by conduction and radiation of heat. It is especially necessary to reduce back-pressure and to obtain the most perfect vacuum possible without overloading the air-pump, if it is desired to obtain the maximum efficiency by expansion, and it then becomes also very necessary to reduce losses by "dead-spaces" and by badly-adjusted valves.

The piston speed should be as great as can be sustained with safety.

The expansion-valve gear should be simple. The point of cut-off should be determined by the governor. The valve should close rapidly, but without shock, and should be balanced, or other device should be adopted to make it easy to move and free from liability to cutting or rapid wear.

The governor should act promptly and powerfully, and should be free from liability to oscillate, and to thus introduce irregularities which are sometimes not less serious than those which the instrument is intended to prevent.

Friction should be reduced as much as possible, and careful provision should be made to economize lubricants as well as fuel.

Guided by these general and fundamental principles of steam-engine practice, a comparison of the work exhibited at Vienna will show that, among stationary engines of the highest class, the American type of engine, with detachable valve-gear, stands at the head of all, and is almost universally regarded as a standard to be copied as closely as possible.

32. EXHIBITED ENGINES WITH DROP CUT-OFF.—The most creditable engine of this class, in the opinion of the writer, was that of Messrs.

Digitized by Google

SOCIN & WICK, of Basle, one of the several Corliss engines exhibited. It was rated at 30 horse-power. The valve-gear was that modification of the Corliss, known as the Spencer & Inglis. The engine is an excellent copy, apparently of good material, and of a style of finish and workmanship which indicates, as does much of the Swiss machinery, that the technical school at Zurich is well placed among people who can profit by the teaching which they are receiving from it. The Swiss exhibit a degree of mechanical skill and engineering capacity which places them at least on a level with any other continental people.

33. The steam-engine of Messrs. SULZER BROTHERS, of Winterthur, Switzerland, was considered by many of the jury the finest steam-engine in the Exhibition. These makers have gained a reputation in Europe as makers of a very efficient and economical engine, and this feeling and the convictions of the jury were indicated by their award of the highest premium to that firm.

The engine exhibited at Vienna, as illustrative of their best type, was a modified Corliss engine, of excellent construction and well finished, but was in no respect, in the judgment of the writer, superior to a little full-Corliss engine exhibited by Messrs. Socin & Wick. The latter engine, also, possessed all of the simplicity and efficiency of a true Corliss engine, while the Sulzer engine, with its "improvement" in valve-motion, was rendered somewhat more complicated, and probably less perfect in regulation, by the modification.

If the modification of design was made, as is frequently the case, for the purpose of giving the manufacturers a ground upon which to base a claim for superiority, and thus to make a market for an engine having peculiarities of design which they control, the object is readily comprehended, and the advantage of such a change of design, even when the gain of efficiency is in itself of no considerable amount, may be appreciated. In this case the changes introduced were, in the opinion of the writer, rather injurious than beneficial. The engine of Socin & Wick would probably drive as economically, regulate more perfectly, and require fewer repairs.

The Sulzer engine (Figs. 4 and 5) had a steam-cylinder of $17\frac{3}{4}$ inches diameter and a stroke of piston of 3 feet $5\frac{3}{8}$ inches. The cylinder was steam-jacketed, and very thoroughly protected by a lagging of cement, felt, and wood, laid one over the other. The frame was similar to that now in general use, and familiar to all engineers, as adopted by Corliss, by Babcock & Wilcox, and by other well-known firms building horizontal engines.

The valve-gear was an ingeniously complex arrangement, embodying some of the devices of Sickles, Corliss, and Greene, and the governor, which is so attached as to determine the point of cut-off, is that of Porter. The whole is a neat combination of devices which have individually been long known in the United States.

Digitized by Google

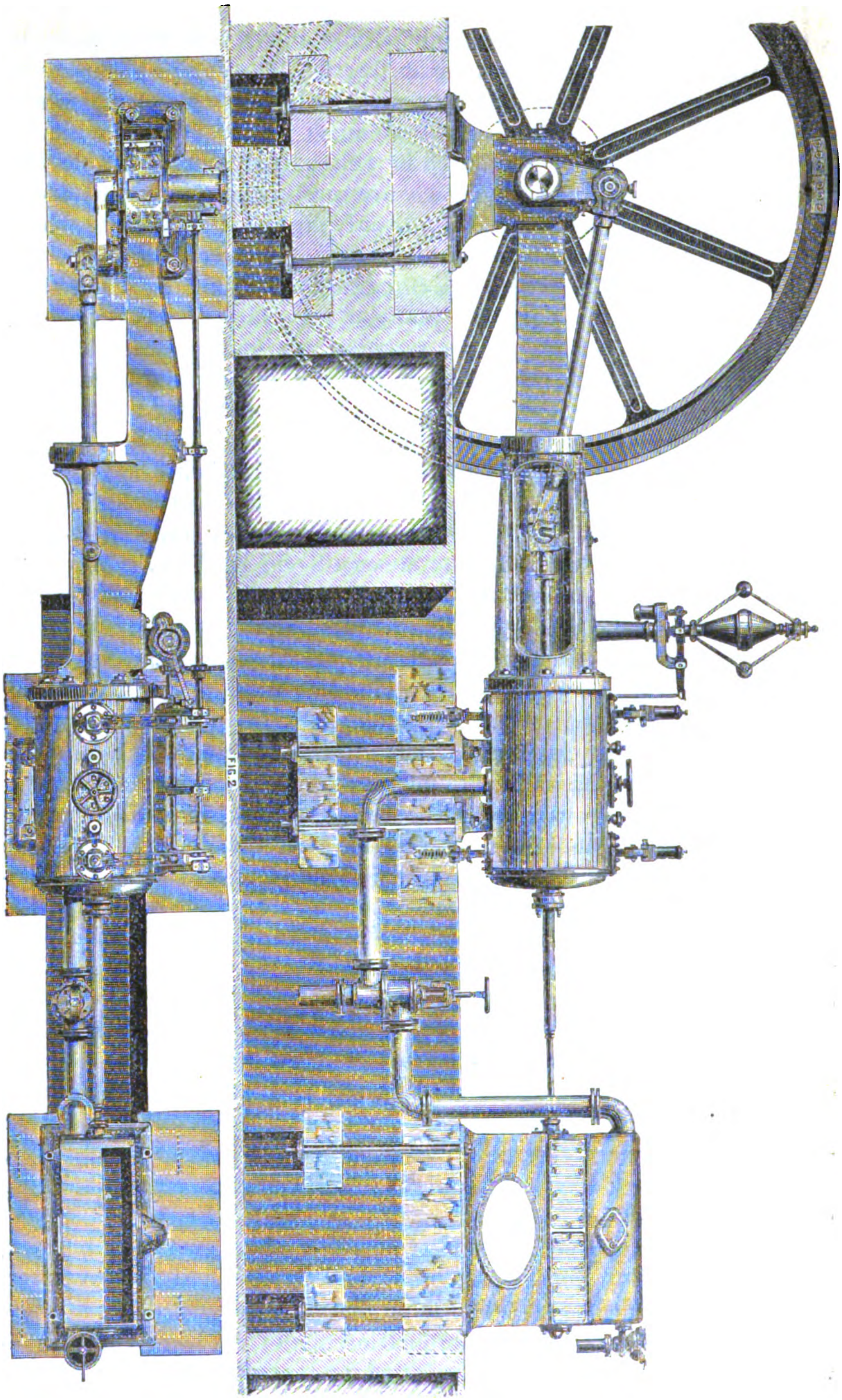


FIG. 4.—Sulzer engine—side elevation.

Digitized by Google

34. The engine here described is of 70 dynamometric horse-power, when making the somewhat moderate number of 50 revolutions per minute, under a steam-pressure of 75 pounds, and expanding about four times.

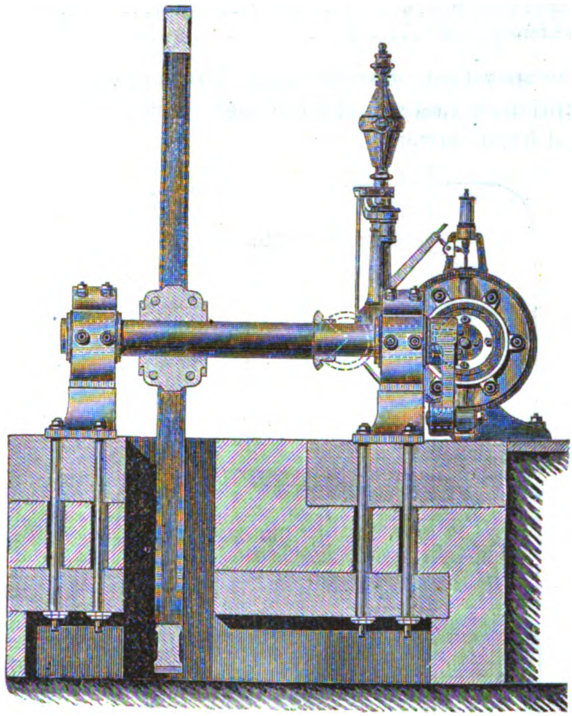


FIG. 5.—Sulzer engine—end elevation.

A similar engine is said to have given an economy which is extremely unusual—18¾ pounds of water per horse-power per hour, and 2⅛ pounds of coal per horse-power per hour.

The distribution of steam was excellent, as shown by the *fac simile* of an indicator-card here shown, Fig. 6, of which the original was given the writer by the agent of Messrs. Sulzer.

More than a hundred engines of this type and size, varying from 15 to 200 horse-power, were said to have been built by this firm.

On a 400 horse-power engine the makers guaranteed a consumption of less than 20 pounds of water per horse-power per hour; and the makers furnished a minute account of the trial made to determine the question of its fulfilment.

Professor Lindé, who was called to make the determination, reports the following results, giving mean values for a trial of four days:

Steam-pressure, pounds	70.
Pressure in condenser, pound	0.27
Expansions	10.
Indicated horse-power	395.

Digitized by Google

Dynamometrical power	365.
Consumption of steam per hour per indicated horse-power	19.6
Consumption of steam per hour per dynamometric horse-power*	21.
Consumption of coal per hour per indicated horse-power	3.3
Consumption of coal per hour per dynamometric horse-power	3.5
Water evaporated per pound coal	6.2
Temperature chimney, Fahr	309°

Had the evaporation of water been 10 pounds per pound of coal, the onsumption of fuel would have been reduced to less than 2 pounds per indicated horse-power.

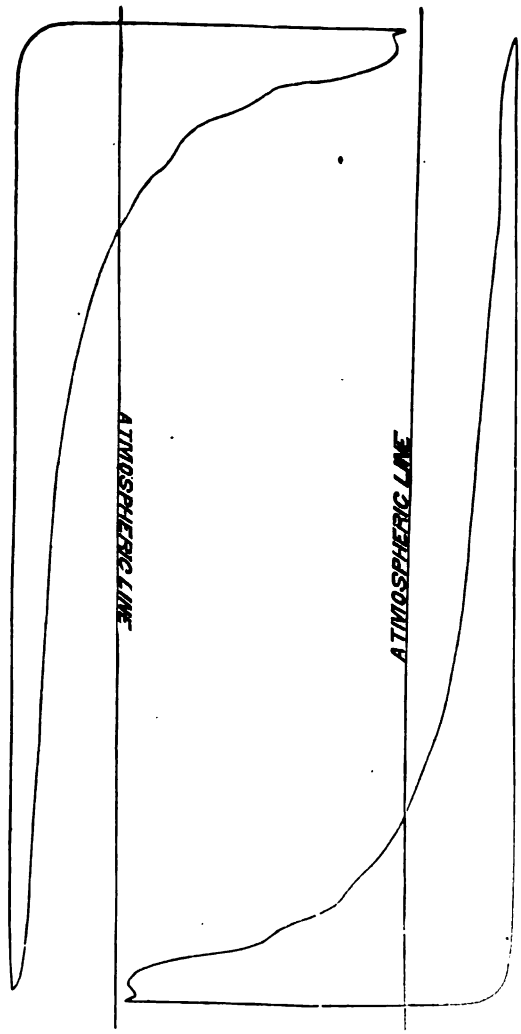


FIG. 6.—Indicator-diagrams from the Sulzer engine.

35. ENGINES WITH OTHER THAN DETACHABLE VALVE-GEAR.—In the construction of the next highest class of engine, that which is

* It would be interesting to know to what extent this exceptionally low figure is due to working exceptionally dry steam.

Digitized by Google

adapted to smaller powers or to situations where fuel is not very expensive, or where perfect regularity of movement is not deemed essential, the British builders stand first. Their standard engine, with Meyer expansion-valve, as built by their best firms, represents the best existing practice in this field. In the construction of their portable engines, which are usually of this type, the British manufacturers also excel, and have attained what seems to builders and engineers in the United States a wonderful success in the attempt to secure high economical efficiency.

It is generally thought that with engines of considerable size a consumption of 2½ pounds of coal per horse-power per hour is an excellent performance. This degree of economy has been attained with English portable engines on more than one occasion.

The peculiarities of British practice by which this result is secured seem to be simply a strict adhèrence to the principles of construction above enunciated and extraordinary care and skill in management.

Of the simplest standard form of steam-engines, there were specimens in the United States section which were unexcelled. The horizontal engine of the Norwalk Company illustrates well a good class of engine, and the vertical engine of the New York Safety-Power Company has no superior in beauty of design or excellence of workmanship. Both of these engines have piston-valves, and only expand steam as far as can be well accomplished by giving lap to the main valve.

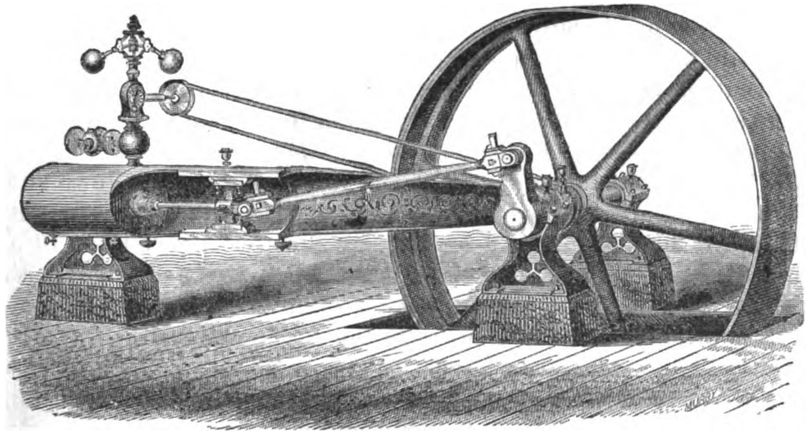


FIG. 7.—Engine of Norwalk Iron-Works.

36. The engine of the Norwalk Iron Company (Figs. 7 and 8) was an excellent example of a very common and serviceable type, of which examples are met with in large numbers of the mills and manufactories of the United States. Figs, 7 and 8 are views, from front and rear, of this engine. The cylinder and bed form a continuous piece, the latter transmitting the longitudinal pull and thrust of the piston directly from cylinder to pillow-block. Two supports, one under the cylinder and the other under

Digitized by Google

the crank-shaft pillow-block, take the weight of the engine and furnish a means of securing it to its foundation. The cross-head guides are cast with the bed-piece.

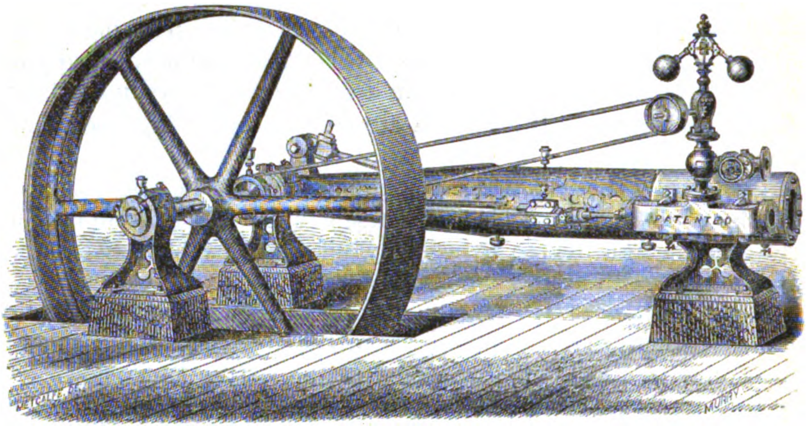


FIG. 8.—Engine of the Norwalk Iron-Works.

The valve used is the Wheeler piston-valve, which consists of two peculiarly-constructed pistons connected by a rod, and is worked by an ordinary eccentric. By a simple arrangement these pistons always have the same pressure inside as out, which prevents any leakage or blowing through, and they are said always to work equally as well and free from friction under one hundred and fifty power pressure as under ten pounds per square inch, and to require no adjustment.

The cut-off valve is not connected with the regulator, but in nearly every respect the engine is most creditable to its builders. It is neat, light, strong, and well finished, and did good work.

37. The accompanying illustrations exhibit the engines shown at the Exhibition by the NEW YORK SAFETY STEAM-POWER COMPANY, with their details. Figs. 9 and 12 are illustrations of their 10 and 2 horse-power engines; Fig. 10 is a sectional view, and Fig. 11 is an enlarged section of the valve-chest, showing the arrangement of the valves and port. Fig. 13 represents the connecting-rods. These rods are forged in a single piece, having no straps, gibs, or key, to get loose; but are mortised through at each end for the reception of the brass boxes, which are curved on their backs, and fit the cheek-pieces, between which they can turn, to adjust themselves to the pins, in the plane of the axis of the rod. The adjustment for wear is made by the wedge-blocks and the set-screws, as shown, and they are so constructed that the parts cannot get loose and cause a break-down, as not unfrequently happens with engines of the ordinary construction. Fig. 14 exhibits the cross-heads. They have adjustable gibs on each side, turned to fit the slides, which latter are cast solidly in the frame, and bored out exactly in line with the cylinder. This permits the cross-head to freely turn on its

Digitized by Google

axis, and, in connection with the adjustable boxes in the connecting-rod, it allows a perfect self-adjustment to the line of the crank-pin. By

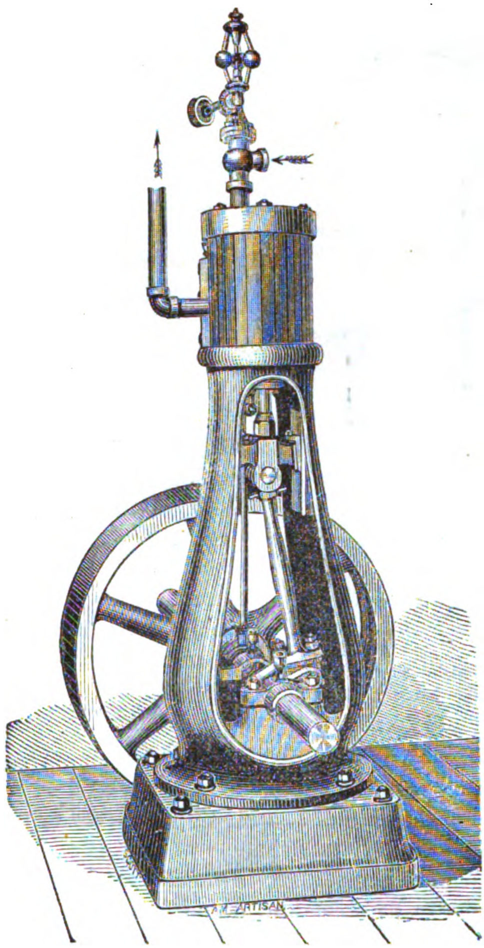


FIG. 9.—New York Safety Steam-Power Company's engine.

adopting this arrangement, the out-board bearing may be moved an inch or more out of position in any direction, without detriment to the engine, every bearing accommodating itself perfectly to whatever position the shaft may assume. Fig. 15, page 30, illustrates the pillow-blocks They have a spherical shell, turned and accurately fitted into the spherically-bored pillow-block, thus allowing a slight angular motion in any direction, and providing neatly and effectively against the heating of journals by getting out of line.

These engines were unexcelled in compactness, in neatness of design, elegance of proportions, or excellence of material and workmanship, by any engines of similar class in the Exhibition. They may justly be re-

Digitized by Google

garded as exceedingly creditable representations of the best American practice in the design and construction of engines of small power.

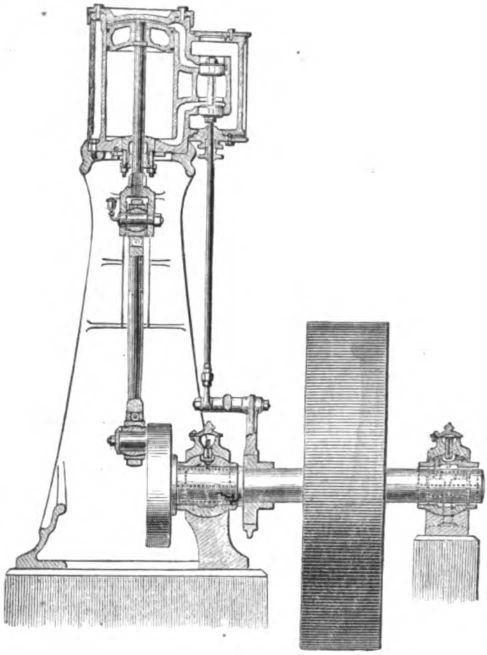


FIG. 10.—Vertical section.

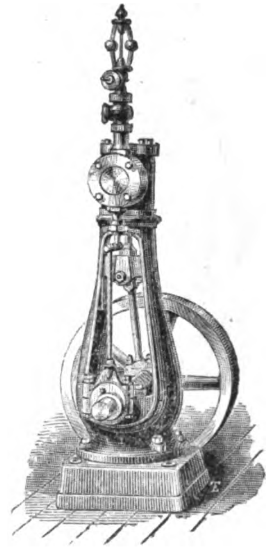


FIG. 12.

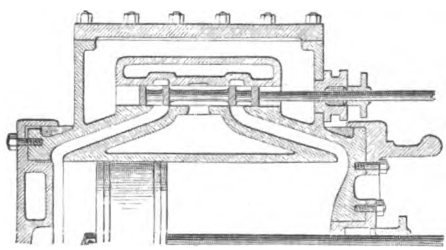
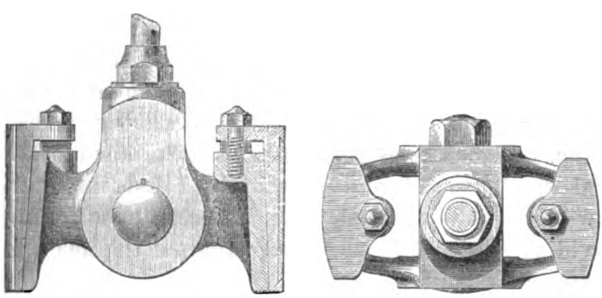


FIG. 11.—Section of valve and steam cylinder.



Side view. FIG. 14.—Cross-head. End view.

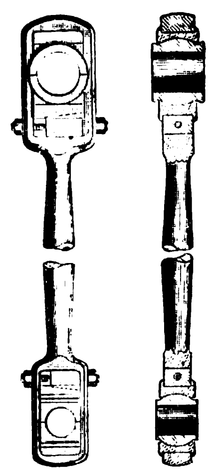


FIG. 13.—Connecting-rods.

The builders of these engines state that they fit up considerable numbers of their engines in small steam-yachts.

Digitized by Google

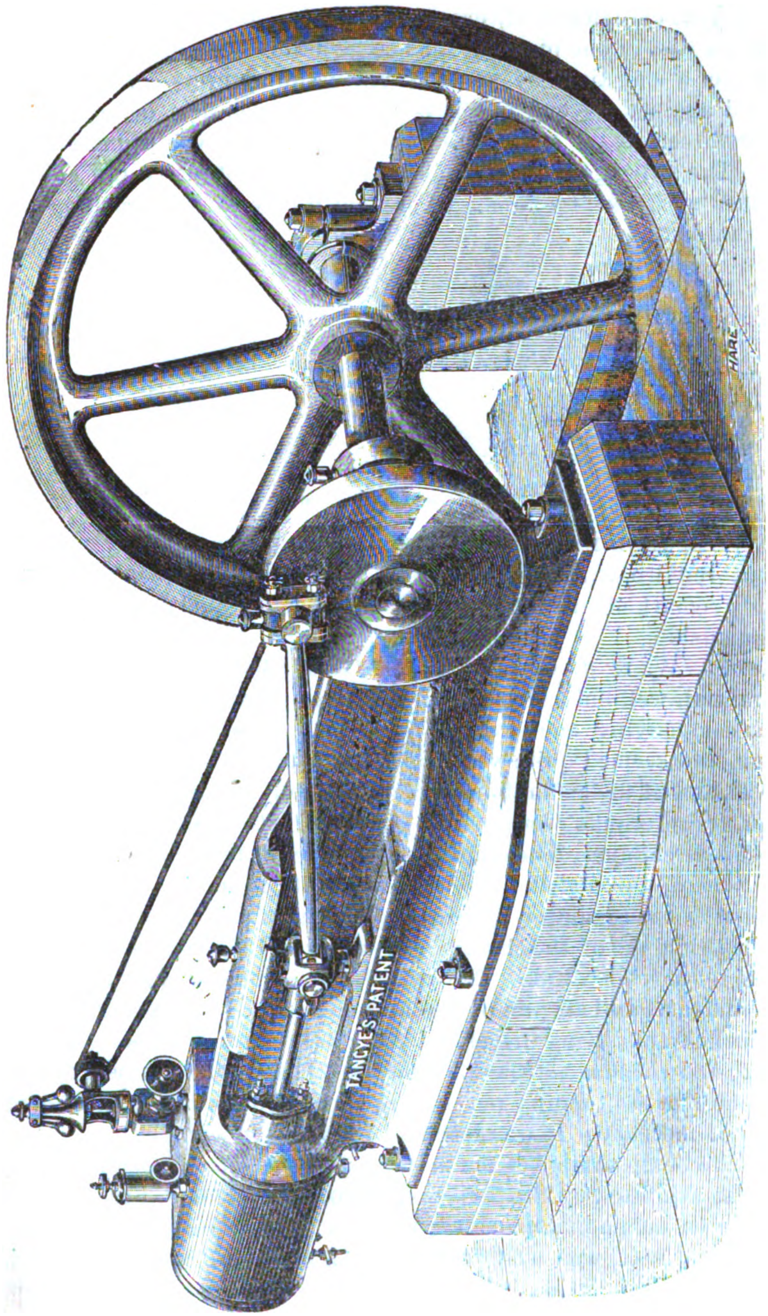


FIG. 16.—Tangye's stationary steam-engine.

38. The engine of TANGYE BROTHERS, of Birmingham, England, shown in the accompanying illustration, Fig. 16, is an example of an excellent British stationary steam-engine. It is simple, strong, and efficient. The

Digitized by Google

frame, front cylinder-head, cross-head guides, and crank-shaft plumber-block are cast in one piece, as has so generally been done in the United States for a long time by some of our manufacturers. The cylinder is secured against the end of the bed-plates as was first done by Corliss, ten or fifteen years ago. The crank-pin is set in a counterbalanced disk. The valve-gear is simple and the governor effective and novel, and provided with a safety-device to prevent injury by the breaking of the governor-belt.

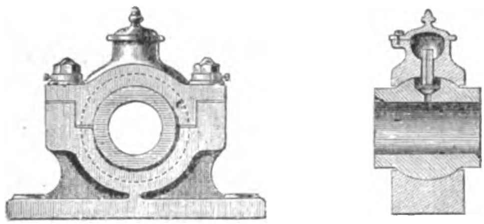


FIG. 15.—Pillow-blocks.

39. COMPOUND ENGINES.—The compound stationary engines exhibited do not require extended mention. They are few in number, and, as already remarked, are not usually remarkable for good design or for good workmanship.

Messrs. W. & J. GALLOWAY, of Great Britain, exhibited a plain substantial, well-built machine of this class, of which a view is given in the accompanying engraving, Fig. 17. It was intended for a mill-engine, and seemed quite well adapted to such use. Its steam-cylinders were 14 and 24 inches in diameter, respectively, with 30 inches stroke of piston. The cranks were set at angles of 180°, the pistons moving in opposite directions. The crank-pins were set in disk-cranks. The valve-gear was of the usual type of slide, with cut-off valve on the back, adjusted by the regulator. The governor was of peculiar design, embodying the principle of the Porter governor, and determined the point of cut-off by moving a link. The cylinder was not steam-jacketed.

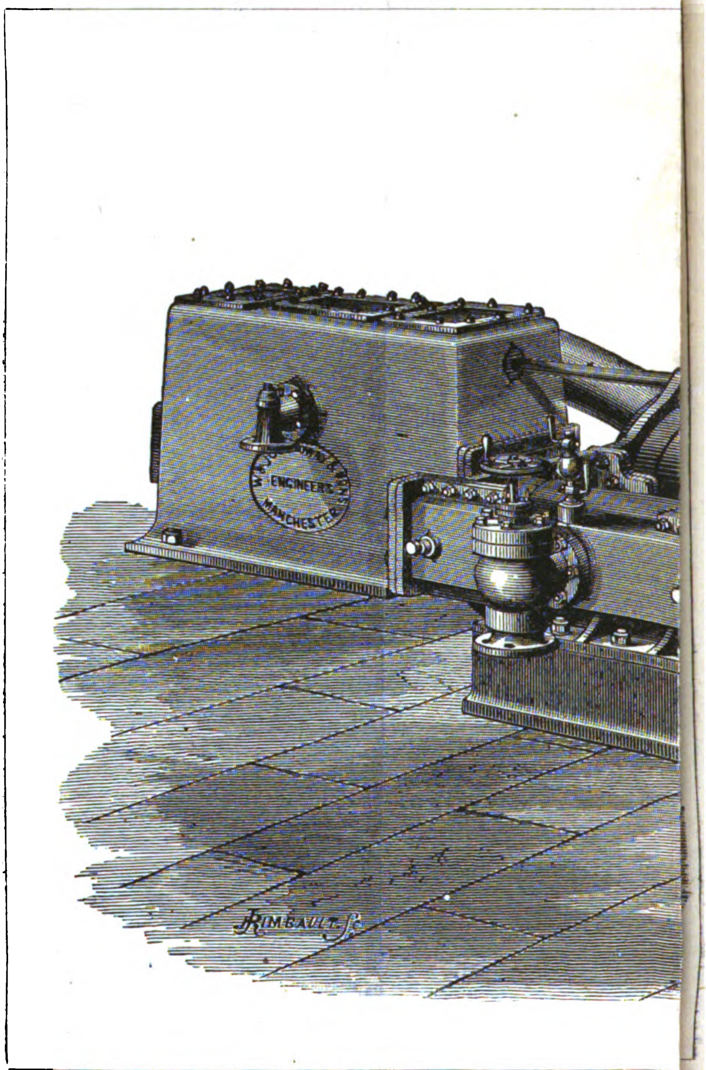
A condenser and air-pump were attached, the latter having a diameter of 8 inches, and, being driven by the extension of the piston-rod of one engine, had the same stroke, 30 inches. The engine was worked under a pressure of 60 pounds per square inch, and formed a vacuum of 28 inches of mercury. It was rated at 100 horse-power.

40. The best example of a finely-finished stationary compound engine was that exhibited by the MM. SCHNEIDER, of Creuzot, France. It was of the now common *marine* type in its general design, of 100 or 120 horse-power. It was well proportioned, and had been given a most remarkably fine finish, which exhibited well the excellence of its material. It was too extensively polished and too expensively finished to represent standard work.

In the accompanying plates, Fig. 18 represents this engine in vertical section; Fig. 19 is a plan, with horizontal section of the steam-cylinders, showing their relative magnitude and general disposition;

Digitized by Google

Digitized by Google



Digitized by Google

Fig. 20 is a vertical longitudinal section, exhibiting the arrangement of ports and valve-gear, and Fig. 21 is a horizontal section along the shaft-line.

The steam-cylinders were 9½ and 15¾ inches diameter, and the stroke of piston was 23⅝ inches. The cranks were arranged at right angles, as practiced by Napier. The details of the design were, in some respects, faulty. The high-pressure cylinder was surrounded by a jacket which received the exhaust-steam—a very ingenious device for producing waste of heat. This exhaust-jacket was also made large to perform the part of the intermediate receiver required on this form of engine, and was probably larger than was needed. It had several times the capacity of the small cylinder; it would be equally, if not more, efficient if made of equal size with that cylinder, or very little larger.

The frames were hollow, strong, neat, and well placed, and the interior was used as a condenser, a practice which has now become very general. The single air-pump was placed back of the frame, and was worked by a beam, or lever, linked to the cross-head in the usual way. Its dimensions were 9 inches diameter and 11¾ inches stroke. It was single-acting.

The cut-off valve on the smaller cylinder was worked by an independent eccentric, which was so arranged as to be adjustable for different ranges of expansion. No expansion-valve was provided for the low-pressure cylinder. The grade of expansion could be varied by means of the valve on the high-pressure cylinder to a minimum of about one-ninth or one-tenth. As customarily set, it would suppress admission at about one-fourth.

Regulation was effected by a governor acting upon a valve in the steam-pipe—a method of less efficiency than that generally practiced in the United States, of adjusting the point of cut-off by the governor. The governor was of the approximately parabolic form with cross arms; the governor-valve was Schneider's patent equilibrium valve.

41. The most striking design of compound engine was that designed by L. EHRHARDT, and exhibited by the Dingler'sche Maschinenfabrik, Zweibrücken. The two cylinders were side by side, and incased in one large cylindrical jacket. The cranks were placed at angles of 180°, the pistons moving in opposite directions. The remarkable peculiarity of the design, and that which attracted most attention, was the use of continuously-revolving cylindrical valves, very similar to those introduced in the United States many years ago by Thomas Goodrum. The governor is attached to determine the point of cut-off in a manner also similar in principle to that of the American inventor. This engine was the quietest and most smoothly-running engine at Vienna, and is an excellent example of a combination of devices, nearly all of which are familiar to many American mechanics. Its general plan was the invention of Hornblower, and is a hundred years old, and the cranks were similarly arranged by Randolph & Elder a quarter of a century ago. The valves are those of Goodrum. The piston is without rings, and has a broad

Digitized by Google

bearing, like pistons which have been long used on the Mississippi River. The governor is that of Porter, an invention which seems, like the Pickering governor, to have become well known and largely introduced in all European countries. The steam-jacket is no novelty.

The members of the International Jury, Group XIII, were furnished copies of a pamphlet written by the designer, in which he reviews this engine and states his reasons for adopting the general plan and for its peculiarities of detail. He presents a *résumé* of the advantages and disadvantages attending the use of steam for high pressure with great expansion, and gives, as the causes of the discrepancy observed between the results shown to be theoretically attainable and those actually reached in practice, the facts that—

(*a*) The size and weight of the machine in all its details must be so much increased as to introduce excessive friction with a comparatively low mean steam-pressure. The ratio of useful to lost work becomes thus reduced seriously.

(*b*) The condensation of steam at the beginning, and its re-evaporation at the end, of the stroke become causes of loss which losses become rapidly more serious as the difference of temperatures and pressures at the two extremes becomes greater.

(*c*) The difficulty of keeping the valves and piston steam-tight becomes, with high pressure, very serious.

(*d*) To reduce this loss, high piston-speed is demanded, as the loss is constant for equal times, whatever the speed, and thus an increase of speed reduces the ratio of loss to utilized heat and work.

He therefore concludes, with Völkers, that—

(*e*) The boiler of the high-pressure engine must be made stronger and in all ways better than that of the engine working under lower pressure

(*f*) The engine itself must be made stronger, of better material, and of better workmanship.

The designer concludes that the point of cut-off on the single cylinder with low piston-speed, for maximum efficiency, when carrying 90 pounds of steam, is at about one-eighth, a somewhat greater expansion than the writer has found best, unless, possibly, with very well built engines, working dry steam, in well-jacketed cylinders, and at a very high speed of piston. He concludes that high piston-speed is an essential element of efficiency, a conclusion previously arrived at and long practiced by builders in the United States.*

* The following principles were enunciated by the writer previous to 1860:

"REQUISITES OF ECONOMICAL MARINE ENGINES.—A speed of piston of $300\sqrt[3]{\text{stroke}}$, or higher.

"A mean pressure as high and as near the boiler-pressure as possible for the given expansion.

"A steady movement of the paddle-wheel or screw.

"A maximum diameter of paddle-wheel, or the minimum area of screw-disk compatible with minimum total resistance of the propelling-instrument. Proportion of boiler heating-surface to grate such as to reduce temperature of escaping gases to minimum needed for draught. Ample space in boiler combustion-chamber to permit thorough intermixture and perfect combustion. Heated surfaces to be thoroughly covered with non-conductors."

Digitized by Google

Digitized by Google

FIG. 20.—H. Schneider
gine—vertical longitudir

Digitized by Google

Ehrhardt, therefore, considering none of the existing designs satisfactory, attempts a new and entirely original plan. He has probably invented all of the devices claimed, but it curiously happens that in all he has been anticipated by independent invention in this country.

He works with a steam-pressure of about 150 pounds per square inch, expanding about ten times. The degree of expansion is, however, variable. His cylinders at Vienna were $4\frac{15}{16}$ and $9\frac{7}{8}$ inches diameter, respectively, the stroke of piston $19\frac{5}{8}$ inches in each.

The speed of piston was very nearly 390 feet per minute.

The two cylinders of the engine at Vienna were covered by one cylindrical casing which gave the whole the appearance of a single large cylinder. The whole was well lagged and carefully protected against losses of heat by radiation and conduction. The piston has no rings but is carefully fitted, and must be rebuilt when it or the cylinder becomes worn and leaky.

42. Beside the description of this engine, and this statement of the claims of the designer, may properly be placed the following statement by Mr. Charles T. Porter of the peculiar features of the Porter-Allen engines built by him, the representative high-speed single-cylinder engine in the United States:

"Their distinctive features are as follows:

"(a) *Rapid piston-speed.*—From 600 feet per minute in the smallest sizes to 800 feet in the largest.

"(b) *Short strokes.*—Varying, in the different sizes, from twice to about once and a half the diameter of the cylinder.

"(c) *Rapid rotation.*—The revolutions per minute ranging from 300 in the smallest to 100 in the largest engines.

"(d) *Heavy reciprocating parts.*—These are calculated to absorb about one-half of the force of the steam at the commencement, and give it out to the crank at the termination of each stroke, compensating for the inequalities of pressure occasioned by working expansively, giving smoothness of running, and enabling the builder to employ—

"(e) *Small and light fly-wheels.*—These are only from one-half to one-third the size usually required on engines giving the same power, but are sufficient to maintain a very uniform motion.

"(f) *A variable cut-off in which the valves have positive movements.*

"(g) *Four-opening equilibrium admission-valves, with adjustable pressure-plates.*—This is an admirable feature, especially in its adaptation to high speeds, admitting and cutting off the steam in a very perfect manner, working without friction under the greatest pressures, easily kept tight, and relieving the cylinder from confined water.

"A maximum diameter of paddle-wheel, or the minimum area of screw-disk compatible with minimum total resistance of the propelling instrument.

"Proportion of boiler-heating-surface to grate, such as to reduce temperature of escaping gases to the minimum needed for draught.

"Ample space in boiler-combustion-chamber to permit thorough intermixture and perfect combustion.

"Heated surfaces to be thoroughly covered with non-conductors."

Digitized by Google

"The exhaust is by four-opening valves working under the pressure in the cylinder.

"This system of valves and valve-gear is the invention of Mr. John F. Allen.

"(*h*) *The Porter governor.*—Giving great regularity of running under extreme changes of resistance."

Its short stroke enables entire solidity to be attained in a bed of rigid form, making it a very completely self-contained engine, adapted to the heaviest work, and requiring only a small foundation. Solidity and simplicity mark all parts of the design.

The journals of the shaft, and all cylindrical wearing-surfaces, are finished by grinding in a manner that leaves them perfectly round. The crank-pin and cross-head pin are hardened before being ground.

The joints of the valve-gear consist of pins turning in solid ferrules in the rod-ends, both hardened and ground. These are found to be extremely durable. Seven years of constant use show, as claimed, no wear to occasion lost time in the valve-movements; but in these engines, besides the fact that the valve-gear needs no looking after, the valve-action is found to be the same after years of running.

The lubrication is self-acting and reliable throughout. Should it be run continuously, as it may be for an indefinite time, the lubricators may all be filled and adjusted with the same facility as if it were standing.

The advantages attained by such a combination are, according to Mr. Porter—

First. *Great power in small compass.*—This is obtained by the high speed and short stroke, and by carrying the steam further before cutting off than is common in engines working expansively. Cutting off earlier than at one-quarter of the stroke, in the opinion of the builder, is always attended with loss.

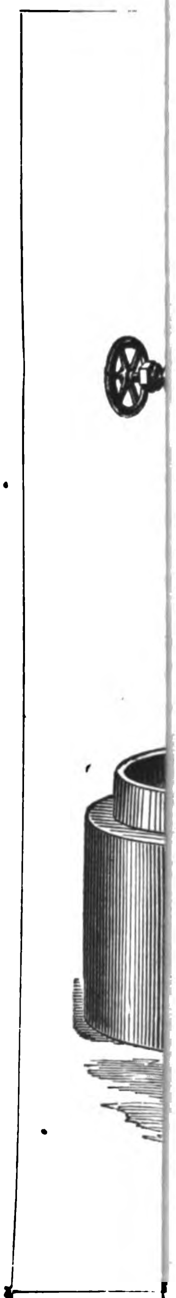
The powers given in the builder's table are said to be fully realized in engines running. They are calculated for 80 pounds pressure, cut off at one-quarter of the stroke.

Second. *Superior economy.*—High speed and short strokes are considered by Mr. Porter essential elements of economy. It is now well understood that all the surfaces with which the steam comes in contact condense it; it is also coming to be known that the extreme claims to economy often put forward are in a large degree fictitious, and that the engines will not stand real tests. The condensation on the interior surfaces of the cylinder, heads, and piston, chilled by re-evaporation during the expansion, and especially during the exhaust, is the chief cause of a loss, which makers try to hide.

Obviously, the way to diminish it is to reduce the extent of surface to which the steam is exposed. In these engines, on account of the rapid speed and short stroke and later cut-off, the surfaces with which the steam comes in contact, while doing a given amount of work, do not

Digitized by Google

Digitized by Google



Digitized by Google

average in extent more than one-third that found in ordinary expansion engines. This is the cause of an economy that slow-speed engines cannot attain.

Third. *Power transmitted by parallel belts.*—This engine possesses the advantage of driving by a parallel belt. Converging belts, transmitting power from great pulleys on the engine-shaft to small ones on the line, involve serious difficulties. In this engine the speed is attained at the engine-shaft, the belts are practically parallel, and may be as short as convenience requires; and, the upper belt being made the loose one, they may always be in contact with more than one-half the circumference of the smaller pulley.

Fourth. *Economy in first cost.*—Besides the saving in transportation, foundations, connections, room, and fuel, such an engine can be afforded at a low price per horse-power.

Where great steadiness of motion is desired, the expense of coupled engines is often incurred. These engines never require to be coupled; a single engine is found to give greater uniformity of motion than is obtained with coupled engines at ordinary speeds.

The speeds prescribed by the maker, in reality, have been considerably exceeded in successful practice. They are speeds settled by experience, and for which the engines are in all respects designed; the ports and valve-movements, the weight of the reciprocating parts, and the size and weight of the fly-wheels are calculated expressly for them.

For special purposes, such as direct connection with lines of shafting, or with trains of rolls, dispensing with gearing, engines of even shorter stroke are made, adapted for any speed up to 500 revolutions per minute.

One of these engines was exhibited at the Paris Exhibition of 1867. It is much to be regretted that another could not have competed with this, the only European rival in 1873. Its economy was stated, in 1870, by a committee of the American Institute of New York, President F. A. P. Barnard, of Columbia College, chairman, to have exceeded that exhibited by two others of the best "drop-cut-off" engines exhibited previously at the same place.

It would be very interesting and probably instructive to embody the principles of the Porter-Allen engine in a compound engine. There would then be combined to an extent previously untried the requisites of high, economic efficiency.

43. Peculiar designs.—Among the peculiar designs of stationary engine which attracted much attention was the Pickering Engine and governor, illustrated in the accompanying engraving, (Fig. 22.) In designing this engine, one of the chief points kept in view seems to have been to dispense with the usual bed-plate, and to resist the strains due to the action of the steam on the piston by a direct connection between the cylinder and the crank-shaft bearings. The engine has no bed-plate; the casting to which the cylinder and the crank-shaft bearings

Digitized by Google

are bolted is merely a light cast-iron tray to catch the oil dripping from bearings and guide-bars. The strains due to the thrust and pull of the connecting-rods are taken by the guide-bars, which in this engine are also used as stays connecting the cylinder-head to the crank-shaft plumber-blocks. The fly-wheel runs between the two plumber-blocks, while the crank-shaft, which is very short, has a crank at each end and a pair of connecting-rods coupling the cranks to the cross-heads. By this arrangement the usual cast-iron bed or frame, with a sectional area of ten or twenty times that of the piston-rod, is dispensed with, being replaced with light wrought-iron stays of a sectional area of but one and a quarter times that of the piston-rod. The crank-shaft is also not only shorter than with other styles of engine, but lighter, as the power, instead of being wholly transmitted from one end, is received by the fly-wheel equally from each end. The position of the fly-wheel is such that its weight tends to prevent the vibration usually noticeable in small, high-speed, reciprocating engines. This engine has a cylinder 6 inches in diameter, with 12 inches stroke of piston, the piston-rod being made of cold-rolled iron, not turned in a lathe; the valve-spindle is made of cold-finished, unturned steel. A close examination of this piston-rod and valve-spindle showed that they had as good a surface and were as perfectly cylindrical as they would have been if carefully finished in a lathe.

The engine was fitted with an ordinary slide-valve; motion was transmitted from the eccentric to the valve-spindle through a rocking-arm, as shown. Speed was controlled by one of Pickering's spring governors. It consists of three balls mounted on springs of thin plate-steel, as shown in the engraving; the ends of the springs are secured to flanges, the lower of which, resting on steel washers, and having a collar to prevent its rising, is capable of only a rotary motion, while the upper one, being at liberty to move lengthwise as well as to rotate, receives its rotary motion from the lower one, through the springs, and communicates any lateral motion due to the varying centrifugal force immediately to the balanced valve, to which the governor is firmly secured by the brackets, a part of which forms a long bearing for the horizontal spindle, which communicates motion from the power to the governor through the miter-gearing. The object of this latter invention is to obtain the requisite centripetal force without making the springs too heavy. It consists in the peculiar construction of the spring and in the shape of the curve given it by the manner in which the ends and middle portion are secured, keeping those parts at all times parallel with the center of motion. By this arrangement steel can be used so thin that all liability to break, or tendency to "set" or lose its elasticity, is avoided. The curve obtained by this arrangement is a double cyma. Two or more strips thus bent, when firmly secured together at their ends, will work freely without any tendency to "buckle" or interfere with each other. The whole arrangement of this engine was very neat. It drove the work attached to it very steadily,

Digitized by Google

and attracted considerable attention. A distinctive feature of this engine was the method of transmitting power from it to the shafting. To render the engine compact, the fly-wheel was made very narrow, and, instead of being made to carry an ordinary flat belt, it had a V-shaped groove, receiving an angular belt, made by Mr. Charles Underhill, of Tolland, Conn. This driving-band, of which a short length is shown in the engraving, is made of leather, and is of ▽-section, the inner or thin edge being notched, as shown, the layers of leather on the broad side of the ▽ only being continuous.

The belt is thus made perfectly flexible. This driving-belt may, perhaps, be better described as a narrow belt having fixed to its inner side a number of teeth built up of thicknesses of leather, and of ▽-shaped cross-section. The pulley on the shafting was grooved like the fly-wheel, and the belt, being griped by the grooves, was run very slack without slipping. The strain on shafting and bearings was thus reduced to a very important extent. This band could be lengthened or shortened as readily as an ordinary belt. This arrangement of driving-gear is one which may probably often do good service.

44. A three-cylinder engine, exhibited by Messrs. BROTHEHOOD & HARDINGHAM, of London, attracted some attention from engineers. In this engine the cylinders are single-acting, and arranged with their axes making angles with each other of 120°. The pistons are coupled to a single crank. The large fly-wheel commonly used is dispensed with, and the crank and the connecting-rods are completely hidden by the casing of the engine in a manner quite similar to that adopted with the steam-engine well known in this country as Hicks's four-cylinder engine. The cylinders and the central casing containing the crank and connections are cast in one piece. The shaft passes out at each end through bonnets, which are carefully fitted and bolted in place.

The regulator is attached to one end of the shaft, its spindle being horizontal. It thus makes the same number of revolutions as the crank-shaft. This is sometimes three hundred revolutions per minute, and it has been stated that the unloaded engine has been driven nearly two thousand revolutions per minute without a serious jar. The valve is a revolving valve somewhat similar to those which have been long in use on the freight-steamers of the Neptune Line, plying between New York and Providence. Its axis is coincident with that of the crank-shaft, and it is turned by a prolongation of the crank-pin.

The central chamber is the steam-chest, and the pistons thus always have steam-pressure on their "forward" faces. The valve permits steam to pass to the rear of the pistons successively, thus disturbing the existing equilibrium and producing rotation. One of the most interesting points noted in this engine was the fact that the builders have apparently succeeded in securing a satisfactorily working crank-pin without especial provision for lubrication. They state that they had at first great difficulty in keeping the pin in working order. The hot

Digitized by Google

steam washed out the lubricant so quickly that it required constant attention and compelled the use of large quantities of the unguent.

They now fit the crank-pin with "brasses" of some special grade of phosphor bronze, and state that the steam itself has proven a sufficient and perfectly satisfactory lubricant, and that they now use no other.

45. The steam-engine of FRIEDRICH SIEMENS, of Dresden, Saxony, was exhibited in machinery hall, and attracted attention rather because of its novelty than as promising to become practically useful. In this machine there were no valves, piston, or moving parts. The steam-boiler itself revolves, and from it power is transmitted to the machinery to be driven. It consists of a steam-boiler of approximately cylindrical form, carried on an inclined axis about which it rotates. Inside this boiler is a worm or screw composed of sheet-metal, and having such form that each portion of the screw having a length equal to its pitch, closely resembles a funnel which has been slit down one side and slightly separated to unite with others above and below it.

The lower portion of the boiler has a double bottom, and the upper is surrounded by a spiral of gas-pipe, having a direction the reverse of the funnel-like spiral below.

Water is placed in the lower portion of the boiler and in the space between it and the external jacket, a communication being established between them by means of small holes.

Surrounding the whole lower portion of the apparatus is a jacket of non-conducting material, and between it and the boiler is a space through which circulate the gases from the furnace, or, in this case, from the gas-burner by which it is heated, passing off by a small chimney at its upper end.

A fusible plug at the top insures safety against injury by overheating.

The motion of the boiler, when revolving, is transmitted to the shafting by means of a neat device of recent introduction, a spiral coil of steel ribbon, which makes an excellent universal joint.

The heat being applied, steam is formed, which rises through the water, impinging on the immersed funnel-like spirals, producing a tendency to rotation. Above the water it enters the helix of gas-pipe, and, condensing, flows back into the boiler, its reaction causing further effort to rotate the boiler. In the small machine exhibited the motion was moderately rapid; but it evidently has little power, and the machine can hardly be considered a motor. It is interesting as a simple and ingeniously-devised apparatus and as suggesting possibly useful application where very little power is needed and where its entire freedom from noise and from the inconveniencies attending all ordinary mechanism are important desiderata.

The boiler being once filled, requires no further attention, as there is no loss of the liquid.

46. RÉSUMÉ.—Among all the stationary engines, of which class nearly a hundred were on exhibition, there were no others which call for

Digitized by Google

special mention. By far too large a number were of a quality which should not be imitated, and of the remainder the best examples were usually copies of types well known in this country, and often they were careful imitations. As a rule, attempts at improvement resulted in producing the reverse effect.

It will be seen from what has been above stated that the principles governing the economical use of steam are becoming more thoroughly studied and more generally recognized by European constructors, and that they are learning gradually how to embody those principles in their practice.

The continental manufacturers generally are still behind their British and American competitors, but by imitation of good standard designs, and by the importation in some cases of British mechanics, they are introducing into their establishments a knowledge of good design and of good workmanship, which promises at an early day to place them fairly by the side of the Anglo-Saxon, who has hitherto always exhibited decidedly higher constructive power. In the character of the raw material from which their skilled mechanic is produced, the advantage is certainly upon the side of the latter.

A peculiar gratification was found in witnessing the progress made by Austria in this direction. Her people seem to have more of the natural constructive talent than many other nations of Europe, and it only requires an intelligent and systematical training to secure its most satisfactory development.

The progressive and enterprising spirit which has been exhibited in the enterprise which brought together the collections of the *Weltausstellung* is certain to secure complete recompense by giving this talent an opportunity for the study of good examples, and by thus securing its most effective stimulus.

47. Reviewing the whole field, it may be stated that the practice of the best constructors of first-class stationary engines in the United States is still in advance of those of other countries. Foreign builders are, however, rapidly placing themselves beside us in this field. In some cases, especially in that of Great Britain, the same conservative but thorough-going spirit which has retarded the introduction of our designs is at work stimulating builders to the use of better material and of more perfect workmanship than the majority of our people are accustomed to adopt, and we shall soon find them in advance of us in our own field, should our steam-engine builders generally neglect to look as carefully to the quality of their work as do our best-known firms of tool-makers.

The advance in this direction which has occurred recently in the United States is, however, the best evidence that a market can be found for good work, and that our mechanics have learned that they may safely do such work and that they purpose doing it.

Digitized by Google

Accompanying is a tabular exhibit of the number, character, and dimensions of the stationary engines exhibited:*

48. A German engineer, T. Rittershaus, an assistant at the Royal *Gewerbe Academie*, at Berlin, in his report published since these remarks were written, makes the following introductory observations:†

"In scarcely any direction does the machinery hall at the Vienna Universal Exposition offer so much that is new and remarkable as among the prime movers, especially in steam-engines and in motors for small industries.

"Principally with reference to stationary engines, a complete change of the principles of construction is to be noted, and *we owe this mainly to the influence of the American Corliss.*

"Formerly, the regulator generally acted upon a throttle-valve, so that the tension of the steam was decreased by the diminution of space in the pipe, and the consequent increase of resistance before entering the valve-chest, and only a few systems (Farcot, Myer, and Dingler) allowed the regulator to act upon the valve-gearing itself, varying the expansion. Since the introduction of the Corliss engine, especially since the last Paris Exposition, when it attracted general attention, this has been changed so completely that to-day regulation by means of the throttle-valve, at least for machines of any importance, may be considered as a thing of the past.

"But not only does the valve-gearing of modern steam-engines indicate the influence of the Corliss engine, but also its external form and arrangement have become typical.

"Steam-engines, at present, are principally horizontal, and in the greater number of cases condensing-engines. But, instead of the bed-plate which was formerly in such favor, we meet almost everywhere that American frame with its solid cast brace which has been adopted by Corliss, and which is constructed so as to resist in the best manner possible all tensile and compressive strains between the cylinder and the foundation of the fly-wheel.

"With reference to the valve-gearing, practice is not so uniform. All important engines have expansion-gearing, adjusted by the regulator, but, with regard to the manner in which they are so adjusted, their construction varies considerably. Nevertheless, they can all be classified in five main groups.

"The first of these five groups closely resembles the Corliss engine. The ideas underlying the essential parts are common to both, such as, for example, opening the parts by the engine, closing them, after disengagement by the regulator, with the assistance of an exterior force, which has been generated in an auxiliary agent (such as a weight, a spring, the tension of steam) during the opening; furthermore, the

* London Engineering, October 17, 1873.

† *Amtlicher Bericht über die Wiener Welt-Ausstellung im Jahre* 1873; *Band II Heft* 1; *Motoren, etc.* T. Rittershaus.

Digitized by Google

Remarks.

t 180 degrees.

ier smaller engines by same firm in ag-
ural hall; not at work.
) and condenser not attached for want
a.

ultural hall; not at work.

ultural hall; not at work, and also a
ned engine.

ork.
other smaller vertical; neither at work.
ultural hall, and also a combined en-
neither at work.
and Stubb's ejector on jacket; also a
ned engine; neither at work.
late wrought-iron side-frames, &c.; not
k.
adapted for high speeds; one also at
driving a "helical" pump.

ork.

lp and condenser can be fitted to this
t and a similar smaller one at option.
ork.
vork.

ork.

ork.

ion with German ice-machines, &c.
linders connected to one crank; not at

-heater is not attached permanently to
l.
rk at any pressure not exceeding 150
ls per square inch; not in motion.
mbined engine; neither at work.

vork.

vork; for rolling-mill.
work; for rolling mill.
rn agricultural hall; not at work.

at 180°. The valves and gear are on
ardt's system.

other engine by same makers in eastern
ultural hall; not at work.
work.
work.

Digitized by Google

Digitized by Google

separation of the parts in order to diminish the dead-space and to prevent the loss of heat by alternate contact of the same surface with fresh and waste steam; and finally, the separate valve-gearing for the entering and the exhaust steam.

"I would like to class this whole group under the name of 'Corliss engines,' although some of them, such as the Sulzer engine, the engine built by Scheller & Berchtold, &c., differ from it in construction, not only with reference to the external, but also with reference to the internal valve-gearing. Some of them have already attained a considerable celebrity.

"A second group is based upon the older Farcot valve-gearing, which is, however, considerably changed, on account of the greater expansion and its variation between wider limits.

"The third group has adopted Meyer's valve-gearing, this being made to depend upon the regulator in various ways.

"Still another large group is formed by those engines in which the regulator varies the eccentricity, or the lead, of the expansion-gearing eccentric, or both at the same time.

"As belonging to this group, I also consider those engines in which the length of the stroke of the valve is varied by changing the point of application at the valve-rod by means of a connecting-link, instead of varying the eccentricity.

"The fifth and last group, finally, is formed by two engines with a peculiar stop-cock valve-gearing, in which the expansion is varied by a special expansion-valve, *i. e.*, by a second cock whose position with reference to the valve depends upon the regulator."

Digitized by Google

CHAPTER II.

MARINE STEAM-ENGINES.

CHARACTER OF EXHIBITS; HISTORICAL SKETCH OF MARINE-ENGINE PRACTICE; INCREASE OF STEAM-PRESSURE; SURFACE-CONDENSATION; RECENT CHANGES; CONDITIONS OF MAXIMUM EFFECTIVE EXPANSION; CAUSES OF THE SUCCESS OF THE DOUBLE-CYLINDER ENGINE; COMPOUND MARINE ENGINE OF BURMEISTER & WAIN; STEAMERS OF THE DONAU DAMPFSCHIFFAHRT GESELLSCHAFT; PRINCIPLES OF ECONOMY OF PROPULSION BY PADDLE-WHEELS AND CHAIN-TOWAGE; ENGINES OF THE DONAU GESELLSCHAFT, OF THE STABILIMENTO TECHNICO TRIESTINO; HER BRITANNIC MAJESTY'S IRON-CLADS MINOTAUR AND BELLEROPHON; OSCILLATING ENGINES OF THE SOCIÉTÉ JOHN COCKERILL; THE FEATHERING PADDLE-WHEEL; THE AMERICAN STEAM-ENGINE; THE MOTALA WORKS; SWEDISH TWIN-SCREW VESSELS; MOTALA PASSENGER-STEAMER.

49. CHARACTER OF EXHIBITS.—The exhibition of marine engines was not remarkable, either for the number of exhibits or for the variety and novelty of designs, although it was probably quite as good as should be expected under the circumstances. But little is to be gained by the study of this class of exhibits at Vienna, either in respect to the direction of progress in design or in respect to the character of material and of workmanship to be observed.

The collection is, however, interesting as exhibiting illustrations of every stage of the progress of the modern revolution which has brought the "compound" engine into general use as a marine engine.

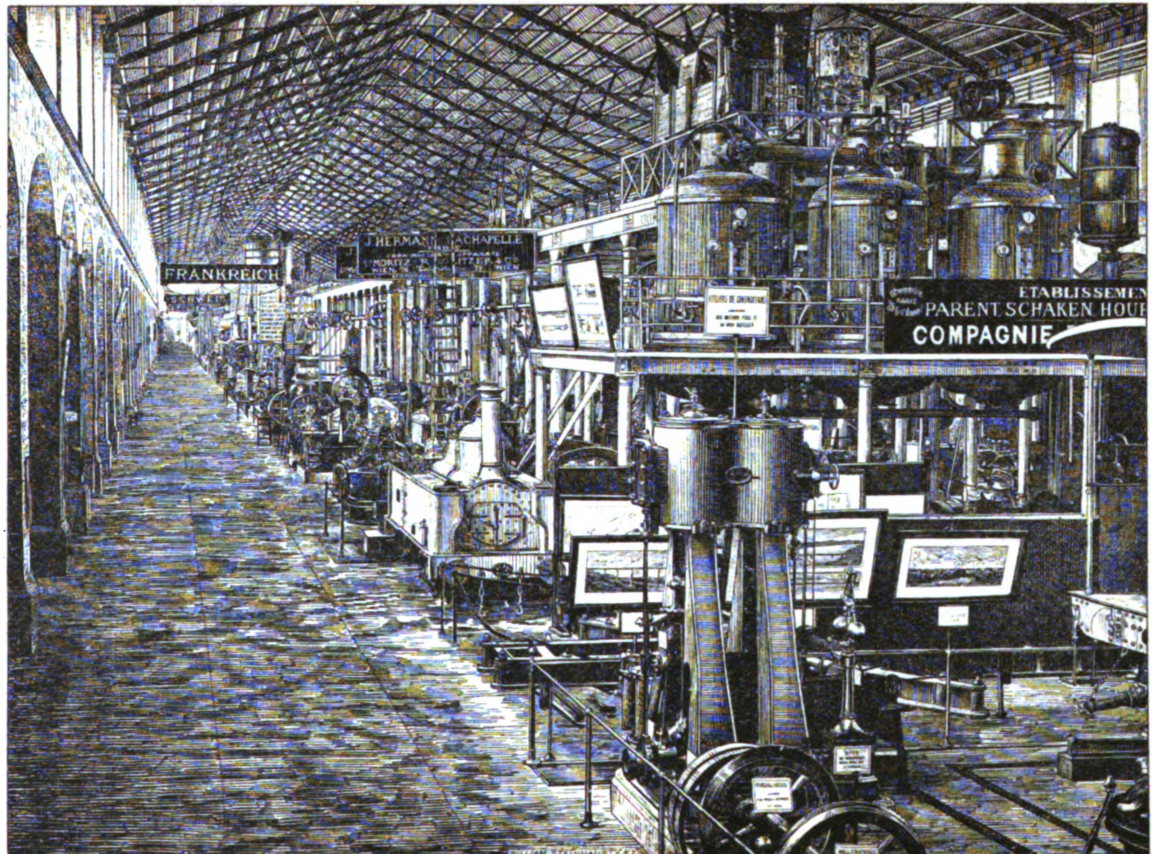
50. HISTORY OF MARINE-ENGINE PRACTICE.—Nearly three-quarters of a century ago this form of engine was brought into the market as a rival of the Watt engine, the use of which was then rapidly extending, driving from the field the ruder machines of Newcomen and Beighton. The time for the success of the former had not, however, then arrived. The principles already stated as the practical bases of the economical success of the steam-engine were not then recognized or understood. Steam was generally carried at very nearly atmospheric pressure; piston-speed was extremely low, and the benefit of the steam-jacket was then, and long after, a subject of dispute.

The double-cylinder engine, therefore, failed entirely to compete with the single-cylinder, and, although occasional attempts were made to bring it up again, it has only within a comparatively short space of time succeeded in holding its own by fair competition with the other style.

As steam-pressures have risen and piston-speeds have become greater, the range of economical expansion has increased at sea, as on land, and,

Digitized by Google

Digitized by Google



American Photo-Lithographic Co. N. Y. (Osborne's Process.)

Fig. 23.

Digitized by Google

with the demand for the maximum economy of fuel obtainable, has risen the necessity of substituting the compound engine with its divided expansion for the single cylinder engine with its irregular strains.

The advantage of introducing double engines at sea is considerably greater than on land.

The coal carried by a steam-vessel is not only an item of great importance in consequence of its first cost, but, displacing its weight or bulk of freight which might otherwise be carried, it represents so much non-paying cargo, and is to be charged with the full cost of transportation in addition to first cost. The best of steam-coal is therefore usually chosen for steamers making long voyages, and the necessity of obtaining the most economical engines is at once seen, and is fully appreciated by steamship proprietors.

Again, an economy of one-fourth of a pound per horse-power per hour gives, on a large transatlantic steamer, a saving of about one hundred tons of coal for a single voyage. To this saving of cost is to be added the gain in wages and sustenance of the labor required to handle that coal, and the gain by one hundred tons of freight carried in place of the coal.

The progress of improvement has been somewhat slow and is easily traced. In the early days of steam-navigation many types of single-cylinder steam-engines were tried, and even, as already stated, occasionally a compound engine. European practice gradually settled down to the adoption of the "side-lever engines" for marine purposes on sea-going steamers. In America the overhead "beam-engine" came into almost universal use in eastern waters, and the direct-acting engine as universally on western rivers. The latter engine has nearly always been made non-condensing. Engines for sea-going steamers have been invariably condensing.

The propelling-instrument was always, until very recently, the paddle-wheel. Watt patented a "spiral oar" in 1784, and Bernouilli seems to have had the idea a quarter of a century earlier. Col. John Stevens, of Hoboken, N. J., built a boat and steam-engine with a single screw, and a second with twin screws, and worked them successfully with steam at 50 pounds' pressure from a tubular boiler, in the years 1804 and 1805.* The plans of these vessels were matured at about the time that Fulton was proposing to order from the English manufacturers the Boulton & Watt engine, which he afterward used to drive the Clermont.

The next boat of Colonel Stevens, the Phœnix, was completed almost simultaneously with Fulton's boat. Paddle-wheels were used instead of the screw, because the size of the boat was too great to permit the economical use of screws in such shallow waters.

The use of the paddle became universal, and it remained the only propelling-instrument used for very many years.

51. The rude workmanship and the faulty design of the machinery of

*This machinery is preserved at the Stevens Institute of Technology at Hoboken.

Digitized by Google

those early days made it impossible to detect faults of detail, and progress was necessarily extremely slow. With gradual improvement in tools and in methods of doing work, it became possible to control higher steam and to work it successfully; and the change in this direction has been steadily going on up to the present time with all types of steam-engine. At sea this rise of pressure was for a considerable time retarded by the serious difficulty encountered in the tendency of the sulphate of lime to deposit in the boiler. When steam-pressure had risen to 25 pounds per square inch, it was found that no amount of "blowing out" would prevent the deposition of seriously large quantities of this salt, while at the lower pressures at first carried at sea no troublesome precipitation occurred, and the only precaution necessary was to blow out sufficient brine to prevent the precipitation of common salt from a supersaturated solution.

52. SURFACE-CONDENSATION.—The introduction of surface-condensation was promptly attempted as the remedy for this evil, but for many years it was extremely doubtful whether its disadvantages were not greater than its advantages. It was found very difficult to keep the condensers tight, and boilers were injured by some singular process of corrosion, evidently due to the presence of the surface-condenser. The simple expedient of permitting a very thin scale to form in the boiler was, after a time, hit upon as a means of overcoming this difficulty, and thenceforward the greatest obstacle to the general introduction was the conservative disposition found among those who had charge of marine machinery, which conservatism regarded with suspicion every innovation. Another trouble arose from the difficulty of finding men neither too indolent nor too ignorant to take charge of the new condenser, which, more complicated and more readily disarranged than the old, demanded a higher class of attendants.

Once introduced, however, the surface-condenser removed the obstacle to further elevation of steam-pressure, and the rise from 20 to 60 pounds' pressure soon occurred.

The writer had occasion in the year 1867, when an engineer-officer in the Navy, to investigate the causes and to determine how to prevent the corrosion frequently attendant upon surface-condensation, and a paper embodying his conclusions was written in November of that year for the Association of Assistant Engineers of the United States Navy at the Naval Academy, where he was then detailed to duty as an acting assistant professor of natural and experimental philosophy.

This action is ascribed by some engineers to a galvanic action induced by the large amount of copper or of bronze entering into the construction of the surface-condenser; by others, it is supposed to be due to the action of impurities retained in the feed-water; still others consider it the effect of the corrosive action of certain vegetable acids derived from the oils or tallow used in lubrication, and some refer it to what the writer believes at least one cause—the action of metals transported mechani-

Digitized by Google

cally in suspension, or in solution as a metallic salt, from the condenser to the boiler.

Engineers generally admit that experiment has not yet satisfactorily answered this important question, and often, without knowing anything of the cause, they take the only well-tested method of preventing the effect, viz, covering interior heating-surfaces with a coating of scale, and seldom make an investigation of the phenomenon with a view to the determination of its cause.

Although observation and experiment have not pointed with certainty to the cause of this "pitting," as it is generally and expressively termed, a careful consideration of known facts and chemical laws may enable us to frame a theory that shall at least possess the merit of accordance with observed facts and of strong probability.

Cases have occurred, and instances are perhaps known to every engineer, in which, after engines and boilers had been working a considerable length of time with jet-condensers, and while the latter were still in good condition, surface-condensers were introduced and a rapid and ruinous corrosion of the boilers immediately ensued. This effect could not have been due to the simple change within the boiler from salt-water to fresh, for such corrosion is not observed in land-boilers using good water. It is also well known that pure water is less active in attacking the metals than water containing salts.

It is extremely improbable that such rapid corrosion and pitting could be due to a galvanic action in a circuit in which the interior of the boiler forms one pole and the bronze of the condenser and pumps forms the other.

That galvanic action may take place to some extent is not unlikely; for the cases so often reported in which the iron of the condenser and hot-well, in arrangements of jet-condenser, is destroyed by oxidation, or, as it is often described by the ignorant, by transmutation into plumbago, are probably due principally to such action; and, while the distance of the boiler from the electro-negative metals protects it very greatly, it probably cannot completely prevent corrosion from this cause.

But that this action must be very slight seems proved by the fact that internal corrosion from all causes is usually inappreciable with jet-condensers, even where external corrosion has partly injured the boiler, although the presence of the copper or bronze, which acts with such serious results on the metal of the condenser and the air-pump in its vicinity, might be expected in such cases to affect the boiler also quite seriously before the lapse of any considerable period of time.

It should also be remarked that "pitting" is not more frequently developed at the points nearest the connections with the engines than elsewhere, as might be expected to be the case were it an effect of galvanic action induced by parts of the engine. Further, if it were possible for galvanic action to produce extensive corrosion, it would still probably take place with tolerable uniformity over the surface as it takes place

Digitized by Google

in the galvanic battery, and as it generally takes place in the oxidized condensers before referred to. It probably would not produce the deep and irregularly-distributed depressions found to accompany surface-condensation.

The addition, therefore, of bronze even to the extent that it is introduced in the surface-condenser does not appear likely to induce serious galvanic action on the boiler.

The necessary conclusion seems to be that the peculiar corrosion under consideration must be caused by some foreign matter carried into the boiler by the feed-water, either in mechanical suspension or in solution.

An analysis made by the writer in 1865 proved the brown deposit above the water-line of a boiler used in connection with a surface-condenser to consist of oxide of iron without a trace of other matter except earth; but an English analysis of the brown, slimy deposit found *upon the pitted surfaces* showed that it consisted of oxide of iron with about one per cent. each of *grease* and of *oxide of copper*.

If, as will presently be shown to be probable, the copper is deposited on the surface of the iron in intimate contact with the metal and in crevices and depressions, the amount given is probably far too small.

The presence of grease bears strongly against the theory which supposes the lubricants carried into the boiler to be decomposed, by high temperature, into the fatty acids which attack the iron. Could such decomposition take place, it is very probable that the iron would be attacked, forming an insoluble soap. But, even then, it is questionable whether such feeble acids as are the fatty acids would not produce a far less violent, as well as a more diffused, action.

Such decomposition of oils cannot, however, take place at the temperatures and pressures of our marine steam-boilers, as it requires a temperature of from 450° to 500° to decompose the oils even when not under pressure, and under pressure still higher temperatures are required.

Consequently the only change that may be anticipated in the lubricants is that which takes place in air, *i. e.*, its slow oxidation and final decomposition into carburetted hydrogens and oxides of carbon.

The only other matters carried into the boiler by the feed-water are organic matters and copper and oxide of iron.

From the first and the last no serious effect is to be apprehended, while from the copper, which analysis shows to exist in the boiler in all such cases, must be expected most injurious action.

There are three ways in which copper may be carried into the boiler:

1st. Mechanically by the current of feed-water in the form either of metal or of oxide; most probably the latter.

2d. Dissolved in the water as a metallic salt.

3d. Dissolved as oxide in the oil or tallow.

Neither copper nor its oxide is soluble in water, and as a salt of copper once formed would not by contact with iron be reduced to oxide, it is very possible that part of the oxide formed by analysis may be car-

Digitized by Google

ried in suspension by the water, as gold and other heavy metals are known to be transported by a current.

The formation of the oxide would take place very readily by contact of bronze in presence of hot water with the air passing with the water through the engine. Its transportation to the boiler might not at first seem probable, but when it is considered that under such circumstances it takes the form of a flocculent mass of extreme levity, such transportation will not be considered improbable.

The only salt of copper that can probably be carried over in solution is the chloride, which is derived by a peculiar, and as yet unstudied, reaction.

When sea-water containing organic matter is brought in contact with oxide of copper, the organic substance takes from the copper its oxygen, and the metal appears then to form with salt a double chloride of copper and sodium by an unknown reaction.

This is a soluble salt, which is carried to the boiler, when by another double decomposition the copper is deposited.

In the main engine the organic matter is introduced as oil, and is found as an impurity in the water or is derived from the packing. The reaction referred to above is not described in any published work, and its exact formula cannot be stated.

Finally the oxide of copper is carried to the boiler dissolved in the oil and tallow used for lubrication, and very probably it may be principally by such solution that the deposit of copper is produced.

The salts of copper entering the boiler in these several ways, swept about in impalpable particles by the circulation of water, are finally lodged in the depressions and minute crevices in the surface of the iron of the boiler, and at every point at which it collects the iron is rapidly corroded and a depression or "pit" produced.

The probable cause of the corrosion accompanying surface condensation is principally copper carried over from the condenser as an oxide dissolved in oily matter or as a chloride in solution in the feed-water, and this action is assisted by addition of exceedingly small quantities of copper carried over in mechanical suspension, and is also stimulated by very slight galvanic action induced directly by the voltaic relations between the copper of the condenser and the iron of the boiler and between different portions of iron in different states of aggregation. All of these causes are far more energetic with the surface than with the jet-condenser, and together may cause very rapid corrosion.

As a particle of copper will induce voltaic action over a surface of many times its own area, but small quantities of copper in actual contact with the iron may produce very serious corrosion; and it may be readily believed that the amount carried into the boiler from a surface-condenser may be in a few months sufficient to produce marked effects.

The action being local, the distribution of pieces of zinc in the boiler cannot be expected to effect a cure, although it would probably have the effect of checking corrosion.

Digitized by Google

The proper remedy would seem to lie either in the substitution of some other metal for the copper or in covering the surfaces, either of the iron or the copper, by a substance that may not act injuriously upon the more oxidizable metal.

The latter method is the one universally adopted. In most cases the heating-surfaces are allowed to become slightly coated with scale, and manufacturers are also adopting the practice of tinning the condenser-tubes.

53. RECENT CHANGES.—Meantime the improvements in design and in workmanship had so far perfected the then standard marine engine in its details that the advantages of the screw became perceivable, and it began to displace the paddle-wheel.

The change from the side-lever single-cylinder engine, with jet-condenser and paddle-wheels, to the direct-acting compound engine, with surface-condenser and screw-propellers, has occurred within the memory and under the observation of even young engineers, and it may be considered that the revolution has not been completely effected. This change in the design of engine is not as great as it at first seemed likely to become. It is a principle which is becoming gradually understood by engineers that, so far as simple expansion is concerned, it is not a matter of consequence whether it takes place in one cylinder or in several. In other words, as stated by Rankine, "the energy exerted by a given portion of a fluid during a given series of change of pressure and volumes depends on that series of changes, and not in the number and arrangement of the cylinders in which those changes are undergone.

"The advantage of employing the compound engine is connected with those causes which make the actual indicated work of the steam fall short of its theoretical amount, and also with the strength of the engine and its framing, the steadiness of action, and the friction of its mechanism."

54. CONDITIONS OF MAXIMUM EFFECTIVE EXPANSION.—The changes of design recently observed in marine engines, and less strikingly in stationary steam-engines, have been compelled by purely mechanical and practical considerations. The increase noted in economy of expenditure of steam and of fuel is, as has been stated, due to increased steam-pressure, greater expansion, and higher piston-speeds, with improved methods of construction and finer workmanship. These several directions of change occur simultaneously, and are all requisite. To secure maximum economy for any given steam-pressure, it is necessary to adopt a certain degree of expansion which gives maximum economy for that pressure under the existing conditions.

This point of cut-off for maximum efficiency lies nearer the beginning of the stroke as steam-pressure rises. For low pressure a much greater expansion is allowable in condensing than in non-condensing engines; but as pressure rises, this difference gradually lessens. For example, with steam at 25 pounds by gauge, the best economical results are ob-

Digitized by Google

tained when expanding about three times in good condensing-engines and about one and a half times in non-condensing engines. With steam at 50 pounds, these figures become five and two and a half, respectively; and at 75 pounds, the highest efficiency is secured in condensing-engines cutting off at one-fifth and in non-condensing engines with cut-off at one-third stroke.

Owing to the increasing proportional losses due to back-pressure and other retarding influences, the departure from the economical result indicated for the perfect engine becomes greater and greater, until, at a pressure of between 200 and 250 pounds, the proper point of cut-off becomes about one-sixth or one-seventh, and very nearly the same for both classes of engines, and the increase of efficiency by increase of pressure and greater expansion becomes so slight as to indicate that it is very doubtful whether progress in the direction of higher pressure will be carried beyond this limit.

55. CAUSES OF THE SUCCESS OF THE DOUBLE-CYLINDER ENGINE.—But this limit cannot be even approached in the recently standard form of marine engine, that with single cylinder.

In the stationary engine a large fly-wheel is admissible, and may be relied upon to secure regularity of motion with a cut-off as short as one-fourth or one-fifth, although, even in this case, the power required to overcome the friction of its shaft becomes a tax which tells somewhat strongly against the moderate gain in the efficiency of the steam which is by its use rendered attainable. A fly-wheel has been used on board ship with a single-screw engine of the old type, and, it has been claimed, with good results. General opinion among marine engineers is, however, entirely opposed to its use, and without it, with high steam and considerable expansion, it is quite impossible to secure regularity of motion in even the usual form of two engines with cranks coupled at right angles when working so expansively as to produce a considerable range of pressure in the cylinder.

Another difficulty, which is common to all cases in which considerable expansion occurs in one cylinder, is that of the size and weight of parts which must be proportioned to carry the maximum stresses of high pressure while transmitting a mean pressure which is but a fraction of the maximum.

The engine which expands steam greatly is, therefore, necessarily a heavier engine than that which uses steam of lower pressure, obtaining the same power without expansion.

Still another objection to great expansion in the single cylinder is to be found in the fact that a large proportion of the total work is done at the beginning of the stroke, and the proportion absorbed by friction becomes an objectionably large percentage of the whole. The serious losses arising from condensation and re-evaporation within the cylinder, and which place an early limit to the benefit derivable from expansion, affect both types of engine, and, so far as seems now known, equally

Digitized by Google

Certainly no reliable determination has yet been made of the comparative effect of this action upon them.

The lightness of engine and the smaller weight of boiler required when the "compound" engine is used are great advantages, and, when coupled with the fact that by no other satisfactory device can great expansion and consequent economy of fuel be obtained at sea, the advantages are such as to make the adoption of this style of engine imperative for ship-propulsion.

The committee of the British admiralty on designs of ships of war have reported recently, "The carrying-power of ships may certainly be to some extent increased by the adoption of compound engines in Her Majesty's service. Its use has recently become very general in the mercantile marine, and the weight of evidence in favor of the large economy of fuel thereby gained is, to our minds, overwhelming and conclusive. We, therefore, beg earnestly to recommend that the use of compound engines may be generally adopted in ships of war hereafter to be constructed, and applied whenever it can be done with due regard to economy, and to the convenience of the service, to those already built." Chief Engineer Charles H. Baker, U. S. N., has collected the results of extended trials of marine engines under ordinary conditions of regular working, and they are condensed in the following table:

Relative economy of simple and compound engines.

Description of engine.	Pounds of steam consumed per hour per total horse-power, inclusive of the quantity condensed in the production of the power.	Pounds of steam condensed in the steam-jackets per total horse-power, calculated upon the basis of an experiment with the engine of the Brooklyn Water-Works.	Pounds of steam condensed in the cylinders per total horse-power, due to all causes other than the production of the power.	Cost of the power in pounds of steam per horse-power per hour. Total.	Indicated.	Net.	Pounds of steam consumed per total horse-power developed in the low-pressure cylinder, inclusive of the quantity condensed in the steam-jackets.
60 x 36 inch Navy engines:							
United States steamer Guerriere	23.67	....	4.99	28.66	35.70	40.56	....
United States steamer Delaware	25.96	....	4.00	29.96	36.40	41.03	....
United States steamer California	24.50	....	5.10	29.60	35.40	41.00	....
United States steamer Congress	25.95	....	4.40	30.35	35.55	40.85	....
50 x 42 inch Navy engines:							
United States steamer Alaska	23.40	....	4.10	27.70	35.30	41.40	....
United States steamer Benicia	23.50	....	4.30	27.80	35.20	40.30	....
36 x 36 inch Navy engines:							
United States steamer Resaca	23.80	....	5.00	28.80	34.80	43.00	....
United States steamer Swatara	23.00	....	4.20	27.20	33.70	38.60	....
Compound engines:							
Steamer ——	15.9	2.18	....	18.08	22.53	27.16	29.18
Steamer Italy	16.7	2.18	....	18.88	21.49	26.10	31.57
Steamer Spain	16.6	2.16	....	18.76	21.85	26.54	32.77
Steamer City of Bristol	16.2	2.11	....	18.31	21.01	25.85	28.07
Steamer Gracia	18.3	2.32	....	20.62	21.97	26.31	....
Steamer Patagonian	15.9	2.04	....	17.94	21.16	25.99	29.42
Steamer Batavia	17.6	2.27	....	19.87	24.78	30.09	34.14
Steamer Egypt	17.7	2.28	....	19.98	24.89	29.42	32.00
Mean:							
60 x 36 inch engines	25.02	....	4.62	29.64	35.76	40.86	....
50 x 42 inch engines	23.45	....	4.20	27.75	35.25	40.85	....
36 x 36 inch engines	23.40	....	4.60	28.00	34.25	40.80	....
Mean:							
Navy engines	23.95	....	4.47	28.46	31.75	40.83	....
Compound engines	16.86	2.19	....	19.05	22.46	27.18	31.02

Digitized by Google

Builders have but slowly learned the principles stated above in reference to expansion in one or more cylinders, and the earlier engines were made with a high and low pressure cylinder working on the same connecting-rod, and each machine consisted of four steam-cylinders. It was at last discovered that a high-pressure single-cylinder engine exhausting into a separate larger low-pressure engine might give good results, and the compound engine became as simple as the type of engine which it displaced. This independence of high and low pressure engines is not in itself novel, for the plan of using the exhaust of a high-pressure engine to drive a low-pressure condensing-engine was one of the earliest of known combinations.

56. EXHIBITED MARINE ENGINES.—At the Vienna Exhibition are illustrated all of these types of engine. There are a number of marine engines of older form exhibited, but they do not call for special mention here.

An engine is exhibited by Messrs. BURMEISTER & WAIN, of Copenhagen, Denmark, which is a good example of the more cumbersome style of compound engine. A high and a low pressure cylinder are mounted in the same line, their pistons secured to the same rod and driving the same crank. (See Figs. 24 and 24 A.) The large steam-cylinders have trunks. A similar pair is coupled to the other crank, which is set at right angles with the first. This forms a four-cylinder compound engine, such as was thought good practice a few years ago. This engine is described as of

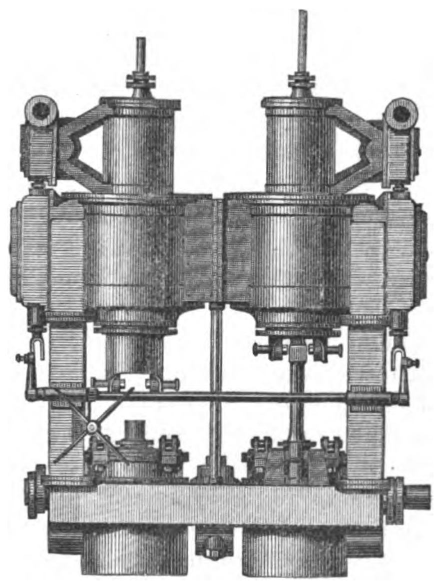


FIG. 24.—Engine of Burmeister & Wain.

thirty nominal horse-power. The builders claim that these engines will give 150 indicated horse-power with a consumption of 2½ pounds (Rhen-

Digitized by Google

ish) of coal per horse-power per hour. They are built complete with boilers, and erected on board ships, for $18,000, Danish money, ($9,900 gold.) These engines are apparently well proportioned in all details,

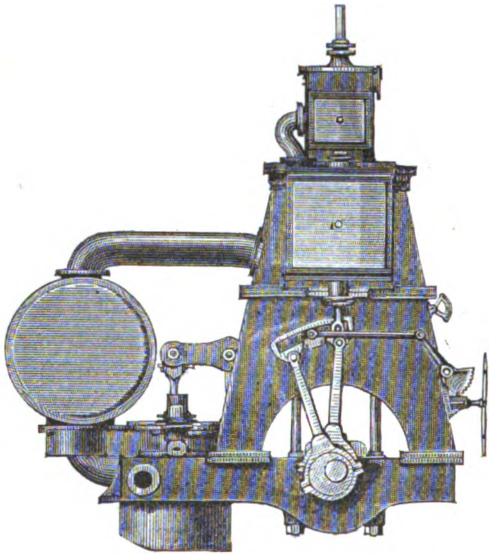


Fig. 24 A.—Engine of Burmeister & Wain.

and of good material. They have a good finish, and their workmanship throughout is excellent. The height of the engines, which would otherwise be very objectionable, has been kept within usual limits by fitting the low-pressure engines with trunks. The valves of the high-pressure cylinders are attached to the same rods which operate the valves of the larger cylinders. The engines are fitted with surface-condensers, and have bucket and plunger air-pumps, worked by levers attached to the main trunk. This firm have built these engines since about 1854, using pressure of 50 to 60 pounds per square inch. The boilers of the Fylla, built in 1861, drove a set of these engines and required no repairs until 1871–'72.

57. The compound marine engines of the Donau Dampfschiffahrt Gesellschaft form a very interesting collection, and the most extensive exhibit of this class on the grounds. This company had a small building appropriated to its exhibits, and filled it with a very fine set of model steamers, and with engines of full size, together with samples of their supplies. This large company supports a line which traverses a distance of more than twenty-five hundred miles—from Donauwerth to the Black Sea—with auxiliary branches. They have 166 steamers, of collectively 148,116 indicated horse-power.

One of their larger steamers, the Orient, which is a fair sample of their vessels, is much like an American Hudson River steamer in general appearance. It is of rather light draught, (4 feet,) with high upper

Digitized by Google

works and a number of state-rooms. This vessel is 250 feet long, of 27½ feet beam, and 9½ feet depth of hold. The number of berths is 178 and of state-rooms 11.

WIRE-ROPE TOWAGE.—One of the most interesting among the models shown by this company is that of a ferry-boat, the Waag. It is a vessel of 120 feet in length, 23 feet beam, and 6½ feet depth of hold. The draught is but 2½ feet. This vessel is propelled by "overhauling" a chain which lies along the bed of the river between Vienna and Pressburg. The same method is adopted on the Elbe and on other rivers of Europe for towage. The chain is laid on the river-bed, from end to end of the route. The steamer is provided with a winding-drum instead of paddle-wheels, and is thus fitted to haul in the chain at one end of the vessel and to pass it off at the other end.

The *Sächsische Dampfschiffs- und Maschinenbau- Anstalt*, of Dresden, also exhibited the machinery of a vessel of similar character, with steam-cylinders 12 inches diameter and 2 feet stroke.

Messrs. Sulzer Freres, of Winterthur, Switzerland, placed on exhibition machinery for wire-rope towage, constructed by them on the system of Baron De Mesnil and Herr Eyth, for a tow-boat to be employed on the Rhine by the Cologne Tow-Boat Company. The steam-engines had cylinders $14\frac{3}{16}$ inches in diameter and $23\frac{5}{8}$ inches stroke, well lagged, and fitted with steam-jacketed heads as well as sides. The expansion-gear consisted of link-motion and main and cut-off slide-valves, adjustable by hand to expand from $\frac{4}{3}$ to 10 times.

The steam is exhausted into tubular feed-water heaters and into a jet-condenser. The engines can be worked with or without condensation, as may be desired. The air-pump is 10 inches diameter. The engines are intended to make, as a maximum, 150 revolutions per minute. We found that steel had been used freely in their construction. The piston-rods, crank-shaft, and other important details were made of that metal. The clip-drum carrying the wire rope is 9 feet in diameter.

58. ROPE-TRACTION VS. PADDLE-WHEELS.—This method of propulsion, where practicable, is decidedly more economical of power than the ordinary methods, especially where, as in towing, the losses by slip and by oblique action of the paddle-floats become very serious. The total loss varies from an average of probably 25 or 30 per cent., in ordinary cases, to 55 per cent., and perhaps much more for tow-boats. It is somewhat remarkable that this method of propulsion, which is so common in Europe, should be so little practiced in the United States.

This appears the more remarkable when an analysis is made of the action of the paddle-wheel,* and the fact is thus shown that these losses by slip and oblique action, which are entirely avoided in chain-propulsion, are necessarily serious in the paddle-wheel. This analysis may be thus made:

* Journal Franklin Institute, 1869.—Losses by oblique action in the paddle-wheel. R. H. Thurston.

Digitized by Google

In a marine steam-engine of good design and in good order, about 7 per cent. of the indicated horse-power may be expected to be consumed in the moving of the parts of the machinery itself, the remaining 93 per cent. being applied to the propelling-instrument.

Where the radial paddle-wheel is used, a considerable part of the work done by the wheel is expended uselessly in forcing the water downward, or in lifting it; and of that power which finally acts horizontally, a part is unavoidably lost in setting in motion the water upon which the wheel acts. Thus the power exerted by the *engines* is considerably greater than that exerted by the *ship* in resisting motion.

To ascertain the amount of these losses, when the vessel is at rest, as on the instant of starting the engines, the first of these losses, that from oblique action, is easily calculated, thus:

Measure the length of the immersed arc described by the center of pressure of the floats and the length of its chord. The ratio of the squares of these quantities will give the ratio of total power exerted to power expended horizontally by the wheel.

When the vessel moves ahead, the conditions of the problem are at once greatly changed.

The floats, then, instead of moving in a circle through the water, describe curtate cycloids.

They then move through the water obliquely, and with velocities varying every instant.

This forward movement of the vessel gives, to some extent, a "feathering" action to the floats, and the loss from oblique action becomes very greatly diminished.

The principal portion of the work is done in the lower portion of the path of the float, where there is less oblique action.

Noticing the positions assumed by the floats at different points, and the direction of their motion, it becomes evident, also, that the amount of "dip"* influences the amount of loss from oblique action very greatly when the vessel moves ahead, as well as in the previous case, and the most economical wheel will be that in which the sum of the losses from dip and slip are reduced to the greatest extent.

To ascertain the amount of loss of power in oblique action:

Let V = velocity of paddle-float at center of pressure.

v = velocity of vessel.

α = angle included between an arm, and horizontal line through the center.

β = any other angle.

$u = \frac{v}{V}$.

r = radius.

---

* The "dip" is the depth of the lower edge of the paddle-float beneath the surface of the water.

Digitized by Google

The tangential velocity of the center of pressure of any float will be $(V - v \sin a) = V(1 - u \sin a)$, and the horizontal velocity through the water will be $(V \sin a - v) = V(\sin a - u)$.

The normal pressure on a unit of area of the float will be measured by the square of its velocity in the direction of that pressure, or $V^2 (1 - u \sin a)^2$, and the total work done by the engine in turning the float throughout any arc will be—

$$rV^2 \int_a^\beta (1 - u \sin a)^2 \, da \ldots\ldots\ldots\ldots \quad (1)$$

The horizontal component of the pressure on the float, which only is useful in propelling the ship, will be—

$$V^2 (1 - u \sin a)^2 \sin a$$

While the float is moving through the arc $r\,da$ in the time $dt = \frac{r\,da}{V}$, this horizontal resistance will be met through a space $V(\sin a - u)\,dt = r\,da\,(\sin a - u)$, and the power expended horizontally upon the water while the wheel moves through any elementary arc will, therefore, be expressed by $r\,V^2 (1 - u \sin a)^2 (\sin a - u) \sin a\,da$; and while moving through any arc, by—

$$r\,V^2 \int_a^\beta (1 - u \sin a)^2 (\sin a - u) \sin a \, da \ldots \quad (2)$$

But while this amount of work is expended upon the water, the wheel must, in consequence of the slip, do a greater amount of work in a proportion varying at each point with the slip, and the total horizontal work of the wheel will be obtained by multiplying the expression for the elementary arc by the factor $\frac{V}{V(1 - u \sin a)}$.

The total amount of work done in this direction, then, while passing through the arc will be, including slip—

$$r\,V^2 \int_a^\beta (1 - u \sin a)(\sin a - u) \sin a \, da \ldots \quad (3)$$

The ratio of (3) to (1) will be the ratio of gross horizontal work to the total work done on the wheel.

Integrating between limits, this ratio becomes—

$$\frac{(3)}{(1)} = \frac{\frac{u^2+1}{2}(\beta - a) + 2u(\cos\beta - \cos a) - \frac{u}{3}(\cos^3\beta - \cos^3 a) - \frac{u^2+1}{4}(\sin 2\beta - \sin 2a)}{\frac{u^2+2}{2}(\beta - a) + 2u(\cos\beta - \cos a) - \frac{u^2}{4}(\sin 2\beta - \sin 2a)}$$

In this equation, making a the angle of entrance of the mean center of pressure of the float,* and calling $\beta = 90°$, $\frac{v}{V}$ being known, the loss of power in *any* wheel by oblique action may be obtained by subtracting the ratio resulting from our final equation from unity.

* See paper by J. D. Van Buren, jr., Journal of the Franklin Institute, 1865.

The following are data assumed and results obtained as above:

First case.	Second case.	Third case.	Fourth case.
$a=60^\circ=\frac{\pi}{3}=1.047$ $\beta=90^\circ=\frac{\pi}{2}=1.570$ $\frac{v}{V}=\frac{3}{4}$ Dip. $=\frac{3}{20}$ radius. Efficiency = .949. Loss by oblique action = .051.	$a=42^\circ=\frac{7}{30}\pi$ $\beta=90^\circ=\frac{\pi}{2}$ $\frac{v}{V}=\frac{3}{4}$ Dip. = $\frac{1}{3}$ radius. Efficiency = .907. Loss = .093.	$a=30^\circ=\frac{\pi}{6}$ $\beta=90^\circ=\frac{\pi}{2}$ $\frac{v}{V}=\frac{3}{4}$ Dip. = $\frac{1}{2}$ radius. Efficiency = .83. Loss = .17.	$a=0^\circ=o.$ $\beta=90^\circ=\frac{\pi}{2}$ $\frac{v}{V}=\frac{3}{4}$ Dip. = to center. Efficiency = .70. Loss = .30.

The first case corresponds to that of light river-steamboats, the second to that of ocean-steamers, while the third is an exaggerated, though not remarkably rare, case. The fourth case is given simply in illustration of the use of the formula; it, of course, is unknown in practice.

Here the efficiency and loss are expressed, not in fractions of total indicated horse-power, but of the power applied to the wheel; and referred to indicated horse-power, those losses would be .047, .068, .158, and .28, respectively.

If it is required to find the loss of power by oblique action and slip combined, and thus to ascertain if the designer of the hull has fulfilled his guarantees, the net power expended in simply overcoming the resistance of the ship must be obtained. The amount of horizontal expenditure of power just obtained must, in this case, be reduced by multiplying by the ratio $\frac{V-v}{V}$, or it may be taken from (2.)

In the examples given above, the slip is assumed to be known, and in each case is taken at 25 per cent., and this net power usefully expended is found, after making this reduction, to be .714, .685, .631, and .52 of total indicated horse-power.

In the fourth case, the slip would actually be very much greater than is assumed above, and the efficiency would probably fall below 20 per centum of the indicated horse-power.

These results agree very closely with those deduced from experiment, and indicate very plainly the economy to be anticipated by the avoidance of these two serious sources of waste of power.

The screw is also subject to both sources of loss, but, working in a following current under the stern of the vessel, it enjoys a counterbalancing advantage which makes it superior to the paddle as an instrument of propulsion.

The objection to the adoption of the chain in general practice is the necessity of following closely the line along which it is laid. This difficulty is not, however, so great as it would at first seem. Boats thus propelled in some cases have turned around quite sharp bends, and

Digitized by Google

readily avoid other craft by a slight change of course, and at the same time altering speed.

59. The engines exhibited by the DONAU GESELLSCHAFT were compound engines of exceptionally good design. One was a screw-engine with intermediate receiver; another was an oscillating paddle-engine, and the third large engine was an inclined engine. The trunk air-pump, the solid-bar Stephenson links, and other details gave good evidence that the designer was more than a mere copyist of the designs of others.

The solid-bar link seems gradually making its way into favor, and displacing the hitherto standard "open" or "strap" link. It has an important advantage in affording a means of taking up wear, and thus avoiding the shake and jar and the noise which follows from the slightest wear in the common link.

60. The STABILIMENTO TECHNICO TRIESTINO," an establishment located at Trieste, exhibited two sets of compound marine engines, which were very creditable indeed, and unexcelled by anything of the same class in the exhibition. These engines were of the "Napier style," well designed and well made, and had a sensible and serviceable appearance, which was quite in contrast with that of some competing specimens of marine work. The finish was plain, but quite as good as should be asked, and the amount of "bright-work" about them was reduced to the least amount consistent with good appearance. The builders evidently understood that much highly-finished work on a marine engine is out of place.

The 150 N. H. P. engines are provided with a centrifugal circulating-pump, driven by an independent engine. This arrangement is in some respects a very excellent one, and it is apparently becoming standard practice. With a plain, simple engine and an effective form of circulating-pump, no objection exists to its adoption.

The large pair of engines had steam-jacketed cylinders, 31 and 60 inches in diameter, and a stroke of piston of 3 feet. The method of securing the inner barrels of the cylinder to the outer casing so as to be at once steam-tight and rigid, in spite of changes of dimensions due to changes of temperature, was stated to be similar to that now generally practiced in Great Britain. It is so excellent and in every way satisfactory that it should be more generally known in the United States. At the lower end, the linings are secured rigidly to the main cylinder-casting by bolted flanges. At the upper ends, the barrel fits snugly, but without jamming, and a stuffing-box is made between it and the casing. This stuffing-box is filled with a wire-rope packing, sometimes of galvanized wire, and with white lead. It is driven in snugly and confined by an annular ring bolted firmly down upon it.

The "box-framing" forms also the hot-well. The surface-condenser is cleared by a single-acting air-pump of 26 inches diameter and 1½ feet

Digitized by Google

stroke. The feed-pumps and the bilge-pumps are driven from the cross-head of the air-pump.

61. Messrs. JOHN PENN & SON, of Greenwich, Great Britain, exhibited a beautifully-made and exquisitely-finished model of one of their marine trunk-engines of large size, such as was fitted up in the British iron-clad Minotaur and vessels of similar character. This form of engine has been built by this firm for many years, and, as constructed by them, has proved itself a very effective machine. In the hands of less experienced and less skillful builders, however, it has not succeeded, and it is generally regarded by engineers as an undesirable form of marine engine. Messrs. Penn & Son are themselves now building compound engines.

The Minotaur was one of the earlier of the British iron-clads. The great length and consequent difficulty of manoeuvring, the defect of speed, and the weakness of armor of these vessels have led to the substitution of far more effective designs in later constructions. The Minotaur is a four-masted screw iron-clad, 400 feet long, of 59 feet beam and 26½ feet draught of water. Her speed at sea is about 12½ knots, and her engines develop, as a maximum, nearly 6,000 indicated horse-power. Her heaviest armor-plates are but 6 inches in thickness. Her extreme length and her unbalanced rudder make it difficult to turn rapidly. With *eighteen men at the steering-wheel* and sixty others on the tackle, the ship, on one occasion, was 7½ minutes in turning completely around.

These long iron-clads were succeeded by the shorter vessels designed by Mr. E. J. Reed, of which the first, the Bellerophon, was of 4,246 tons burden, 300 feet long by 56 feet beam, and 24½ feet draught, of the 14-knot speed with 4,600 horse-power; and, having the "balanced rudder" used many years earlier in the United States by Robert L. Stevens,* it can turn in four minutes with eight men at the wheel. The cost of construction was some $600,000 less than that of the Minotaur.

62. The "SOCIÉTÉ JOHN COCKERILL," of Seraing, Belgium, exhibited a well-made pair of large oscillating engines, with feathering-paddle wheels, such as are very common in Great Britain and in the continental harbors and rivers. They presented no essential peculiarity of design and the remarks just made with reference to the trunk-engine will apply with almost equal force here.

63. THE FEATHERING-PADDLE is often used in Europe to the exclusion of the common or "radial" wheel, over which it possesses some decided advantages. As usually made, the diameter of the feathering-wheel is one half that of a radial wheel acting similarly upon the water. In other words, the floats traverse the water as if they were attached to a radial wheel of double diameter. This reduction of size permits the use of a smaller engine, making a greater number of revolutions, and thus cheapens its cost, permits a high speed of piston, and produces

*It is still in use on the Hoboken ferry-boats, and has now been largely introduced in naval vessels.

Digitized by Google

some economy. The small paddle-boxes present a comparatively small surface to the wind, and, by thus reducing head-resistance, give increased speed.

The disadvantages of this wheel are its complication and the expense of constructing it. In the United States, where the navigable rivers are usually obstructed by ice during some months in each year, it is impossible to adopt it with advantage. In Europe, where this rarely occurs, the feathering-paddle is almost universally used.

64. The high rate of speed required for economical expansive working is obtained in the United States by adopting the typical "American" overhead-beam engine, of which the long stroke of piston, the ease of working, and the readiness with which it accommodates itself, without difficulty, to changes in the shape of our flexible vessels, render it probably the best possible type to couple with our great radial wheels. It is only excelled in economy by the best compound-engines.

Some manufacturing firms, among them the principal Montreal engine-builders, are "compounding" this engine with satisfactory results.

This engine can readily be adapted to the feathering-wheel, and its use on the rivers and harbors of the South and in boats intended only for summer travel in the North would prove, if properly designed, satisfactorily economical.

65. Among the most interesting exhibits of marine machinery were the compound-engines of the Swedish twin-screw gunboats, exhibited by the MOTALA WORKS. These were horizontal compound-engines, with an intermediate receiver, with cranks set at right angles. The steam-cylinders were 10 and 20 inches in diameter, and the stroke of pistons 17½ inches. The air-pumps were 7⅝ inches in diameter and 8⅝ inches stroke. The cylinders were not steam-jacketed. The valves were the ordinary slide, driven by a link-motion. The engines were fitted with jet-condensers.

The steam-boilers supplying these engines were stated to be tubular boilers of 950 square feet of heating-surface, and 26½ feet of grate-surface.

The engines built from the same designs for the gunboat Ulf were said to have developed 160 indicated horse-power, with a consumption of less than 2½ pounds of coal per horse-power per hour.

66. The Motala Works also exhibited a small passenger-steamer on the river. This little craft, the Motala, was 56½ feet long, 11⅝ feet beam, and drew, loaded, 4¼ feet of water. It was driven by a plain non-condensing engine of 8 horse-power. The screw was 3⅙ feet diameter, 6¾ feet pitch, and the boiler, of locomotive type, contained 120 square feet of heating-surface, and 3⅝ square feet of grate-surface.

Digitized by Google

CHAPTER III.

LOCOMOTIVE-ENGINES.

NUMBER EXHIBITED, DIMENSIONS; TABLE; AMERICAN LOCOMOTIVES; BRITISH TANK-ENGINES; LOCOMOTIVES OF MM. HENRI SCHNEIDER & CO., MM. CLAPAREDE, THE COMPAGNIE DE FIVES-LILLE, THE SOCIÉTÉ JOHN COCKERILL, THE SOCIÉTÉ ANONYME DE COUILLET; THE GUINOTTE VALVE-GEAR, ITS DESIGN, CONSTRUCTION, APPLICATION TO REVERSING-ENGINES; PECULIAR APPLICATIONS; USE ON HOISTING-ENGINES; AUTOMATIC ADJUSTMENT; CAREL'S LOCOMOTIVE; RUSSIAN, ITALIAN, GERMAN, AND AUSTRIAN LOCOMOTIVES; THE STAATS EISENBAHN-GESELLSCHAFT; CHARACTER OF EUROPEAN WORK; BELPAIRE'S FIRE-BOX; STEAM-PRESSURES; RIVETING AND CALKING; MATERIAL—STEEL VS. IRON; KRUPP'S STEEL WHEELS; IRON WHEELS HISTORICAL; THE INTRODUCTION OF STEEL.

67. NUMBER AND DIMENSIONS.—More than forty locomotive-engines were exhibited at Vienna, all, with a single exception, having outside cylinders; the diameter of cylinders, varying from 8½ to 21½ inches, was usually 16½ or 17 inches. The driving-wheels ranged from 2½ feet diameter on a little English contractors' locomotive, to 6½ feet on two of the German engines. The weights of engines, in working order, ranged from 6½ to 70 tons.

68. The accompanying table, published in London Engineering, of date of June 6, 1873, contains the leading dimensions of nearly all; and, so far as the writer has been able to check it, it is very accurate:

69. AMERICAN LOCOMOTIVES.—It will be noticed that no American locomotive was exhibited.

Our builders seem to have assumed that no advantage would be gained by exhibiting at Vienna. This was probably an error. The American locomotive, which was formerly looked upon with little favor by European constructors, is now well known, and its advantages are well recognized. The fact that continental builders, and to a less extent the British, are copying it, both in general plan and in details, is the best evidence of the truth of this statement. One American firm has recently received a large European order, which, it is not unlikely, was prompted partly, if not wholly, by the exhibition of American locomotives in 1867, in Paris. Even more satisfactory returns might have been anticipated from similar enterprise in 1873. The reputation of American mechanics and engineers in Europe has steadily and rapidly increased since 1867, and a strongly favorable impression now exists, which, if properly taken advantage of by our people, will be found of great assistance in securing foreign orders and in the introduction into Europe of good American inventions.

Digitized by Google

That the American locomotive is looked upon with great favor by European engineers is indicated not only by the gradual adoption of that design in construction, but, in the case of Russia, particularly, by extensive purchases from firms in the United States. The Baldwin Locomotive Works, of Philadelphia, have sold a considerable number to the Russian lines of railroad, and the Grant Locomotive Works have concluded negotiations for the sale of fifty engines in a single contract. It is stated that these engines will be built for burning anthracite coal, of which a considerable deposit exists in that country.

The work done in Europe by our countrymen, Whistler, Harrison, Winans, and others, is still exerting an influence, to some extenttr aditional in origin but still proverbial, in favor of the work of American mechanics. The reputation of this nation abroad for ingenuity, tact, and power of adaptation to circumstances is largely due to them.

70. BRITISH TANK-ENGINES.—The British section contained two tank-engines, of good workmanship, and apparently of excellent material. The design is in each case neat, and the engines seem well fitted for doing good work. One, by FOX, WALKER & CO., of Bristol, was built for 3½ feet width of gauge, and was fitted with the Le Chatelier counter-pressure brake and a rude spark-arrester. It had outside cylinders, of 10 inches diameter and 18 inches stroke; driving-wheel, 3 feet diameter, with axles 6 feet from center to center, a pair of leading-wheels 2¼ feet diameter, fitted up with the radia axle-boxes applied by Adams. The boiler contained 96 tubes 1¾ inches diameter and 8⅜ feet long; its total heating-surface was 406 square feet and its grate-surface 7½ feet. The engine, in working order, weighed 18 tons, of which 66 per cent. was carried on the driving-wheels. Without fuel and water, the weight was 15 tons. It was fitted with "ring-tanks," and the coal was carried on the foot-board.

The other engine, by HUGHES & CO., of Loughborough, had cylinders 8½ inches diameter by 1¼ feet stroke; driving-wheels, 2½ feet diameter and 4½ feet from center to center of axles; heating-surface, 235 square feet; grate-surface, 5 feet; weight, 10 tons in working order, 8 tons empty; tank extending over the top of the boiler.

71. FRENCH LOCOMOTIVES.—France was represented in this class by three engines. One built by MM. SCHNEIDER & CIE, of Creuzot, for the Chemin de Fer du Midi, was a powerful outside-cylinder freight-engine, with eight coupled wheels. It was well designed, of excellent proportions, and the most beautifully finished locomotive in the Exhibition. It had a large area of grate, 20 square feet, (2.4 square meters,) and 208 square meters, (nearly 2,500 square feet,) of heating-surface. The cylinders were 21¼ inches (0.54 meter) diameter, with a stroke of piston of 2 feet, (0.61 meter.) Its weight was nearly 54 tons in working order. By giving a certain amount of play (0.20 meter) to the axles, it had been made capable, as was supposed, of running smoothly around curves of 1,000 feet radius. The connecting-rods were made with lateral

Digitized by Google

joints to avoid strain. It was a fine piece of work, but lacked the flexibility and easiness which are best seen in the American type of locomotive. As a specimen of good work, it was unsurpassed. The running-gear was all of steel. Its tender was not exhibited, but was said to have a weight, loaded, of about 18 tons.

A pump and injector were attached, the former on the right, the latter on the left hand side of the engine. The Le Chatelier counter-pressure brake is used, and a screw-brake is also attached.

The wheels were 47¼ inches in diameter, and their axles were spaced about 4¼ feet apart, giving a wheel-base of 12¾ feet. The boiler was 5 feet diameter of shell and 22½ feet long; the tubes were 2 inches in diameter, 16 feet long, and one-tenth of an inch thick. Steam-pressure was to be carried at about 125 pounds per square inch.

72. The other locomotives in the French section were exhibited by MM. CLAPAREDE and by LA COMPAGNIE DE FIVES-LILLE. That of the first-named firm was a plain machine of ordinary finish, and seemed a serviceable engine. It had six wheels, all coupled. The cylinders were 19 inches (0.48 meter) diameter and 26 inches (0.65 meter) stroke. It was designed by M. Forquenot, the engineer of the Paris and Orleans Railroad Company. The diameter of wheels was 4½ feet; length of wheel-base, 11¼ feet; and its width from frame to frame was 4 feet. The boiler had a shell 4½ feet in diameter, of one-half-inch iron, with 2-inch tubes 14½ feet long. The heating-surface was about 1,650 square feet; grate-surface, 16 square feet. The engine weighed 35 tons empty, or 38 tons on the line. A stay-plate at the middle of the boiler supports the tubes; the piston-rods pass through both heads. Many of the details of this engine seemed badly proportioned and awkwardly arranged.

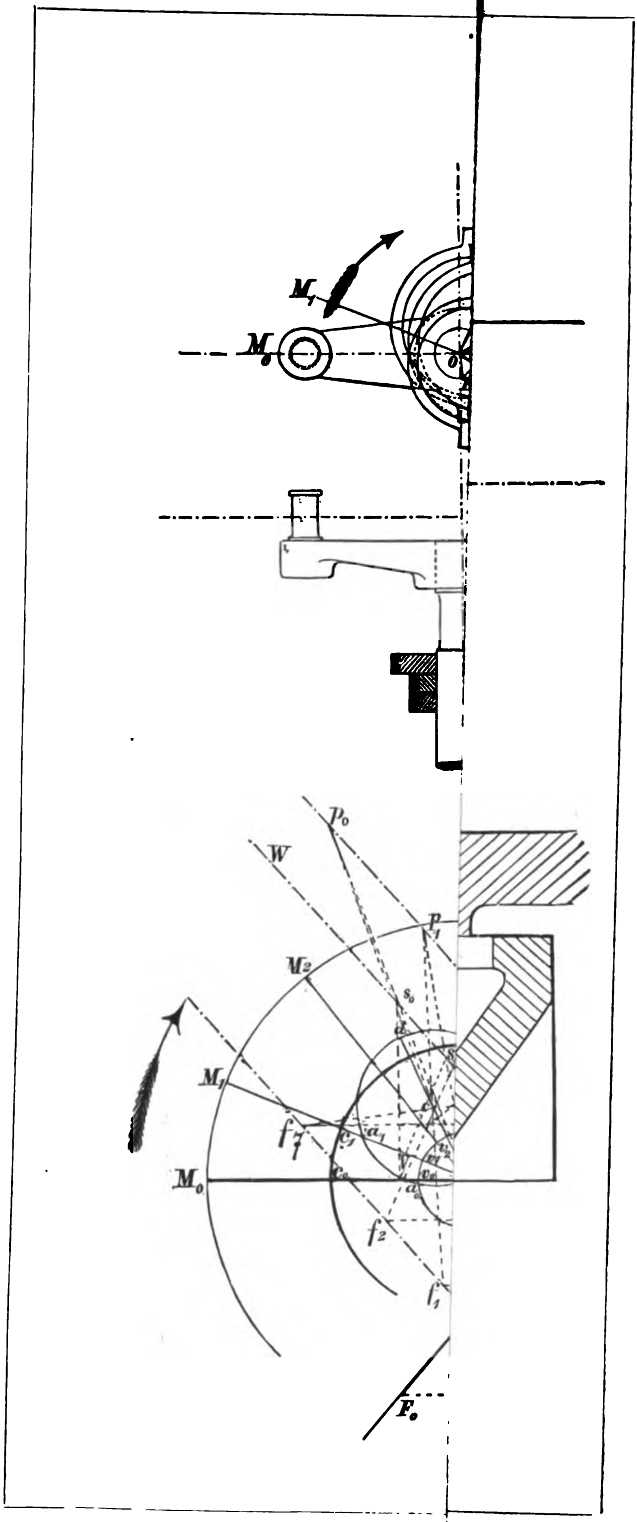
73. The engine of the second exhibitor was a small tank-engine with six wheels, all coupled and fitted to a track of one meter (3.28 feet) breadth of gauge. The weight of the engine was but 14 tons, and its cylinders had a diameter of 10 inches (0.25 meter) and a stroke of piston of 14½ inches (0.36 meter.) It was claimed to be capable of drawing 220 tons 20 kilometers (twelve and one-half miles) per hour on a level track. The distance between forward and after axles was 1.72 meters, (5 feet 8 inches,) and, as is usual in American practice, the middle pair of wheels were fitted with tires without flanges. It might be expected, therefore, to move freely on a sharp curve.

A Friedmann injector, a form which seems a favorite in Europe,* and a pump were attached to the boiler.

74. THE BELGIAN LOCOMOTIVES exhibit fairly the excellent position which their manufacturers have assumed in Europe. They are only second to those of Great Britain, although both France and Switzerland are rivaling them very closely.

* It has now been introduced into the United States by Messrs. Nathan & Dreyfus. Giffard's injector, and its modifications, seem to be more exclusively used in Europe than in the United States.

Digitized by Google



Digitized by Google

The SOCIÉTÉ, JOHN COCKERILL, of Seraing, exhibited two machines, of good design and plain finish, which seemed capable of making excellent performance. The larger one was intended for an Italian road which had already purchased nearly fifty locomotives from the same builders. This engine carries injectors under the foot-plate. The piston-rods are carried through both cylinder-heads, a plan which has manifest objections and which has been adopted to overcome difficulties which are perhaps imaginary rather than real. The smaller engine is a plain contractors' tank-engine, which requires no special notice.

75. The GRAND CENTRAL RAILWAY, of Belgium, exhibited a passenger locomotive built by the Société Anonymé de Couillet, as one of a lot of twenty-five built on one order. They are intended to draw trains of twenty or more carriages, at a speed of over thirty-five miles per hour, over a road having gradients of 20 to 50 feet per mile. The engine has six wheels, four of them coupled. The cylinders are 0.44 meter, (17½ inches,) with a stroke of piston of 0.60 meter, (24 inches.) The weight of the engine ready for work is 33 tons. This engine is most creditable in general design, in material, and in workmanship. The steam-cylinders are placed between the leading and middle wheels, the trailing-wheels being the drivers. Immensely long guide-bars, a Walschaert main-valve gear, with the Guinotte expansion-gear, are the peculiarities of this engine. The main valve is always kept at full gear while running, the point of cut-off being determined by the expansion-gear. In reversing, the main-valve gear is used, and the point of cut-off remains unaltered by the change of direction.

76. THE GUINOTTE VALVE-GEAR.—A model of the Guinotte valve-gear was exhibited, which was intended to facilitate the study by engineers of the system of variable cut-off invented by that gentleman. Its construction is very simple, but it requires some study to be well understood. This system has been successfully applied to hoisting-engines about three years. The Exhibition contains two characteristic examples of this gear: one on a locomotive of the Belgian Grand Central Railroad type, which is exhibited by the Société Anonymé de Marcinelle et Couillet, and one on a hoisting-engine of 250 horse-power, to be sent to the Société de Kladno, (Austria,) exhibited by Messrs. Quillacq & Co., of Anzin, (France, département du nord,) and placed in Group 1 of the French section.

This system of valve-gearing consists of two superposed slide-valves; the second, or cut-off valve, being single and rigidly fixed to its valve-rod.

77. Figs. 25 and 26 show its general construction for a non-reversible engine. The crank is supposed to be at its dead center, M_0, and the direction of rotation is indicated by the arrow. The steam-valve is worked by an ordinary eccentric, of which the center is at D. The cut-off valve is worked by means of the valve-rod jointed to the rod of the cut-off valve at *a*, and to a connecting-rod, which can be moved in the link C C at *b*.

Digitized by Google

This link is worked:

1. At g by an eccentric keyed to the main shaft, its radius being O Q, and its center being at Q when the crank is at M_0.

2. At b by an eccentric, also keyed to the main shaft, its radius being O S, and its center being at S when the crank is at M_0.

The link is hung by means of the rod d jointed to the valve-rod K and to the lever L, which varies the cut-off.

If the link is at x_0, there will be no steam admitted; if it is placed at x_1, steam will be admitted while the crank is revolving through M_0 M_1, and so on. The admission can be varied to any extent from total suppression to a point at which steam is admitted during the whole stroke, the variation being produced by moving the link-block* in the link.

Let us suppose the eccentric of the steam-valve to be represented by its radius OD, (Fig. 27,) the crank being supposed to be at M_0. Draw Od symmetrically with OD with reference to the line IG, which is perpendicular to the line joining the two dead centers. On Od as a diameter, draw the circle a_0 a_1 a_2 . . . . . , having c as the center.

With O as a center, draw the circle v_0 v_1 v_2 . . . . . . , its radius being taken equal to the inside lap of the edges of the steam slide-valve, the lap being measured by o^1 v^1 in Fig. 28.

Draw the radius of the crank OM_7, passing through the point of intersection v_7 of the two above-mentioned circles. The radius OM_7 indicates the position of the crank when the steam-port of the cylinder is closed, *i. e.*, that position in which the edges O^1 and v^1 (Fig. 28) coincide.

With O as a center draw the circle c_0 c_1 c_2 . . . . . . , having a radius equal to the distance between the edge y of the steam-valve and the edge z of the cut-off valve, when the axes of symmetry coincide as in Fig. 28.

Through the middle of Oc_7 and perpendicular to it, draw the line uW upon the radius OM_7; through the point c_7 draw p_0 c_7 parallel to uW. Draw f_0 f_7 parallel to the line p_0 c_7 and on the other side of, and equally distant from, the center c. Finally draw the line F_0 F_7 symmetrical to f_0 f_7, with reference to the line IG.

The first part of the problem will be solved when we have found the line F_0 F_7. It can be clearly shown that if the cut-off valve, instead of being worked by an eccentric of a fixed throw, be worked by an eccentric of a variable throw, and whose center could be displaced at will along the straight line joining F_0 and F_7 (so as to make the lines joining the different points of F_0 F_7 with the center O express the different pos-

* Those who desire to study the subject thoroughly may consult the following special memoirs, in which the subject has been fully treated:

Étude générale sur la détente variable. Liége, 1872.

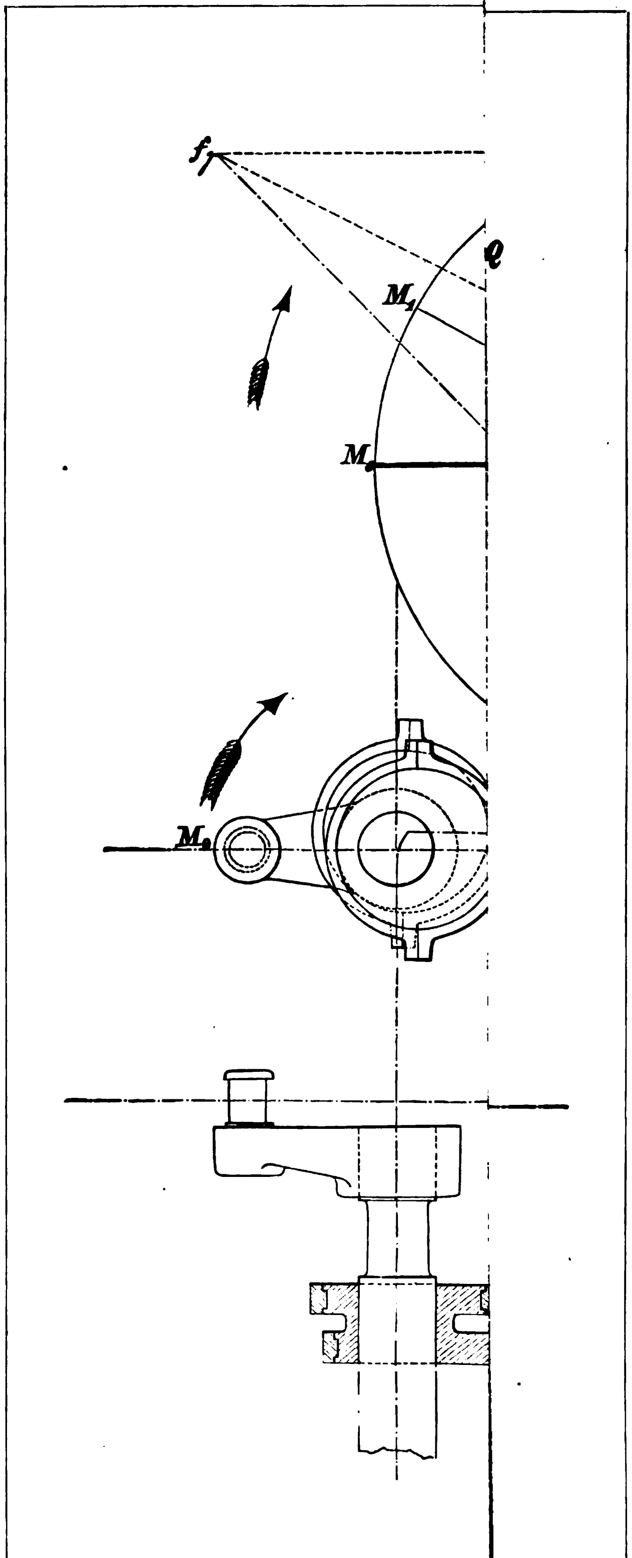
Variable expansion gear, designed by M. Lucien Guinotte, director of the Mariemont and Bascoup collieries, Belgium.

Engineering, September 29, 1871.

Les Houilleries en 1872, par Amédée Burat. Paris, 1872.

Digitized by Google

Digitized by Google



Digitized by Google

sible lengths and positions of the radius of the eccentric, the crank being supposed to remain at OM_0,) then the period of the admission of steam into the cylinder would be varied at will, from no admission up to full admission.

To indicate the method of finding the position of the center of the eccentric for every period of admission, as, for example, that corresponding to the movement of the crank from M_0 to M_1:

On the radius OM_1, and through the middle point V of Oc_1, erect a perpendicular Vs_1. This will cut uW in s_1. Draw the straight line Os_1 and prolong it until it intersects the line $p_0\ c_7$ in p_1. Join c and p_1 by a straight line, and continue it until it cuts $f_0\ f_7$ in f_1. Through f_1 draw a perpendicular to IG and prolong it until it cuts the line $F_0\ F_7$ in F_1.

F_1 is the point sought, being the position of the center of the eccentric for the admission $M_0\ M_1$, when the crank is at M_0.

Proceeding in the same manner with the radii OM_0 and OM_7, the extreme points F_0 and F_7 of the throw, which the center of the eccentric should be capable of, to produce a variation in the period of admission, within the limits mentioned before, are found.

In the same manner, by operating upon the radius OM_2, the position F_2, which the center of the cut-off's eccentric should occupy for the period of admission corresponding to the travel $M^{\circ}\ M_2$, of the crank, is obtained.

Theoretically, in Fig. 27, the port of the cut-off valve will re-open, for all periods of admission when the radius of the crank arrives at $O\,M_{17}$, the moment when the steam-port is closed by the steam-valve. This arrangement would evidently not be efficient, as the slightest wear would destroy the proper distribution of steam. Fig. 27 must be modified to make the distribution a practicable one, as shown in Fig. 29. This differs from the first in the following particulars:

1st. Instead of being constructed upon the radius $O\,M_{17}$, the drawing is made by taking the radius OQ. When the crank assumes the position of this radius the steam-valve covers the port by an amount equal to $r\ g$.

2d. The line UW, or $o_{\circ}$ U, is replaced by the line $o_{\circ}\ o_7$; the line $p_0\ c_7$ is replaced by $p_{\circ}\ p_7$.

By inspecting Figs. 27 and 29 we may infer immediately what effect this change will have upon the line $f_{\circ}\ f_7$, and upon the line $F_{\circ}\ F_7$.

78. It now remains to realize in practice the principle enunciated above, as found and demonstrated. In other words, we must obtain the same result as if the center of the cut-off eccentric could be moved at will along the line $F_{\circ}\ F_7$, determined in the manner just shown.

Returning to Fig. 25, in which the line $F_{\circ}\,F_7$ has the same significance as in Figs. 27 and 29, the crank is supposed to be at $M_{\circ}$, and the two eccentrics OQ and OS drive the points q and s of the link. If the eccentric rods are long enough, and if the curvature of the link is not too sharp, (this can always be easily realized,) then, without an appreciable error—

Digitized by Google

1st. We can substitute for the geometrical motion of the curved line $x_0\ x_7$, that of the straight line $q\ s$, passing through the joints of the eccentric rods.

2d. We can say that, when the system is set in motion, the points q and s will move in the same manner as the projections of the eccentrics Q and S upon the axis $O M_0$.

It is, therefore, easy to show that any point t, of the line $q\ s$, will move with the projection, upon the axis OM_0, of a point T, which is the extremity of an imaginary eccentric OT, so determined that

$$\frac{Q\ T}{T\ S} = \frac{q\ t}{t\ s}$$

Similarly the other points, x_0, l, x_7 ...... of the link will move, as if they were worked by eccentrics O F_0, O L, O F_7, these points being such that

$$\frac{F_0\ S}{F_0\ Q} = \frac{x'_0\ s}{x'_0\ q}$$

$$\frac{L\ S}{L\ Q} = \frac{l'\ s}{l'\ q}$$

$$\frac{F_{17}\ S}{F_{17}\ Q} = \frac{x'_7\ s}{x'_7\ q}$$

It follows that by moving the connecting-rod to different points along the link, the cut-off valve will receive different and varying motions, as if the center of the cut-off eccentric had been moved along the line F_0 F_7. The cut-off will therefore be variable within the widest limits.

The object of the construction shown in Figs. 25 and 26 was to assist in explaining the system and in resolving the principles which unite in the solution. This arrangement is not usually employed. That shown in Figs. 30 and 31 is at once more simple, more elegant, more exact, and easier in its application, and it requires but a single eccentric. In describing it we will, at the same time, employ Fig. 31, which gives the proportions of all parts.

O D always represents the radius and the throw of the eccentric of the steam-valve, the crank being at M_0. The line F_0 F_7 or the line connecting the centers of the cut-off eccentrics having the same significance as in the preceding figures, intersects the line of dead points M_0 O in X. An eccentric O X, opposite to the crank, moves the point x of the cut-off link, and simultaneously the extremity of a lever, $x\ o\ t$, vibrating about a fixed o. The point t receives the same motion as though it were attached to an imaginary eccentric O T, such that $\frac{O\ T}{O\ X} = \frac{o\ t.}{o\ x.}$ The motion of t is communicated to the joint t', of the lever $t'\ d\ q$, by means of the rod $t\ t'$. This lever is jointed to the valve-stem of the steam-valve at d—a point which partakes of the motion of the steam-valve eccentric O D.

Join T and D and prolong the line to Q. The points t' and d, of the

Digitized by Google

Digitized by Google

Digitized by Google

lever $t' d q$, being moved like the projections of the eccentrics T and D, a third point, q, so situated that $\frac{q d}{q t} = \frac{QD}{QT}$, will move like the projection of an eccentric O Q; that is, it will be moved as though it were actuated by an eccentric O Q. The same end will be attained by communicating this motion to the point q of the link by means of the rod $q q'$. The combination of levers $t o x$ and $t' d q$ then allows the eccentric O Q to be dispensed with, and the obliquity of the eccentric-rods to be avoided.

79. This construction being understood, we may consider the application of the system to engines having a reversing motion.

The crank being at M_0, (Fig. 33,) the center of the steam-valve eccentric is at D when the engine moves in the direction of the arrow Z, and at D′ when the engine moves in the direction of the arrow Z′.

Let us consider the two directions of motion separately—first the eccentric D, and then the eccentric D′, as for an engine having but one direction of motion. We will then find the line of $F_0 F_1 \ldots\ldots F_{17}$, to be the line of centers of the cut-off eccentrics for the direction of motion Z, and the line $F'_0 F'_1 \ldots\ldots F'_{17}$ for the direction Z′. These two lines will intersect at X, on the line of dead-centers M_0 O, being the prolongation of the radius of the crank. One of the points of the link can then be marked by an eccentric OX, and the motion of this point will follow equally well the direction Z and the direction Z′.

The problem is then to obtain another point of the cut-off link, such that no additional operation is required in reversal of the motion. This is done by adapting the construction seen in Figs. 30 and 32, which is given for reversible engines in Figs. 34 and 36. The design shown in Fig. 35 represents the proportions of the parts, their number not having been increased.

When motion takes place in the direction Z, the point t', of the lever $t' d q$, is moved as though it were worked by an eccentric OD; the point d is moved as though it were worked by an eccentric OD. Therefore the point q, and the point g' of the link, move as though actuated by an eccentric OD.

Suppose the motion reversed by the ordinary means, and taking place in the direction Z′. The point t' will have the same motion as before, but the point d will move as though it were worked by an eccentric OD′, instead of OD, and hence the point q, and the point g' of the link, will be worked by an eccentric OQ′.

The line joining the two points of application of the driving force at x and g' will then represent the line XQ for the motion Z, and the line XQ′ for the motion Z′.

This also may be stated thus:

In changing the position of the lever, the position of the point g' of the link will change of itself, and the link will represent the line $F_0 F_7$, accordingly as the reversing lever is thrown to one side or to the

Digitized by Google

other. Otherwise stated, the reversal of the motion does not merely reverse the position of the steam-valve, but it also changes the cut-off valve, so that this is also set properly for the opposite direction of motion of the engine. The period of admission will not be changed. This result is obtained without the use of additional levers, and the engineer has nothing more to do than in the case of simple reversing engines without cut-off. The lever for the variable cut-off should be worked for no other purpose than to change the period of admission.

80. The preceding statement is sufficient to show to how many different combinations this system may be applied, and to show how easy it is to apply it in each particular case. Space will not permit entering into details, and we will only consider two or three cases, showing some remarkable peculiarities. First, however, the attention should be drawn to a point of great importance in all reversing engines.

One of the principal conditions to be realized in these engines is, to avoid increasing the difficulty which the engineer meets with in working his reversing-lever. This condition is evidently realized. Not only does the cut-off valve have an extremely small area, (much smaller than that of the cut-off valve of any other system,) but the connecting-link is in such a position that the motion which the engineer gives to the valves in reversing is identically the same for both steam and cut-off valve.

It follows, therefore, that the resistance, which he must overcome, is the same as though he only had to move the steam-valve, for the cut-off valve moves simultaneously, and, therefore, does not produce extra friction. The position of the connecting-link is that which corresponds to the point *m* of the line F_0 F_7 on the slot, in Fig. 29. This point *m* is formed by drawing a line parallel to the line of dead-centers through D, until it intersects F_0 F_7 in *m*. The model exhibited this fact. It may also be easily demonstrated theoretically. This position, which may be called the *working position*, is constant on the index-sector of the cut-off lever. It generally corresponds to the point of full admission.

The motion of the steam-valve on the locomotive exhibited by the Société de Couillet is of the Walschaertz system, which has but one eccentric, and the Guinotte system of cut-off is applied without adding a second eccentric. That usually employed is replaced by a lever, worked by the cross-head, as Walschaertz moves his steam-valve.

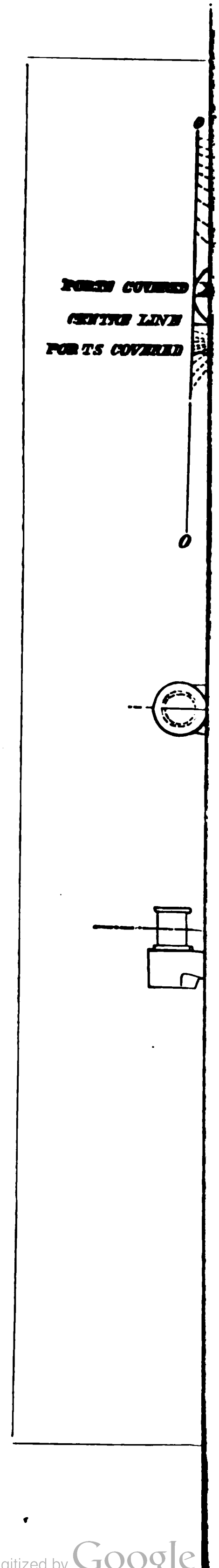
81. The hoisting-engine exhibited by Messrs. Quillacq & Co., shows another arrangement. It is shown in Fig. 37, and Fig. 38 shows the result obtained for different periods of admission.

The full-lined curve shows the positions of the steam-valve for different positions of the piston. The distance between the curve and lines of the points of re-opening, x and z, indicates the opening of the steam-port for each point in the stroke of the piston.

The dotted lines indicate the closing of the steam-ports by the cut-off valve, according to the position occupied by the connecting-rod in the

Digitized by Google

Digitized by Google



Digitized by Google

link. The lines, marked with the same letter, correspond to the front and the back ends of the cylinder, the position of the connecting-link being the same.

The reverse motion gives a construction which does not differ materially from the preceding.

Finally, in Fig. 39 is shown the arrangement adopted in several cases already for the slide-valves of powerful hoisting-engines. As shown, the steam-ports are divided into two parts, and the expansion-valve is formed of three pieces, bound firmly together and constituting but a single piece. This arrangement increases the bearing surfaces of the valves slightly, but it also decreases the length of travel; therefore, the reversing-lever moves easily. Repeated trials indicate that a man of ordinary strength can easily handle a pair of engines of 47½ inches diameter of cylinder, provided with the expansion-gearing, where the valves are arranged as shown in Fig. 39.

Another advantage of this system of expansion-gear, peculiar to hoisting-engines, is that it affords a complete solution of the problem of the regulation of such engines.

82. The expansion-gear may be made continually variable automatically, according to any law which may serve to establish a constant equilibrium between the driving force and the resistance. All that is necessary for this purpose is that the connecting-link of the expansion-gear be moved by the engine itself, instead of being worked by the engine-driver. The model exhibited at Vienna was made to illustrate both cases. By connecting the forward with the backing gear thus arranged, the model is made to illustrate the case of a hoisting-engine, the power of which varies at every instant, according to a law determined by the curvature of the lever on either side the endless screw driven by the main shaft. A mere inspection of the model, as of the engine exhibited by Quillacq & Co., shows the arrangement perfectly. It is also shown in Fig 40.

The two nuts E E′ press upon the two levers L L′. The motion of translation of one nut is communicated to the side-lever L, and thus displaces the connecting-link of the expansion-gear. When one of the nuts, as E, has reached the end of its travel, and has thus pushed its lever L entirely out, it has produced the maximum of expansion necessary, and this lever is allowed to regain its original position by means of the counterweight T. This produces a full admission, and prepares the second lever L′ for the action of its nut E′. The two levers connected together are relieved simultaneously.

At the succeeding motion, the nuts return to their positions and the nut E′ acts upon the lever L′, in the manner already described.

The irregularity of resistance when heavy loads are to be lifted from a great depth being unfavorable to the action of the engine, it has been attempted to diminish it. In some cases the radius of the hoisting-drum is made very small, in order to compensate the variation in the

Digitized by Google

resistance by an inverse variation of the lever-arm; this, however, produces rapid wearing of the ropes, and such a number of revolutions is required to raise the load, that the hoisting is done very slowly, and the engine works under unfavorable conditions. In other cases, counterweights are used to regulate this action, but a considerable resistance is thereby added, and sometimes a considerable extra expense. These expedients are evidently imperfect, since their object is to render a force constant which is variable. It is much simpler to allow the irregularity of the resistance to remain, and to apply a force which is correspondingly variable. This is the method which should naturally be first attempted.

Experiment, as the inventor claims, has already decided this question, and the application of the Guinotte system to hoisting engines certainly affords a simpler and more efficient arrangement than the preceding methods.

It seems to the writer somewhat doubtful whether this arrangement would obtain favor with either engineers or builders in the United States. It is, however, stated that the engines fitted with it are very economical in their consumption of fuel, and many European engineers look upon the device with great favor.

83. The Société Général d'Exploitation des Chemins de Fer, of Turbize, exhibited a fine-looking locomotive, which, however, does not require special notice.

The most remarkable engine was that of Carels, of Ghent, shown in the accompanying plate, Fig. 41. This was a six-wheeled coupled passenger-locomotive, in which the steam-cylinder is mounted above the wheels in the horizontal line, and drives through a vertical working-beam, 3 feet 7 inches between end centers. This arrangement, which was many years ago proposed both in the United States and Great Britain, is here attributed to M. Belpaire, the distinguished inspector-general of the Belgian railways. It is claimed, and probably correctly, to give much greater steadiness at high speeds in consequence of the counterbalancing of the reciprocating parts thus secured. It is also considered to have important advantages in bringing the cross-head and other parts higher above the rail, where they will be less exposed to injury by dirt and dust, and where they are directly under the eye of the fireman, and where also they are accessible for oiling at any time. In this engine greater care has been taken than is usual with European builders to equalize the weights upon the several axles. None seem to have succeeded as well as our own manufacturers. The valve of each cylinder is driven from the cross-head of the opposite engine. The finish of the engine was not remarkably good.

84. Russian and Italian locomotives.—Russia and Italy exhibited locomotives. The Russian engines are extremely creditable in every respect, and are very nearly equal to those of the British constructors, from whose designs they seem to have been copied. The Italian engines,

Digitized by Google

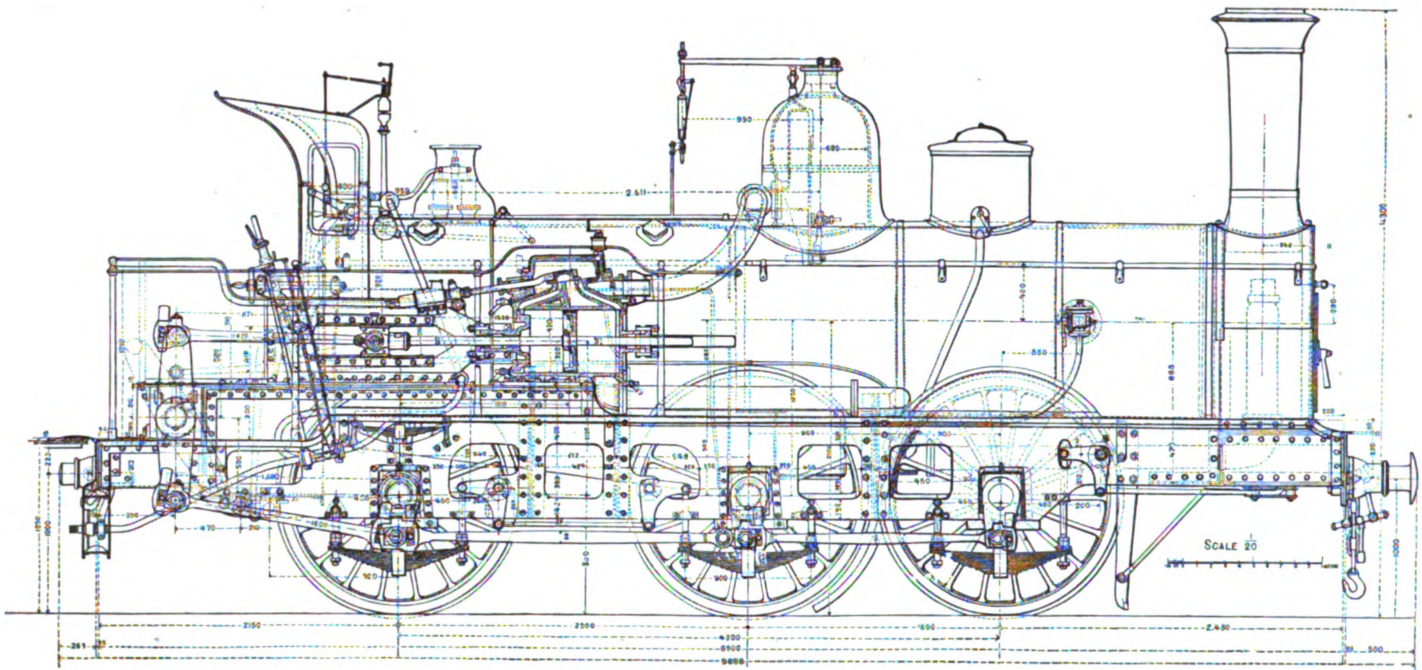


FIG. 41.—Carel's locomotive.

Digitized by Google

like all of the machinery from that country which came to my notice in the Exhibition, did not compare favorably with the exhibits of other countries. Attempts at original design were very unsuccessful, the materials used were not of superior quality, and the workmanship and finish were invariably inferior.

85. GERMAN AND AUSTRIAN LOCOMOTIVES.—Germany and Austria each exhibited a large collection of locomotives, among which were many of excellent design and fine workmanship.

Bosig, of Berlin, Sigl, of Vienna, Krauss & Co., of Munich, the *Maschinen=fabrik und Eisengiesserei*, Darmstadt, are among the most prominent of the exhibitors.

86. THE STAATS EISENBAHN=GESELLSCHAFT exhibited some exceptionally fine engines. The latter are distinguished by the substitution, to some extent, of wrought for cast iron in parts usually constructed of the latter material, and by the use of "hydraulic forgings."

The Austrian "*Staats Eisenbahn=Gesellschaft*" issued to members of the International Jury a very interesting collection of lithographed outline-drawings of the locomotives built for the Austrian railroads at their works during the past thirty-five years, which supplemented well the very excellent exhibit made by them at the *Ausstellung*.

87. This locomotive-building establishment was founded in the year 1839, under the directorship of Herr Mathias von Schönerer. There was then no other iron-works and foundery in Vienna. The first locomotive was built from American designs, as shown in the accompanying plate, Fig. 42, (Type 1,) and was first placed on the road in 1841, at the opening of the Vienna and Gloggnitz Railroad.

In 1855 the works were enlarged under General-Director Jacquse Maniel, and under his direction were built over fifty different styles of engines. A freight-engine with six coupled drivers was built in 1846. An eight-wheeled engine was built in 1855, and exhibited at Paris. The play given the rear driving-axle of this engine permitted it to pass around sharp curves with a facility which was then considered remarkable.

A locomotive was exhibited which was built in 1870, the thousandth engine built by this company. It had been in service three years, and was in excellent order.

The express-engine Duplex, exhibited in the same collection, was a four-cylinder engine, which was placed in the London Exhibition of 1862. A ten-wheeled locomotive, the Steyerdorf, was said to be capable of readily passing the shortest curves on the Austrian roads. It had been exhibited both at London in 1862 and in Paris in 1867.

88. The accompanying sketches (Figs. 42–47) are copied from those furnished the jury, and the dimensions given with each will enable the experienced builder to read all important particulars at a glance. This collection illustrates the gradual change of style and dimensions taking place decennially from the date of the erection of these works to the present time.

Digitized by Google

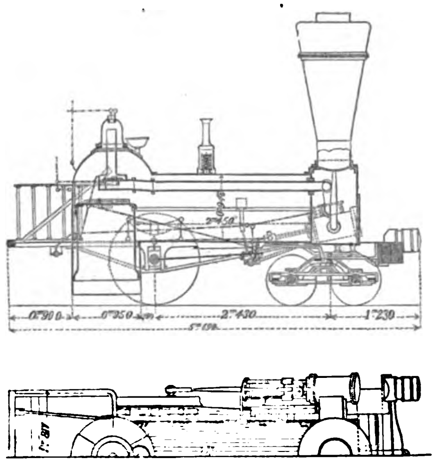


FIG. 42.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 1, *built* 1840.

Diameter of driving-wheels, meters	1.264
Diameter of leading-wheels, meters	0.790
Wheel-base, meters	2.845
Diameter of boiler, meters	0.048
Thickness of boiler-shell, meters	0.009
Pressure in atmospheres	5.5
Number of tubes	75
Diameter of tubes, meters	0.052
Length of tubes, meters	2.450
Area of tubes, surface, square meters	30.4
Total area of heating-surface, square meters	33.5
Total area of grate-surface, square meters	0.74
Weight on driving-wheels, kilograms	10,510
Weight of engine, kilograms	16,805
Weight of engine empty, kilograms	14,560
Extreme length, meters	5.694
Extreme breadth, meters	2.250
Extreme height, meters	3.025

Digitized by Google

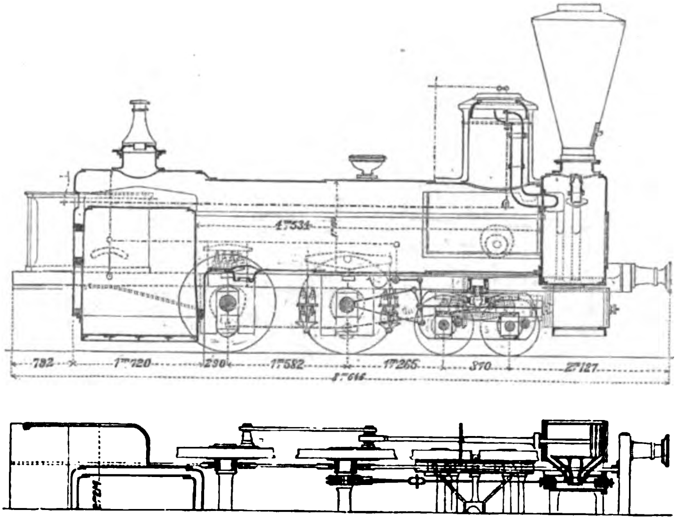


FIG. 43.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 12, *built* 1850.

Diameter of driving-wheels, meters	1.264
Diameter of leading-wheels, meters	0.791
Wheel-base, meters	3.747
Diameter of boiler, meters	1.160
Thickness of boiler-shell, meters	0.013
Pressure in atmospheres	5.5
Number of tubes	134
Diameter of tubes, meters	0.052
Length of tubes, meters	4.534
Area of tubes, surface, square meters	100.5
Total heating-surface, square meters	108.5
Total grate-surface, square meters	1.5
Weight on driving-wheels, kilograms	9,240
Weight of engine, kilograms	29,120
Weight of engine empty, kilograms	26,320
Extreme length of engine, meters	8.676
Extreme breadth of engine, meters	2.425
Extreme height of engine, meters	4.557

Digitized by Google

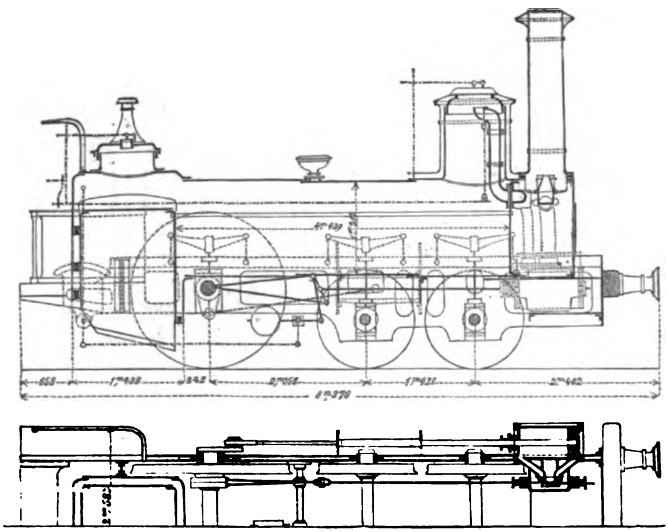


FIG. 44.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 32, *built* 1861.

Diameter of driving-wheels, meters	2.055
Diameter of leading-wheels, meters	1.264
Wheel-base, meters	3.479
Diameter of boiler, meters	1.212
Thickness of boiler-shell, meters	0.013
Pressure, in atmospheres	8
Number of tubes	160
Diameter of tubes, meters	0.052
Length of tubes, meters	4.429
Area of tubes, surface, square meters	117.2
Total heating-surface, square meters	125.0
Total grate-surface, square meters	1.4
Weight on driving-wheels, kilograms	12,500
Weight of engine, kilograms	32,200
Weight of engine empty, kilograms	29,600
Extreme length of engine, meters	8.370
Extreme breadth of engine, meters	2.681
Extreme length of engine, meters	4.653

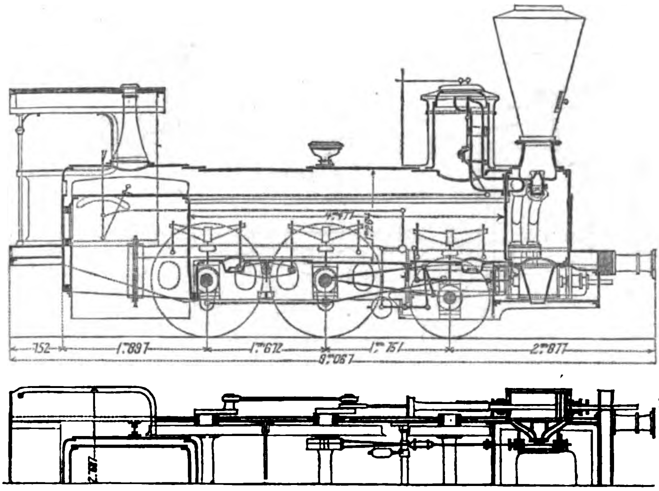


FIG. 45.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 49, *built* 1869. *Hall's system.*

Diameter of driving-wheels, meters	1.580
Diameter of leading-wheels, meters	1.106
Diameter of boiler, meters	1.264
Thickness of boiler-plates, meters	.011
Pressure in atmospheres	9
Number of tubes	162
Outside diameter, meters	0.052
Outside length, meters	4.477
Area of tube-heating-surface, square meters	120
Total heating-surface, square meters	229
Total grate-surface, square meters	1.925
Weight on axles, kilograms	35,000
Extreme length of engine, meters	9.067
Extreme breadth of engine, meters	2.687
Extreme height of engine, meters	4.583
Wheel-base of engine, meters	3.423

Digitized by Google

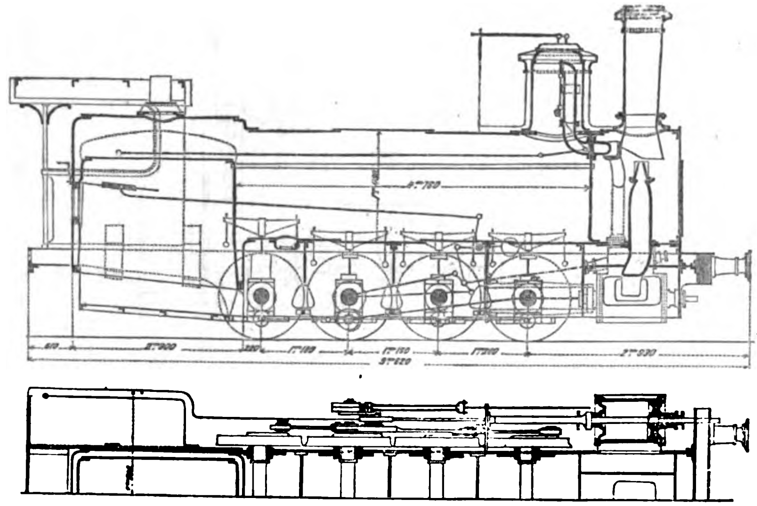


FIG. 46.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 51, *built in* 1871.

Diameter of driving-wheels, meters	1.106
Wheel-base, meters	3.560
Diameter of boiler, meters	1.430
Thickness of boiler-shell, meters	0.015
Pressure in atmospheres	9
Number of tubes	205
Outside diameter of tubes, meters	0.052
Length of tubes, meters	4.760
Area of surface of tubes, square meters	159.3
Total heating-surface, square meters	170
Total grate-surface, square meters	2.16
Total weight on drivers, kilograms	50,750
Weight of engine empty, kilograms	45,191
Extreme length of engine, meters	9.620
Extreme breadth of engine	2.800
Extreme height of engine	4.400

Digitized by Google

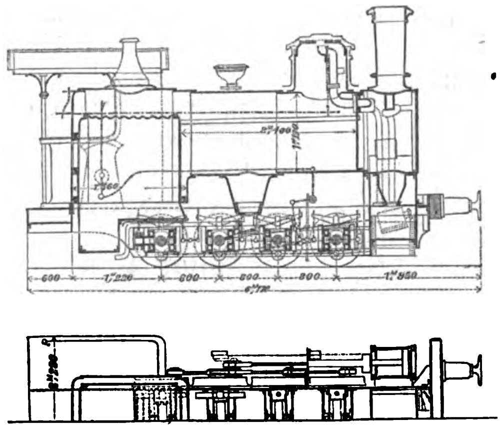


FIG. 47.

K. K. Priv. Staats-Eisenbahn-Gesellschaft.—Type 54, *built in* 1873. *Haswell's system.*

Diameter of driving-wheels, meters	0.720
Wheel-base, meters	2.400
Diameter of boiler, meters	1.120
Thickness of boiler-shell, meters	0.010
Pressure in atmospheres	12
Number of tubes	102
Outside diameter of tubes, meters	0.052
Area of surface of tubes, square meters	40.
Total heating-surface, square meters	46.
Grate-surface, square meters	1.40
Weight on each axle, kilograms	5,000
Weight on axles, total, kilograms	20,000
Weight of engine empty, kilograms	18,000
Length of engine over all, meters	6.170
Breadth of engine over all, meters	2.210
Height of engine over all, meters	3.500

Digitized by Google

The establishment is now under the direction of Mr. J. Haswell, the distinguished engineer who has succeeded so well in the introduction of the hydraulic press in forging.

Mr. Haswell states that in 1872 the works turned out ninety-two locomotives, making a total of one thousand two hundred and forty-two since the commencement in 1840.

89. CHARACTER OF CONTINENTAL WORK.—By far the finest work of continental mechanics is seen in this splendid collection of the locomotives built in Germany and Austria. The designs are usually intermediate between those of British and of American builders. The general design is more nearly that of the former. The truck, or "bogie," under the forward end of the boiler is rarely seen. The American system of "equalizers" is used to a considerable extent, and often with much skill. The "cab" is much more frequently met with on continental than on English-built engines, and is very frequently given the form and proportions of that detail as made in America.

90. The frames of these engines, British as well as continental, are not made of square bars of forged iron as with us, but are cut out of heavy rolled plate, usually about thirty millimeters (1.2 inches) in thickness. All but one of the engines exhibited have outside cylinders. The valves in many instances are driven by eccentrics, placed outside the crank-pin and without the intervention of rock-shafts.

91. The boilers of some of the leading examples are of what is called in Europe the "Belpaire" style, in which the fire-box end is enlarged, (Fig. 48,) somewhat as it is frequently done in the United States, to obtain a wider grate and a higher steam-space above the crown-sheet. Instead, however, of making this portion semi-cylindrical, as we are accustomed to seeing them, tops and sides are made flat, forming a rectangular box, as seen in the plate, with rounded corners. These flat surfaces are strongly stayed, and no difficulty seems to have been yet observed in making or in working them. The connection between this enlarged part of the boiler and the remaining part of the shell is not, as in the United States, made by a conical portion which tapers from one end, where it is riveted to the fire-box end, to the other which is riveted to the cylindrical part of the boiler. In these boilers the connection is made by a single sheet of heavy plate, which has a large hole cut through it and a flange turned all around its circumference to take the sheets of the small part of the shell, while the outer edge is flanged and has such a shape that it may be riveted to the sheets forming the fire-box. This makes a very strong connection between the two parts, and at the same time forms an effective expansion-joint. It evidently can only be done where good iron can be found and good flanges made. Should this method, on the whole, prove superior to that in use in the United States, however, our manufacturers will find here no obstacle to its introduction.

Staying the fire-box top from the crown-sheets has the advantage of

Digitized by Google

Digitized by Google

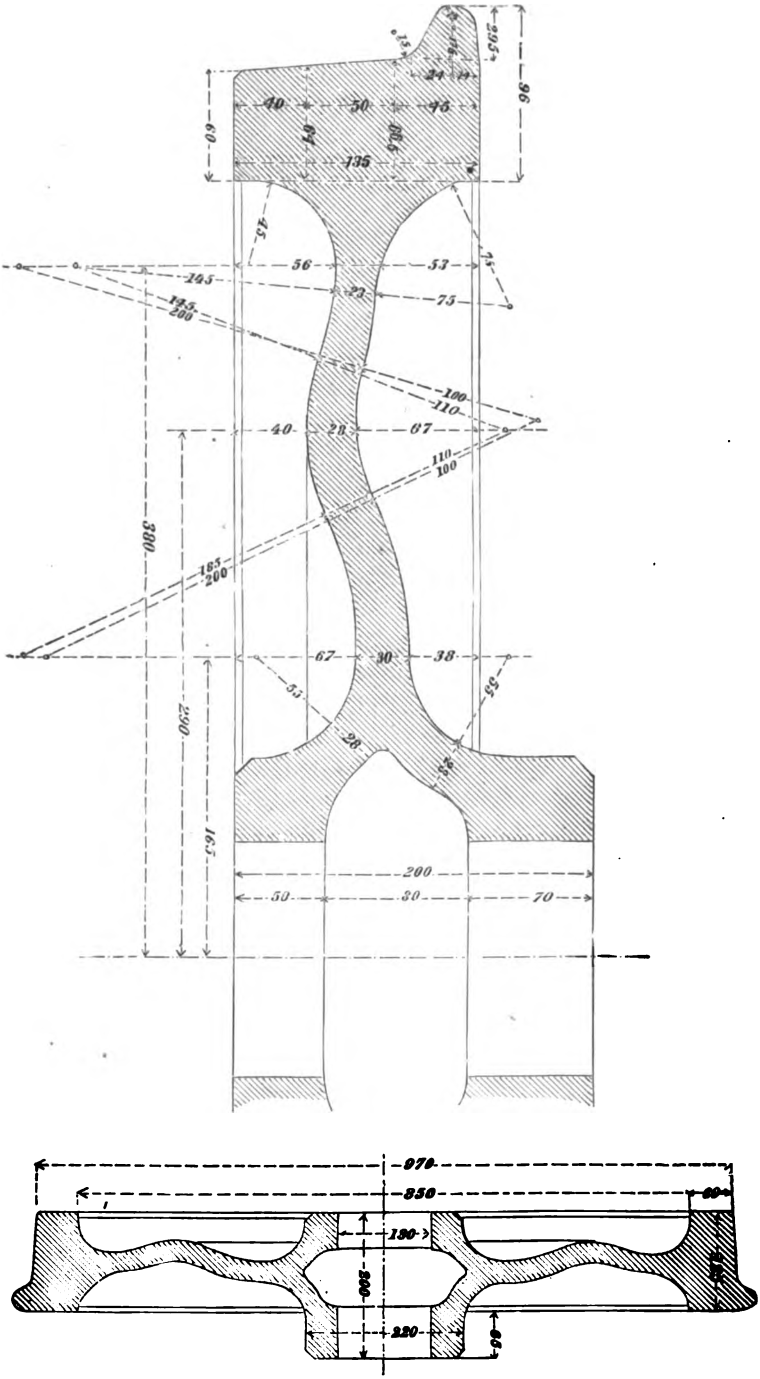


FIG. 49.—Krupp's standard cast-steel wheel.

Digitized by Google

doing away with the objectionable girder-stays, which are the usual supports of the crown-sheets in American locomotives.

92. The pressure of steam allowed on these boilers is usually eight or nine "atmospheres," as pressures are reckoned in Europe. The boilers have a greater "factor of safety" than we are accustomed to adopt in the United States, a point in European practice which it might be well for us to copy.

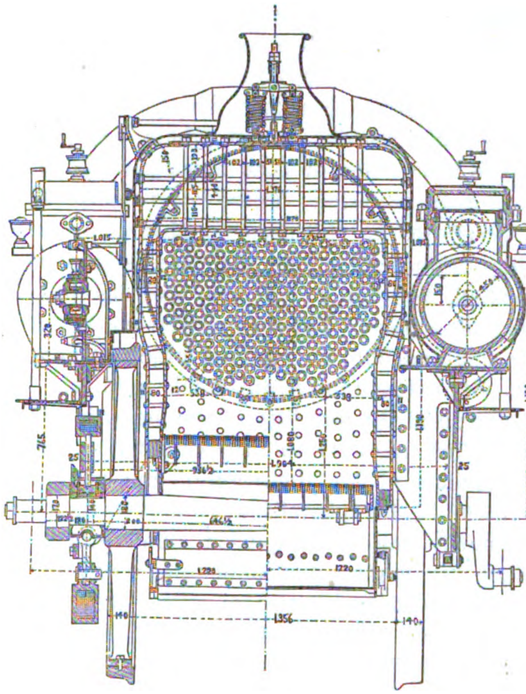


FIG. 48.—Belpaire's fire-box.

93. The riveting is usually done by the riveting-machine, which, *properly used* *, does much better work than can be done by hand, making the seam both lighter and stronger. The rivets are usually snap-headed, and, when made by hand, are headed-up by blows of a heavy hammer on the head of a forming-tool. In some cases the calking of seams had been carelessly done, as was shown by the marks of the calking tools on the sheet under the lap.† The serious results which follow so frequently from the creation of furrows and grooves along these lines are well known to all intelligent builders, and the manufacturers of these engines were seriously in fault in permitting these boilers to be thus injured, and of a great

* Probably the best form of riveting-machine yet produced is that of the Providence Steam-Engine Works, at Providence, R. I., in which one die closes the laps, and another, by an indepedent steam-piston, then heads-up the rivets.

† The "concave" system of calking introduced in the United States recently by Mr. Connery at the Baldwin Locomotive Works and elsewhere is, in the opinion of the writer, a vast improvement upon the ordinary method.

Digitized by Google

oversight in sending such evidence of carelessness to be exhibited at Vienna.

94. MATERIALS—SOFT STEEL *vs.* IRON.—The material used for running-gear and valve-motion, and not infrequently for the boiler also, is becoming quite universally "low steel," or, as it should more properly be called, homogeneous iron. The irons of commerce, which are usually sold as iron, contain barely a trace of carbon, and invariably contain also a certain amount of cinder, which cannot be entirely removed in the ordinary process of puddling and rolling or hammering, even with the most careful manipulation. They are, therefore, weaker than a pure metal would be, and have a fibrous structure, which is caused by the drawing down of the masses of impurity in the puddle-ball into lines, or striæ, which prevent the acquisition of that homogeneous character which is always desired in good material. These "low steels" are usually made either by the Bessemer or the Siemens-Martin process, and, taking form in the ingot-mold, into which they are poured when liquid, the cinder is separated, floating to the top, and leaving the metal quite free from it and nearly pure. These steels also contain from one-quarter to one-half per cent. carbon, an amount which strengthens the metal greatly without conferring upon it any steely quality. The elastic limit is raised somewhat, and the ductility of the metal is practically equally great. The unworked ingot is liable to exhibit a considerable degree of porosity in consequence of the liberation of gas, while the molten mass is solidifying whenever the spiegelisen, employed as a conveyor of carbon, is not sufficiently rich in manganese. This porosity, although less objectionable than the condition of malleable or wrought irons, in which the cavities are filled with impurities, is still a defect, which, when the ingots are worked down into pieces of smaller section, is seen in the formation of a fibre, which becomes perceptible, however, only when the metal is examined by some exceptionally delicate method of test. Strain-diagrams, produced by the autographic-recording testing-machine, exhibit these characteristics very completely.

The metal here described has usually an elastic limit nearly 50 per cent. higher than that of common iron, and its ultimate tensile strength reaches 70,000 or 80,000 pounds per square inch. It stretches, if of good quality, 25 per cent. before breaking. It is claimed, by many manufacturers, that it can now be obtained quite as uniform in quality as wrought iron, and at prices which make it good policy to use it whenever possible. Its homogeneousness in quality and structure are considered quite as important qualities as its strength, high elastic limit, and ductility. It is the best material now available for use where a tough, strong, ductile material is required, as whenever heavy shocks are to be sustained.

Where the quality desired is durability under heavy load and abrasion, as is the case with rails, the high elastic limit constitutes its distinguishing merit. The metal should always be carefully chosen with

Digitized by Google

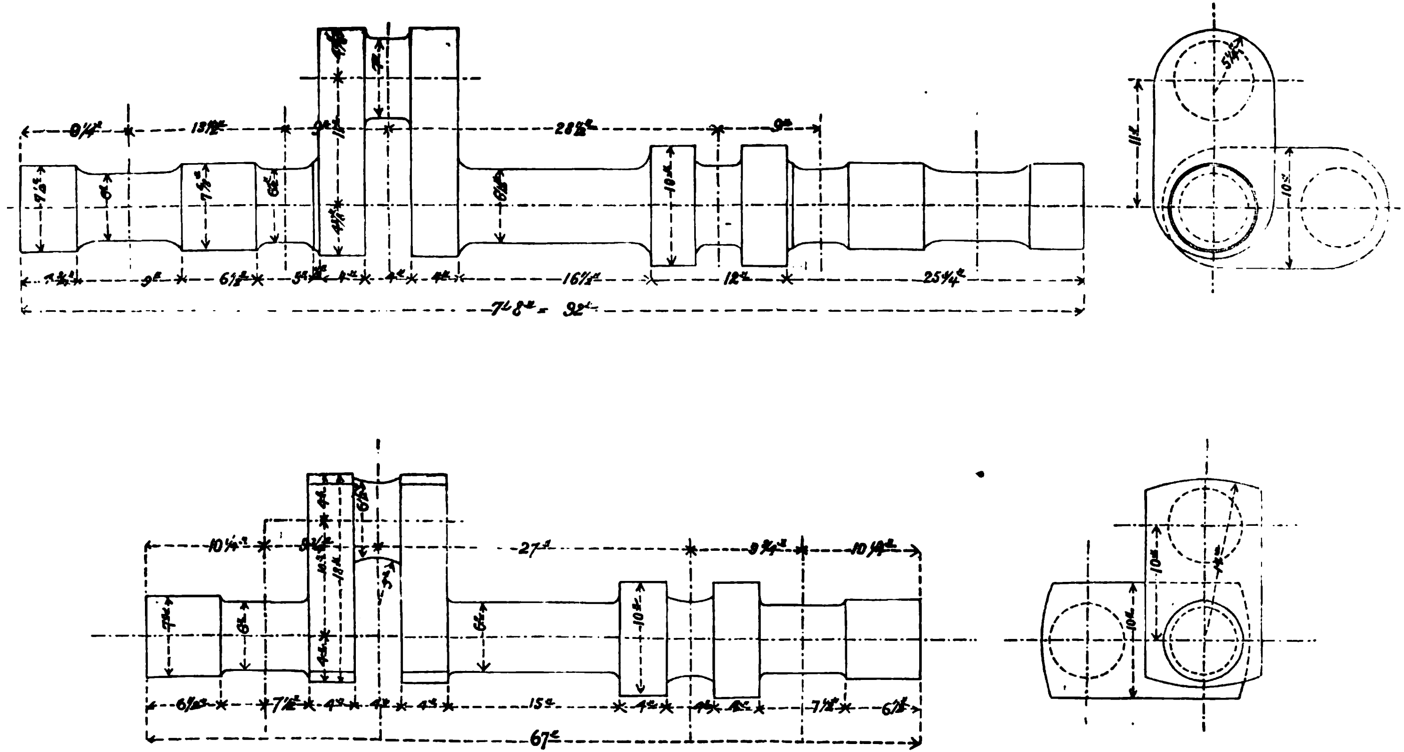


FIG. 50.—Krupp's driving-axles.

Digitized by Google

Digitized by Google

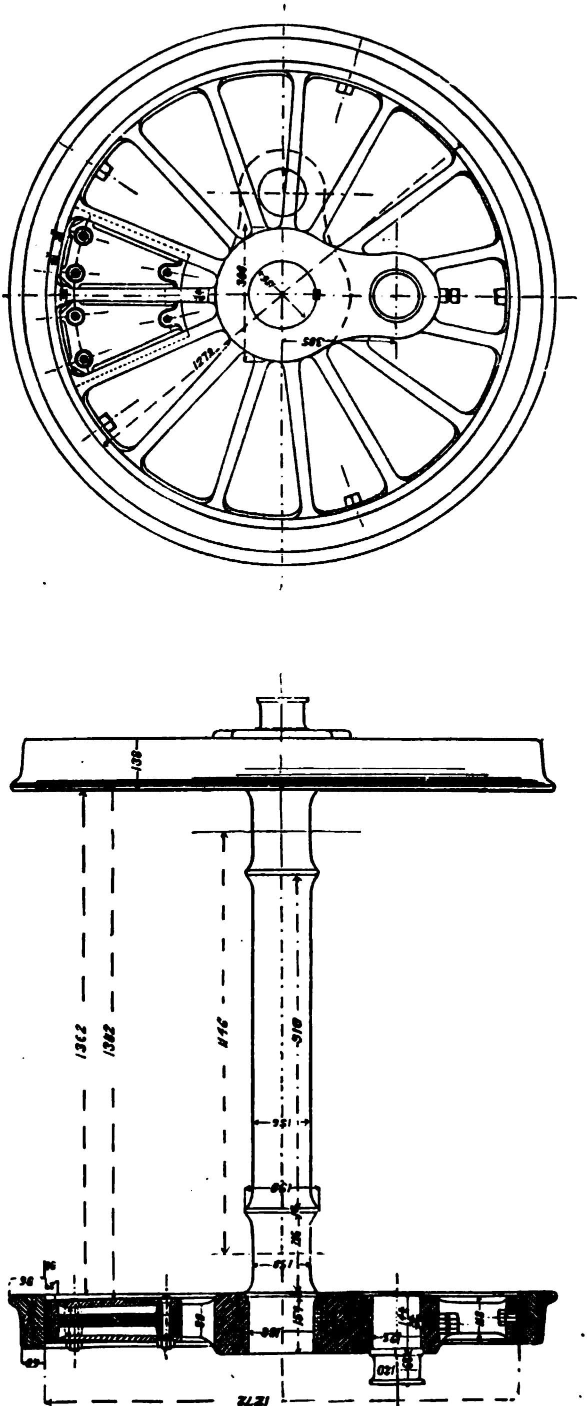


Fig. 51.—Krupp's wheel and axle. (Sizes in millimeters.)

Digitized by Google

reference to its intended use. By changing the dose of carbon it is made fit for every purpose.

Another valuable quality of the low steels which should not be overlooked is that of taking a beautifully fine finish.

95. EUROPEAN RAILROAD WHEELS.—The driving-wheels, as well as the other wheels of locomotives, are invariably forged. A cast-iron driving-wheel is never seen in Europe, and European builders seem quite unable to believe that they can be used with safety. They regard American practice in this particular as simply illustrating that recklessness which is looked upon by them very generally as one of the most remarkable traits of our national character.

96. In the exhibit of Krupp, of Essen, were some fine specimens of locomotive work, of which scale-drawings are here shown, (Figs. 49, 50, 51, 52,) with dimensions given. They serve to illustrate both the character of the work done at Essen and the proportions adopted for these details; also the extent to which steel is applied in locomotive building. The driving-axle (Fig. 50) is a fine piece of work; the material is free from flaw or blemish, and the finish is remarkably fine. The sketch of the driving-wheel and axle (Fig. 51) illustrates the proportions adopted for standard work in this part of Europe, and the crank and eccentric (Fig. 52) form an example of an exceptionally awkward piece of work excellently well done.

97. CONCLUSIONS.—An examination of this collection, illustrating as it does the best contemporary European practice, has, after all, revealed but little that is new to American engineers. The novelties are few in number, and are not usually of a character which will be likely to be imitated.

The changes now going on in transatlantic practice are principally in minor details, and in the introduction of better material. Such changes of design as are noticed are usually in a direction in which our own builders have already gone in advance.

98. Forty years ago Robert Stephenson, in a letter to Robert L. Stevens,* wrote: "I am sorry that the feeling in the United States in favor of light railways is so general. In England we are making every succeeding railway stronger and more substantial. * * * Small engines are gradually losing ground, and large ones are daily demonstrating that powerful engines are the most economical." This is still the direction of change, although it is far less rapid than formerly. Stephenson incloses in the letter above referred to a sketch of an engine weighing *nine tons*, and capable, as he stated, "of taking one hundred tons gross load at the rate of sixteen or eighteen miles an hour on a level." The largest locomotive at Vienna weighed *seventy tons*, and it is capable of drawing a load of probably 1,000 tons, at a speed of thirty miles an hour.

* Preserved in the "Relic Corner" of the lecture-room of the writer at the Stevens Institute of Technology.

Digitized by Google

For many years locomotives have remained practically unchanged in all except size and in the form and proportions of the minor details.

There is undoubtedly good reason for this fact, and it is not impossible that it may continue to be the fact for an indefinite period, although no thoughtful engineer would be surprised were some new discovery or some unanticipated invention to suddenly revolutionize locomotive practice at any time. The locomotive is a simple machine, and the essential requisites of strength, lightness, and compactness are insuperable obstacles to such a multiplication of parts and range of modification of form as are permissible with the stationary, or even the marine, engine, and the opportunities offered for the exercise of inventive skill and for the application of frequently desirable devices are greatly restricted. The modification of size to suit various loads, and of type to adapt the machine to various speeds and to various special kinds of work are the directions in which designing is afforded an open field. In construction, good material and good workmanship are becoming more generally understood and more universally adopted.

In none of the engines shown at Vienna is seen that flexibility and consequent ease of traction on the smoothest of European railways, as well as on the roughest of our American roads, which is a common characteristic of American locomotives. Improvement is evidently taking place, although slowly, in feeding-apparatus, in the adoption of continuous breaks, in the use of metallic packing, and in the substitution of coal for the more expensive coke formerly exclusively used.

99. The use of steel has become more common in Europe than in America, but it is, nevertheless, now becoming rapidly introduced into the United States. Its use is becoming very general in fire-boxes, although the frequent cracking of plates which contain too high a percentage of carbon is retarding it.

The metal, if given barely sufficient carbon to enable the steel-furnace heat to melt it, will rarely be found to give trouble. The less the dose of carbon, and the nearer the metal becomes in character a homogeneous iron, the better will it serve this purpose.

Digitized by Google

(Sizes in millimeters.)

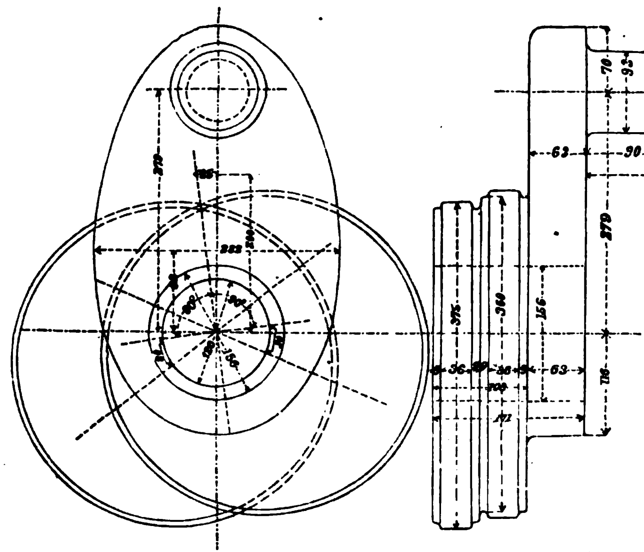


FIG. 52 *a*.—Driving-crank, without eccentric, for the Schweizer Nord-Ost. Bahn.

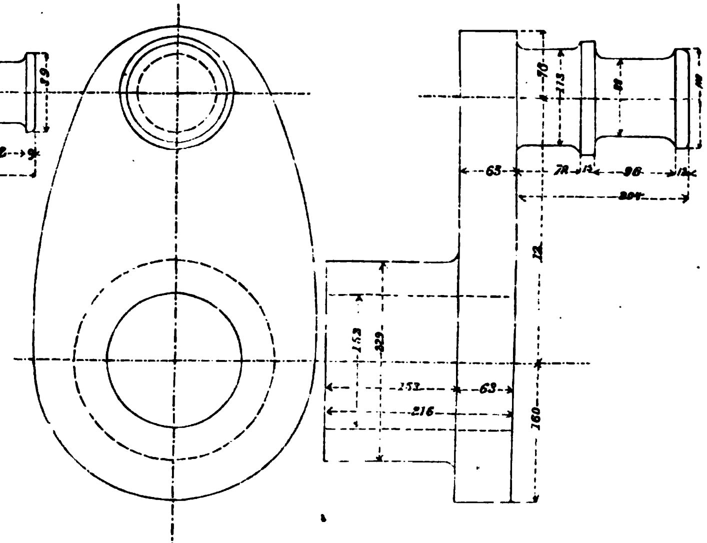


FIG. 52.—Krupp's driving-crank, with eccentric, for the Maschinenbau-Gesellschaft, Carlsruhe.

Digitized by Google

Digitized by Google

ES AT T

BASE.

Length rigid wheel base.	
Ft.	*In.*
4	6
6 0	
7	9
4	[illegible]
10	4
8	[illegible]
3	7
10	5
10	0
8	6
12	4
14	0
10	6
6	6
4	7
15	3
7	10
12	[illegible]
9	[illegible]
8	[illegible]
5	[illegible]
11	[illegible]
10	[illegible]
10	[illegible]

Digitized by Google

CHAPTER IV.

ROAD-LOCOMOTIVES; TRACTION-ENGINES.

BELGIAN LOCOMOTIVES WITH RUBBER TIRES; ENGLISH TRACTION-ENGINES; HISTORICAL; FOREIGN TRIALS OF ROAD-ENGINES; TRIAL BY THE AUTHOR AT SOUTH ORANGE, N. J.; DEDUCTIONS; TRACTION-FORCE; WORKING TIME; FIRST COST; RUNNING EXPENSES; GOOD ROAD-BEDS ESSENTIAL TO THEIR SUCCESS; ADVANTAGES OF STEAM-TRACTION.

100. BELGIUM ROAD-LOCOMOTIVES.—Several road-locomotives or traction-engines were exhibited in the British section, and one of these machines, fitted with the Thompson India-rubber tires, was entered in the Belgian catalogue. The latter was frequently seen at work, and was driven about the grounds to exhibit its power and speed and its facility of maneuvring. The action of the elastic tire was very interesting, and it was claimed to be durable. The exhibitor stated that it enabled the machine to be used in situations where the usual iron tire refuses to take hold.

101. BRITISH TRACTION-ENGINES.—Messrs. FOWLER, the well-known builders of steam-plows, exhibited a very neat and apparently substantial and effective style of road-locomotive.

Messrs. AVELING & PORTER exhibited a road-locomotive with a crane attached for lifting and transporting loads, and also another engine intended simply for traction. These machines were the most noticeable of this class in the exhibition.

102. HISTORY OF ROAD-LOCOMOTIVES.—The introduction of the road-locomotive, in substitution for horses whenever heavy work is done, is taking place slowly but steadily, so slowly that it seems to attract but little attention, notwithstanding its immense importance.

This movement began more than a century ago. As early as 1759, Dr. Robinson, who was at the time a graduate of the University of Glasgow, and an applicant for an assistant professorship there, and who made the acquaintance of the instrument-maker James Watt, when visiting the workshop of the latter, called his attention to the possibility of constructing a carriage to be driven by a steam-engine.

In 1765 that singular genius, Dr. Erasmus Darwin, whose celebrity was acquired by speculations in poetry and philosophy as well as in medicine, urged Matthew Boulton—subsequently Watt's partner, and just then corresponding with our own Franklin in relation to the use of steam-power—to construct a steam-carriage of which he sketched a set of plans.

Digitized by Google

A young man named Edgeworth became interested in the scheme, and, in 1768, published a paper which secured for him a gold medal from the Society of Arts. In this paper he proposed railroads on which the carriages were to be drawn by horses, or by ropes from steam-winding engines.

The first actual experiment was made, as is supposed, by a French army officer, Nicholas Joseph Cugnot, who, in 1769, built a steam carriage which was set at work in presence of the French minister of war, the Duke de Choiseul. The funds required by him were furnished by the Comte de Saxe. Encouraged by the partial success of the first locomotive, Cugnot, in 1770, constructed a second, which is still preserved in the *Conservatoire des Arts et Metiers*, Paris.

Watt patented a road-engine in 1784, after he had made the more essential improvements in general design and in the details of his pumping-engine. At about the same time Murdoch completed and made a trial of a model locomotive, driven by a "grasshopper-engine" having a steam-cylinder three-quarters of an inch in diameter and two inches stroke of piston. It is reported to have run six to eight miles an hour.

In 1786 Oliver Evans asked of the Pennsylvania legislature the monopoly of his method of applying the steam-engine in driving flour-mills *and to propelling wagons*. In the same or following year Wm. Symington constructed a working model of a steam-carriage, which may be seen in the patent museum at South Kensington, London.

In 1802 Trevithick and Vivian took out a British patent for a locomotive-engine, and their model is also preserved in the museum of the British patent office.

In 1804 Oliver Evans completed a flat-bottomed boat to be used at the Philadelphia docks, and, mounting it on wheels, drove it by its own steam-engine to the river-bank. He then propelled it down the river, using its steam-engine to drive its paddle-wheels. Evans asserted that carriages propelled by steam would soon be in common use, and offered a wager of $300 that he could build a "steam-wagon" that should excel in speed the swiftest horse that could be matched against it.

In 1821 Julius Griffiths, of Middlesex, England, made a steam-carriage for common roads, which he designed to carry passengers, and, which was probably the first ever constructed for that purpose only.

In December, 1833, about twenty steam-carriages and traction road-engines were running, or were in course of construction, in and near London.

In our own country the roughness of roads discouraged inventors, and, in Great Britain even, the successful introduction of road-locomotives, which seemed at one time almost an accomplished fact, finally met with so many obstacles that even Hancock, the most ingenious persistent, and successful constructor, gave up in despair. Hostile legislation procured by opposing interests, and possibly, also, the rapid progress of steam-locomotion on railroads, caused this result. In con-

Digitized by Google

sequence of this interruption of experiment, almost nothing was done during the succeeding quarter of a century, and it is only within a few years that anything like a business success has been founded upon the construction of road-locomotives, although the scheme seems to have been at no time entirely given up.

J. Scott Russell, Boydell, and a few others in England, and Messrs. Roper, Dudgeon, Fawkes, Latta, and J. K. Fisher, in the United States, have all, at various times, labored in this direction. The last-named engineer designed his first steam-carriage in 1840.

Abroad, a few firms have succeeded, within a few years past, in making a business of considerable extent in constructing road-locomotives for hauling heavy loads, and in building steam road-rollers. The great impediments seem to be the roughness and bad construction of the ordinary highways, the damages arising from the taking fright of horses, the engineering difficulties of construction, and the limited power of the machine as it has usually been built.

103. FOREIGN TRIALS OF ROAD-ENGINES.—The capabilities of the road-locomotive are readily determined by experiment, and the following are the results of several series of trials made by the writer and others:

A trial of the machines of the British makers, Aveling and Porter, was made by Mon. H. Tresca, Sous Directeur du Conservatoire Imperial des Arts et Metiers, Paris, and a member of the International Jury. The report was submitted to the Directeur-general, Morin, January 15, 1868.*

The results may be summarized as follows:

1. The co-efficient of traction was determined to be about 0.25 on a good road with easy grades.

2. The consumption of coal was found to be 4.4 pounds per horse-power per hour.

3. The consumption of water was determined to be 132.2 gallons an hour with "ten-horse" engine.

4. The "co-efficient of adherence" or of friction between the wheels and the soil was 0.3.

5. A rate of motion of seven miles an hour produced no special difficulty in managing either the locomotive or its load.

This engine was of large size, having a steam-cylinder of 11 inches diameter, and a stroke of piston 14 inches. The crank-shaft was geared to the driving-wheels in such a manner as to make 20.33 or 14.25 revolutions, at pleasure, for each revolution of the drivers. The driving-wheels were 6½ feet in diameter, and the weight of the machine, exclusive of fuel and water in its tanks, was 14½ tons. Including fuel and water, its weight was 17½ tons. The load drawn on a level road was 79 tons, 19 hundredweights, 1 quarter, (77,597 kilograms,) including the weight of the machine itself.

* Proces-verbal des Experiences faites sur une machine de traction; Conservatoire des Arts et Metiers; Paris, 1868.

Digitized by Google

This weight was distributed as follows:

	Per centum of totals.
Weight of engine	21.8
Weight of wagons	25.9
Weight of paying-load	52.3
	100

In an addenda to the report of M. Tresca, it is stated that M. Lalouette had set the engine at work transporting heavy material, and with the following results:

It transported a total weight of 2,500,000 kilograms a distance of 4 kilometers, drawing, on each trip, 25,000 kilograms of paying load, and making four trips per day. Five hundred kilograms of coal were consumed in eight journeys.

At about this same time M. Servel, Ingenieur-en-Chef de la Compagnie Générale des Messageriés à Vapeur, conducted a series of experiments with a similar machine upon paved and upon macadamized roads, during what he described as the most trying of winter weather. Under such conditions, M. Servel reports the following distribution of weights by percentum:

Weight of locomotives	41.4
Weight of wagons	18.2
Weight of paying-loads	40.4
	100

The average total weight of three loaded wagons, which was the usual load, was 22,575 kilograms, or very nearly 22 tons. The experiment was made in 1867-'68 of applying these engines to the towage of boats on the French canals. The results seem to have been very encouraging. M. Géraldi reported that an eight-horse engine towed, on the canal between Caen and Oyestreham, a fleet, having an aggregate measure of 800 tons, at the rate of three miles an hour, and that the speed had been pushed up to six miles an hour.

M. Carfort reported to M. Huet that a six-horse engine, doing similar work on the Dunkerque and Saint Omer Canal, had towed 800 tons, and was regularly towing 500 to 700 tons, at an expense not exceeding 40 per centum of the cost of horse-power. In the year 1871 a number of traction-engines were exhibited before the Royal Agricultural Society of England, at their show at Wolverhampton, and the judges appointed by the society made a series of exceedingly interesting and instructive tests.*

The judges stated that, on a road in good order, wheels fitted with India-rubber tires, as patented by Thompson, have an advantage over iron rigid wheels in traction-force, but that the cost of such wheels—50 per cent. of the cost of the locomotive—forms a most serious obstacle to

* Journal of the Royal Agricultural Society of England, vol. vii. London. J. Murray, 1871.

Digitized by Google

their adoption; still, they say that they "are not prepared to express a decided opinion upon that subject." On farm-roads and in fields the India-rubber tires "signally failed." Plain iron wheels, with "paddles" attached, succeeded where the former failed. A ten-horse locomotive entered by Messrs. Aveling & Porter received the first prize at the termination of these trials; two competing systems of rubber tires—those of Thompson and of Adams—were each awarded a silver medal; a six-horse-power road-locomotive, by Aveling & Porter, and an eight-horse-power road-engine, by Burrell, were very highly commended.

The prize-engine had a cylinder of 10 inches diameter and a stroke of piston of 12 inches, a fire-grate area of 6½ square feet, an area of heating-surface of 204.4 feet, driving-wheels 6 feet in diameter and 18 inches breadth of face. These wheels made one revolution to seventeen of the crank-shaft. The total weight of the engine was 12 tons, of which 8¾ were on the driving-wheels. The coal used, on special trial, amounted to 3.2 pounds per indicated horse-power per hour, and the evaporation of water was 7.62 pounds per pound of coal consumed, the average temperature of feed being 175° Fahrenheit. The load drawn up the maximum grade of 264 feet to the mile on Tottenham Hill, which is 1,900 feet from top to bottom, was 26 tons, or, including weight of engine, 38 tons, giving a co-efficient of traction of 0.35. On a country-road, sixteen miles long, it drew 15 tons at an average rate of speed of three and a half miles per hour, using 2.85 pounds of coal and 1.94 gallons of water per ton of useful load per mile. On farm-soil, soaked with recent rains, the load drawn was 9 tons, and speed something less than an average of two miles per hour, using 13.6 pounds of coal per ton of paying load per mile. This engine was fitted with smooth-tired driving-wheels.

104. Trial of Road-Locomotives by the Author.—The writer made a public trial of these engines and a steam road-roller by the same builders (Aveling & Porter) in October, 1872, at South Orange, N. J., which was attended by the commissioners of public roads for the neighboring county, and by many members of the engineering profession from New York and other cities. Two road-steamers, or traction-engines, and a steam road-roller were brought out for exhibition and trial.

No. 1 was a new road-locomotive (Fig. 53) built by Messrs. Aveling & Porter; it had previously done no real work. A sketch of this machine is here given. It was of precisely the same size and pattern of one of those exhibited at Vienna, and above referred to. The following description will apply to both:

Principal dimensions:

Weight of engine complete, 5 tons 4 cwt., pounds	11,648
Steam cylinder, diameter in inches	7¾
Stroke of piston, inches	10
Revolution of crank to one of driving-wheels	17
Driving-wheels, diameter in inches	60
Driving-wheels, breadth of tire in inches	10

Digitized by Google

Driving-wheels, weight, pounds, each	450
Boiler, length over all, feet	8
Boiler, diameter of shell, inches	30
Boiler, thickness of shell, inches	$\frac{7}{16}$
Boiler, fire-box sheets, outside, thickness in inches	$\frac{1}{2}$
Load on driving-wheels, 4 tons 10 cwt., pounds	10,080

The boiler was of the ordinary locomotive type, and the engine was mounted upon it, as is usual with portable engines.

The driving-pinion on the crank-shaft was made capable of being slipped out of gear, thus allowing the engine to be kept in motion when the locomotive was at rest, either to pump water into the boiler, or to drive as a "portable engine" by a belt which could be carried on the pulley, 4½ feet in diameter and 5 inches face, which was fitted to act as a fly-wheel. When used as a "portable engine," regulation was effected by means of a fly-ball governor conveniently attached. The cylinder was steam-jacketed in accordance with the most advanced practice here and abroad. The crank-shaft, and other wrought-iron parts subjected to heavy strains, were made of Lowmoor iron, and were strong and plainly finished. The gearing was of malleableized cast-iron, and all bearings from crank-shaft to driving-wheels, on each side, were carried by a single sheet of half-inch plate, which also formed the sides of the fire-box exterior. This simple device united all parts peculiarly exposed to injury by jarring, with such firmness as would seem to give perfect security against such injury even on rough roads. The engine valve-gear consisted of the standard arrangement of three-ported valve and Stephenson link, with the reversing lever, as used on locomotives. The feed-pump was driven by an eccentric keyed on the crank-shaft. The connection between the gearing and the driving-wheels was effected by one of the neatest and most ingenious devices known to engineers. This arrangement is called by builders of cotton machinery a "jack-in-the-box" gear, and the "differential" gear. As constructed, one wheel turns freely on the driving-axle, while the other driving-wheel is keyed fast. A bevel-gear is bolted on the hub of the wheel, and a similar gear is keyed to the driving-axle. Between these revolves a spur-gear, which is driven by the engine, and which carries two small bevel-pinions, the latter engaging both bevel-wheels, their axles being in the plane of revolution of the large gear. Resistances being equal on both wheels, if the spur-gear be turned it will carry with it both driving-wheels at the same time with equal angular velocities, the effort exerted by the engine being equal to both wheels at all times. If the engine be turning a corner, however, the greater resistance on the inside wheel retards that, while the outer wheel necessarily moves more rapidly over its longer path, and, while the engine still exerts the same force on both wheels, the work done is distributed unequally between them through the then revolving bevel-pinions, without loss, and without either wheel being necessarily slipped or disengaged. Should one wheel, however,

Digitized by Google

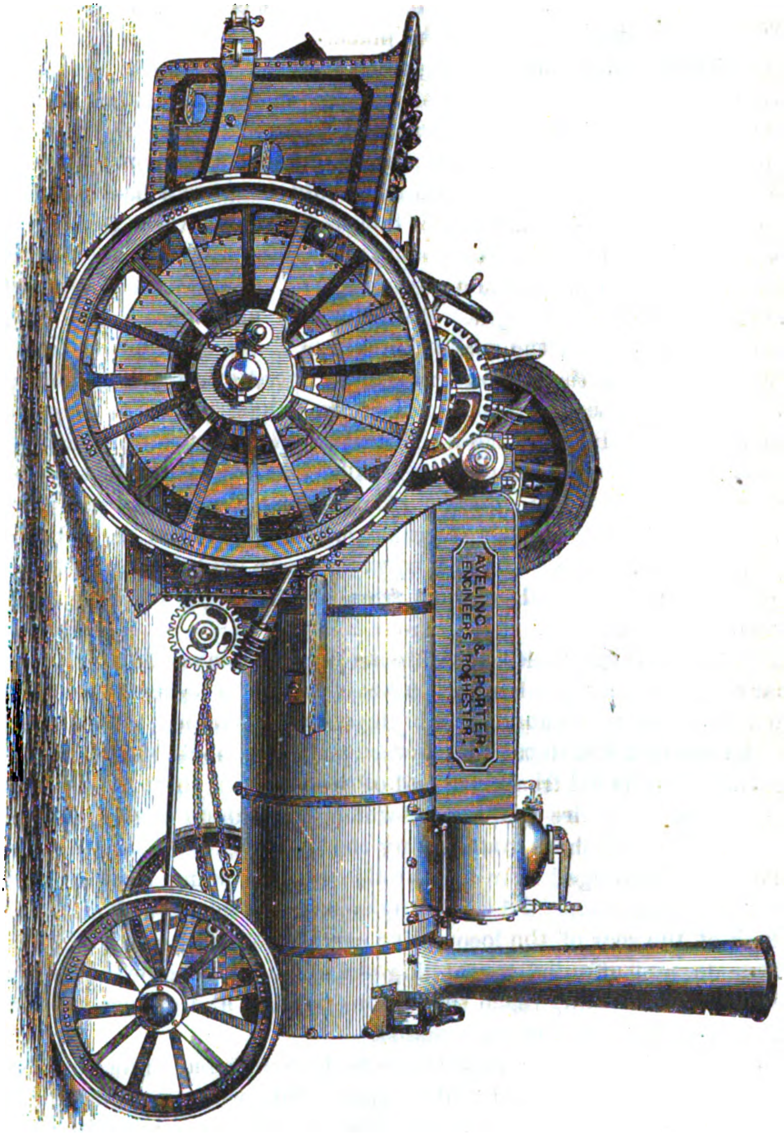


FIG. 53.—Aveling and Porter's road-locomotive.

Digitized by Google

strike into a soft spot, as a patch of muddy soil, and finding so little resistance as to turn freely, leaving the opposite wheel at rest on firmer soil and thus checking the motion of the locomotive, a heavy bolt, which is furnished with each machine ready fitted to its place, is inserted and keys the loose wheel to the shaft. Both wheels must thus turn together until, the locomotive being extracted, the bolt is withdrawn. Such an occurrence is seldom likely to take place.

The driving-wheels were wrought-iron, strong but light in their construction, and were fitted with strips of iron, thickest at the middle of their lengths, which were laid diagonally across the face of the wheels, with separating spaces of about two inches between them. The angle was such that one end of one strip would come to a bearing on the ground just as the opposite end of the preceding strip was leaving it.

The builders claim that this method of obtaining tractive-power in the wheel gives the engine a pulling-power, on good ground, equal to 0.45 of the insistent weight. On extremely hard and smooth roads, bolts are inserted in the wheel-rim, whose heads give better holding-power than even these iron strips, and on very soft ground the same bolts are used to secure to the rim of the wheel pieces of angle-iron, called by the builders "paddles," which take a good hold on the more unstable kinds of soil. The weight of this locomotive rested principally upon the driving-wheels. About 15 per centum was left upon the forward axle, to insure good steering power. The total weight on the drivers was somewhat increased, when pulling a load, by the inclination of the line of traction downward from the pulling-bolt to the point of attachment to the load.

The forward axle is fitted with wheels of 42 inches diameter and 8 inches face; it swings about a king-bolt, which is secured above in a bracket secured to the under-side of the boiler smoke-box, and is steadied by a strong rod, connecting its lower end with the forward end of the fire-box. Chains led from each end of the axle to a shaft carried on the forward end of the fire-box, around which they wound in such a manner that turning this shaft would swing the axle. A hand steering-wheel, conveniently arranged near the throttle and reversing handles, turned this shaft, being connected with it by means of a worm-shaft and pinion. A tank at the rear of the locomotive carried coal and water in its compartments, and afforded a standing-place for the engine-driver, from which he could readily reach the various handles and gauges. Draught was secured by means of the exhaust.

The boiler and steam-cylinder were both well protected against losses of heat by coverings of felt and lagging. No springs were used on the engine exhibited, as, being intended for heavy work at slow velocities, their advantages would not justify the expense and complication attending their use. A strap-brake was fixed on the driving-axle for the purpose of controlling the engine on heavy grades.

Road-locomotive No. 2 (Fig. 54) was of the same size and of similar

Digitized by Google

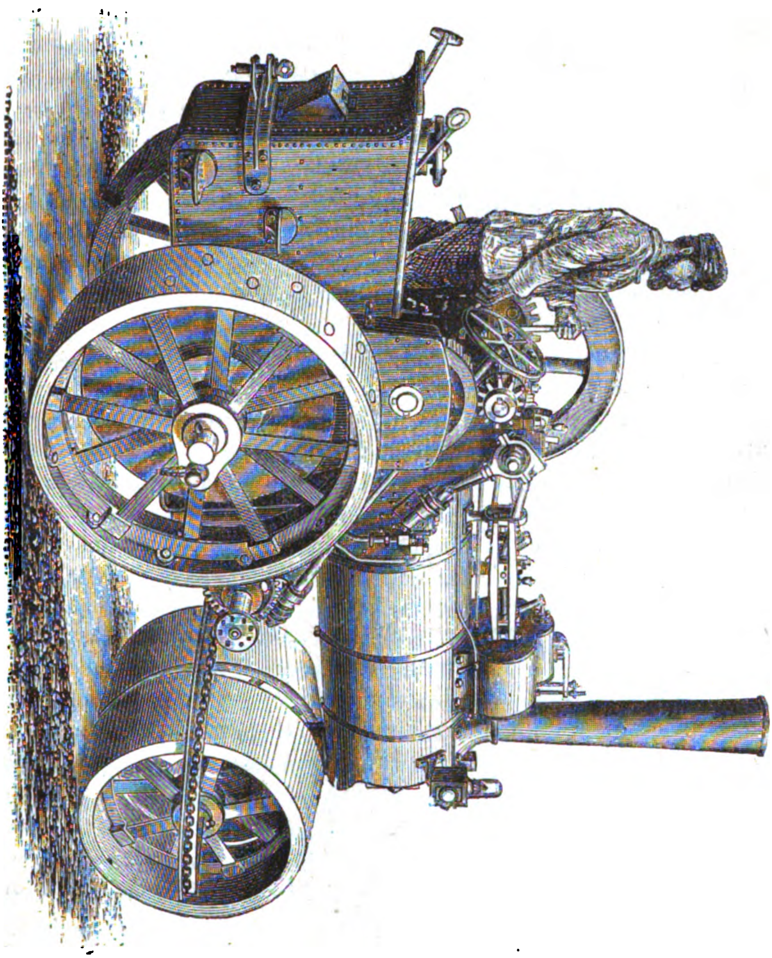


FIG. 54.—Aveling and Porter's steam road-roller.

make to No. 1. It had been two years in use, or longer, as a steam road-roller. To convert it into a road-roller, its ordinary driving-wheels had been removed, and in their place were fitted a pair of cast-iron wheels of similar diameter, but of 20 inches breadth of face, and weighing 3,800 pounds each. Their faces were left smooth, as hauling power was not desired; and as it was intended that they should leave the surface of the road as smooth and as firmly compacted as possible. In these driving-wheels the engine carried an excess of weight of 6,700 pounds as compared with No. 1. In statements of work done, this excess should be entered as a part of the paying-load where No. 2 is employed as a traction-engine. The great weight of these wheels was important in preventing the liability of slipping, which is a consequence of their smooth surface, and should bring up the equivalent co-efficient of adherence, in terms of the original weight of the engine, to about 0.42, or nearly equal to that of No. 1 with its regular traction-wheels. As during the trial no slip was in any case observable, this difference would not in any way affect the results.

The road-bed was macadamized, and was remarkably smooth, hard, and compact.

Such remarkably fine roads are, unfortunately, too seldom seen in this country, although not infrequently met with in Great Britain and on the continent of Europe. The fact is due partly, no doubt, to the infrequency of occurrence of such excellent material for metalling, but it principally arises from the circumstance that very few boards of road commissioners are sufficiently interested in their work, and, at the same time, sufficiently energetic and far-sighted to indulge in what often seems extravagant expenditure, but what is really one of the most important among the means available for economizing greatly the cost of local and suburban transportation.

From the results obtained at this trial were made the following:

105. DEDUCTIONS.*—(1.) A traction-engine may be so constructed as to be capable of being easily and rapidly manoeuverd on the common road and in the midst of any ordinary obstructions.

(2.) Such an engine may be placed in the hands of the average mechanic, or even of an intelligent youth of sixteen,† with confidence that he will quickly acquire, under instruction, the requisite knowledge and skill in its preservation and management.

(3.) An engine weighing rather more than five tons may be turned continuously in a circle of 18 feet radius without difficulty, and without slipping either driving-wheel, even on rough ground, and may be turned in a road-way of a width but slightly greater than the length of the locomotive by proper manoeuvring.

(4.) A road-locomotive weighing 5 tons 4 cwt., has been constructed,

* Communicated by the writer to the Journal of the Franklin Institute, 1873.

† The manufacturers state that one of their most skilful drivers at Wolverhampton was a boy of fourteen.

Digitized by Google

which is capable of drawing, on a good road, more than 23,000 pounds up the almost unexampled grade of 533 feet to the mile at the rate of four miles an hour.

(5.) Such a locomotive may be made, under similar conditions, to draw a load of more than 63,000 pounds up a hill rising 225 feet to the mile, at the rate of two miles per hour, doing the work of more than twenty horses.

(6.) The action of the traction-engine upon the road is beneficial, even when exerting its maximum power, while, with horses, the injury to the road-bed is very noticeable.

(7.) The co-efficient of traction is, with such heavily laden and roughly made wagons as were used at South Orange and under the circumstances noted, not far from *four per centum* on a well-made macadamized road.

(8.) The amount of fuel, of good quality, used may be reckoned at less than 500 pounds per day, where the engine is a considerable portion of the time heavily loaded, and, during the remaining time, running light. It may be considered, without probability of serious error, that, during the trials at South Orange, engine No. 2 performed pretty nearly an average day's work.

106. A number of interesting problems may be solved by reference to the facts just stated. A comparison of the efficiency of the road steam-traction engine with that of horse-power, in drawing heavy loads, is especially important, and we will now make such a comparison, basing it upon the most reliable data at hand.

Traction-force.—Engine No. 2 developed a tractive force equal to that of twenty horses. The actual tractive force may be determined as follows: The co-efficient of traction was, as has been shown, not far from 0.0427, which is also very nearly the maximum figure given by General Morin, as determined by his experiments with "dray-carts" and "*chariot-porte-corps d'artillerie*," upon metalled roads and upon roads paved with sandstone.* This co-efficient is large, partly in consequence of the very slight breadth of the wheel-tires and the small diameter of the wheels of the wagons used, and partly because the wagon-bodies were not mounted on springs. To be absolutely certain that no error is committed by overestimation in the following calculation, this co-efficient will be taken at 0.03.

The actual traction-force required to overcome the rolling resistance was, then, $63{,}400 \times 0.03 = 1{,}902$ pounds. The force required to overcome that component of the force of gravity which directly resisted the motion of the load, in this case, where the road lay at an angle with the horizontal whose tangent was 0.0427, was $W \sin T = 2{,}700$ pounds; the total resistance was, therefore, 4,602 pounds.

Including the weight of the traction-engine itself, these figures become 2,251 and 3,002 pounds, giving a total of 5,253 pounds direct resistance,

* Morin's Mechanics. New York, D. Appleton & Co., 1860, p. 348.

Digitized by Google

and a co-efficient of adherence of 5,253 ÷ 18,348 = 0.28, which slightly exceeds that found on earlier trials of smooth wheels.

Experiments made by Capt. Robert Merry, at the Jackson Iron Mine, Negaunee, Mich., and the observations and experiments of the writer, indicate the maximum direct tractive force of a good horse to be about 250 pounds. This corroborates the estimate already made, making the tractive power of this engine equal to that of twenty horses.

Deducing from the above the weight which could be drawn on an equally excellent but level road, by this locomotive, the co-efficient of traction being the same, we find it equal to $\frac{5,253}{0.03} = 175,000$ pounds, or very nearly 80 gross tons, and, excluding the weight of the locomotive, (163,452,) 75 tons. With the machine, as with the animal, it would not be expected that, in regular work on ordinary roads, more than one-half of the maximum power would be exacted,* although, with such a reserve, the machine possesses a decided advantage over the animal.

107. *Working time.*—The working time of a horse is usually considered to be eight hours per day for dray-horses, and less for carriage-horses. The dray-horse, which is kept in harness eight hours per day, is usually standing unworked a considerable proportion of this time, while his load is being handled, and also during one-half, usually, of the remaining time his vehicle is drawn unloaded. The horses of the Third-avenue street-railroad in New York City are worked less than six hours per day, and given one day in seven as a day of rest. This is about equal to the working time of horses and cattle crossing our western plains with moderate loads.

The steam-engine requires no such careful limitation of working time. It can work twenty-four hours uninterruptedly as readily as a single hour. Ten hours a day would be, in most cases, made the daily working-time of a road-locomotive, the period being determined by the proper length of the working-day of the driver, rather than by the capabilities of the machine.

The working time of the traction-engine may therefore be stated to be, ordinarily, 20 per cent. greater than that of the dray-horse, and to be capable of indefinite extension when required. The loss of working time by the horse through illness, at the farriery, &c., and that lost by the locomotive in the repair-shop, are proper subjects for comparison; but it is difficult to determine them in the absence of reliable data. We may estimate these losses as equally affecting the two motors, with a probability that the correction of any error in such estimate may make a change favorable to the locomotive.

108. *First cost.*—Comparing the first cost and running expenses of steam and of horse power, we may work from tolerably well-established data. The list-price of the Aveling & Porter road-locomotive experimented with at South Orange was, delivered in New York, about $4,000.

* *Vide* "Steam-engines and Prime Movers," Rankine, chap. 3, p. 85.

Digitized by Google

The average cost of horses purchased by the Third-avenue Railroad in New York City was $157.50, and it would require more than twenty such horses to pull the load of the traction-engine, while an addition of 25 per cent. must be made for the greater length of the working-day of the locomotive. Twenty-five such horses would have a first cost of $3,937.50, to which must be added the large item of cost of harness.

The first cost of steam and of horse power is, therefore, nearly equal, the difference being in favor of steam, leaving, also, on the side of the engine the immense advantage arising from its ability to work longer hours when required, and indefinitely. The interests on these first costs also nearly balance each other.

109. *Running expenses.*—The running expenses of the locomotive are for attendance, fuel, oil, and repairs, and for depreciation in value with use; those of horse-power are for attendance, food, stabling, sickness, and depreciation with age.

The cost of attendance upon the one engine and the twenty-five horses may be taken at $939 and $3,130, respectively, assuming each driver of the latter to be able to manage a six-horse team. The engine-driver received $3 per day and the other men $2.50, and there are 313 working days in the year.

The cost of fuel, oil, and incidentals, excluding repairs of the engine and its depreciation, may be averaged at $900 per year in the vicinity of New York. This is somewhat higher than the cost of similar items on railroad-locomotives in New York State.*

The cost of repairs and depreciation had been so small at South Orange that it could not be estimated, but for the life of the engine it will be likely to average something less than 15 per cent. of the first cost, or, in this case, $600 per annum. This we arrive at by an examination of railroad-locomotive expenses,† as officially reported.

The total annual expense, therefore, of the traction-engine referred to may be reckoned at $2,439 as a maximum figure, including cost of attendance. A similar estimate will give for the annual expense of keeping one horse, very exactly $300, excluding attendance. In the year 1870, 10,315 horses in the State of New York cost for stabling, feeding, repairs to harness, and shoes, &c., according to the official statement, $3,182,838.24, or $308.56 each animal. From this is to be deducted about $8 per head for receipts from sales of horses, leaving for annual expenses, say, $300 per horse. The expense account, excluding attendance, would be, for twenty-five horses, $7,000 against $1,500 for a similar amount of steam-power, and, *including attendance*, $10,500 as against $2,439.

Referring once more to the expense-account of the Third-avenue Railroad, we find it working more economically than the average as

* State Engineer's Reports.

† This is about the figure on good railroads in the United States; on British roads the range is from 10 to 25 per cent., averaging very exactly 15 per cent.

Digitized by Google

above given. This company employs an immense number of horses, buys its supplies in large quantities, taking advantage of the market, and is able to do much better than could any individual or smaller capitalists. The following data were kindly furnished by Mr. Charles S. Arthur:

Average cost (first) of horses, per head....................	$157 50
Average price obtained when sold, three and one half years later..	65 00
Cost of stabling, general expenses, and incidentals............	180 00
Total annual expenses, including depreciation.................	206 43
Add to the above the cost of harness, (not stated,) say........	3 00

The total annual cost of horse-power, for comparison, 25 × $209.43 = $5,235.75, to which we add $3,130 for drivers, and we make a total cost per year of $8,365.75, to be compared with $2,439, the total annual expense of the road-locomotive, capable of doing an equal amount of work.

The expense-account when doing heavy work on the common road, under the described conditions, by steam-power is, therefore, less than 25 per centum of the average cost of horse-power, as deduced from the total expense of such power in New York State, while, if we take for comparison the lowest estimate that we can find data for in our whole country, we still find the cost of steam-power to be but 29 per centum of the expense of horses. We may state the fact in another way: A steam traction-engine, capable of doing the work of twenty-five horses, may be worked at as little expense as a team of six or eight horses.

110. One of the most important of the prerequisites to ultimate success in the substitution of steam for animal power on the highway is, that our roads shall be well made. As the greatest care and judgment are exercised, and an immense outlay of capital is considered justifiable, in securing easy grades and a smooth track on our railroad routes, we may readily believe that similar precaution and outlay will be found advisable in adapting the common road to the road-locomotive. It is undeniably the fact that, even when relying upon horse-power, so far, less attention has been paid to the improvement of our roads than true economy would dictate. With steam-power, the gain by careful grading and excellence of construction of the road-bed becomes still more important. The animal mechanism is less affected in its power of drawing heavy loads than is the machine. With the horse, a bad road impedes transportation principally by resisting the movement of the load rather than of the animal, while with the traction-engine the motor is as seriously retarded as the train which follows it, and frequently much more, on soft ground. Steam, therefore, cannot be expected to attain its full measure of success on rough and ill-made roads; but where highways are as intelligently engineered and as thoroughly well built as those on which the trials at South Orange were made, or where nature has relieved the engineer and the road-builder of the ex-

Digitized by Google

pensive work of grading, as throughout a very large extent of the western and southern portion of our country, we may expect to see the road-locomotive rapidly introduced.

111. The earliest and most perfect success of the traction-engine, and its probable successor, the steam-carriage, may be expected to occur in these districts. Its great economical advantage over animal power, as exhibited above, its freedom from liability to become disabled by epizootic diseases, its reliability under all circumstances, and the many other advantages which are possessed by the machine, are already securing its rapid introduction, despite the difficulties arising from popular prejudice and unfamiliarity, from hostile municipal laws and other existing obstacles.

We are learning that this motor, when it can be used at all, is comparatively inexpensive; that our roads are improved by it, and that the ancient idea of its conflicting with the interests of owners and workers of horses is only a superstition.

The principal inconvenience that may be anticipated will probably arise from the carelessness or avarice of proprietors, which may sometimes cause them to appoint ignorant and inefficient engine-drivers, giving them charge of what are always excellent servants, but terrible masters. Nevertheless, as the transportation of passengers on railroads is found to be attended with less liability to loss of life or injury of person than their carriage by stage-coach, it will be found, very probably, that the general use of steam in transporting freight on common roads may be attended with less risks to life or property than to-day attends the use of horse-power.

Digitized by Google

CHAPTER V.

PORTABLE ENGINES; STEAM FIRE-ENGINES.

SOURCES OF ECONOMY IN PORTABLE ENGINES; READING IRON-WORKS ENGINES; MARSHALL, SONS & CO.; CLAYTON & SHUTTLEWORTH; AVELING & PORTER; ROBEY & CO.; E. R. & F. TURNER; RANSOME, SIMS & HEAD; THE STRAW-BURNER; OTHER ENGINES; IMPORTANCE OF THE PORTABLE-ENGINE TRADE; ROTARY STEAM FIRE-ENGINES; THE ENGINE OF THE SILSBY MANUFACTURING CO.; ADVANTAGES; BRITISH AND AMERICAN STEAM FIRE-ENGINES; MERITS OF AMERICAN STEAM FIRE ENGINES; HISTORICAL SKETCH OF THEIR INTRODUCTION.

PORTABLE STEAM-ENGINES built by British builders have for many years excelled all others, with, perhaps, the exception of an American builder, Mr. J. C. Hoadley, of Lawrence, Mass., and the later work of the best English builders has given economical results that have surprised engineers. The sharp competition of leading firms at the annual shows of the Royal Agricultural Society has recently brought out most gratifying evidences of skill in management as well as of excellence of design and construction. Some of these little portable engines have exhibited an economical efficiency superior to that of the largest marine engines of any but the compound type, and even closely competing with that form. The causes of this remarkable—almost incredible—economy are readily learned by an inspection of these engines as exhibited at Vienna, and by observation of the method of managing them at the test trial. The engines are usually very carefully designed. The cylinders are nicely proportioned to their work, and their pistons travel at high speed. Their valve-gear consists usually of a plain slide-valve, supplemented by a separate expansion-slide, driven by an independent eccentric, and capable of considerable variation in point of cut-off. This form of expansion-gear is very effective—almost as much so as a drop cut-off—at the usual grade of expansion, which is not far from four times. The governor is usually attached to a throttle-valve in the steam-pipe, an arrangement which is not the best possible under variable loads, but which produces no serious loss of efficiency when the engine is driven, as at these competitive trials, under the very uniform load of a strap-brake and at very nearly the maximum capacity of the machine. The most successful engines have had steam-jacketed cylinders, an essential to maximum economy with high steam and a considerable expansion. The boilers are strongly made, and are, as are also all other heated surfaces, carefully clothed with non-conducting material, and well lagged over all. The details are carefully proportioned; the rods and frames are strong and well secured together; the bearings have large rubbing surfaces;

Digitized by Google

BENEFIT UNIV. University of MICHIGAN

the connecting-rods are long and easy working, and every part is capable of doing its work without straining and with the least friction.

In handling the engines at the competitive trial, most experienced and skilful drivers are selected. The difference between the performances of the same engine in different hands has been found to amount to from 10 to 15 per cent., even where the competitors were both considered exceptionally skilful men. In manipulating the engine, the fires are attended to with the utmost care; coal is thrown upon them at regular and frequent intervals, and a uniform depth of fuel and a perfectly clean fire are secured with remarkable success. The sides and corners of the fire are looked after with especial care. The fire-doors are kept open the least possible time; not a square inch of grate-surface is left unutilized, and every piece of coal gives out its maximum of calorific power and in precisely the place where it is needed. Feed-water is supplied as nearly as possible continuously and with the utmost regularity. In some cases, the engine-driver stands by his engine constantly, feeding the fire with coal in handfuls and supplying the water to the heater by hand by means of a cup. Heaters are invariably used in such cases. The exhaust is contracted no more than is absolutely necessary for draught. The brake is watched carefully lest irregularity of lubrication should cause oscillation of speed with the changing resistance. The load is made the maximum which the engine is designed to drive with economy. Thus all conditions are made as favorable as possible to economy, and they are preserved as invariable as the utmost care on the part of the attendant can make them.

These trials are usually of only three or five hours duration, and thus terminate before it becomes necessary to clean fires.

The following are results obtained at the trial of engines which took place in July, 1870, at the Oxford agricultural fair:

Makers' name and residence.	Cylinders.		Stroke.	Horse-power.		Point of cut-off.	Revolutions per minute.	Pounds coal per horse-power per hour.
	Number.	Diameter.		Nominal.	Dynamometric.			
		In.	*In.*					
Clayton, Shuttlewood & Co., Lincoln	1	7	12	4	4. 42	......	121. 65	3. 73
Brown & May, Devizes	1	7 3-16	12	4	4. 19	11-48	125. 65	4. 44
Reading Iron-Works Company, Reading		5 3-4	14	4	4. 16	......	145. 7	4. 65

These were horizontal engines, attached to locomotive boilers.

At a similar exhibition held at Bury, in 1867, considerably better results even than these were reported as below from engines of similar size and styles. Subsequent trials have given similarly excellent results.

Digitized by Google

Makers' name and residence.	Cylinders. Number.	Diameter.	Stroke.	Horse-power. Nominal.	Dynamometric.	Point of cut-off.	Revolutions per minute.	Pounds coal per horse-power per hour.
		In.	*In.*					
Clayton, Shuttleworth & Co., Lincoln	1	10	20	10	11.00	3-10	71.5	4.13
Reading Iron-Works Company, Reading	1	8 5-8	20	10	10.43	1-4	109.4	4.22

With all these engines steam-jackets were used, the feed-water was highly and uniformly heated by exhaust steam, the coal was selected, finely broken, and thrown on the fire with the greatest care, the velocity of the engines, the steam-pressure, and the amount of feed-water were very carefully regulated, and all bearings were run quite loose; the engine-drivers were usually expert "jockeys."

113. Yet, even under such conditions as have been described, the results obtained seem very extraordinary. The Reading Iron-Works, Marshall, Sons & Co., and Messrs. Clayton & Shuttleworth, all of whom exhibited at Vienna, obtained most excellent economy, and other firms did quite good work.

The first-named firm, in 1872, were reported to the Royal Agricultural Society at Cardiff to have obtained the following results on such a trial: The engine, with a cylinder of 8½ inches diameter and 14 inches stroke of piston, had 205 square feet of heating surface, of which about 40 were in the fire-box. Its grate had an area of 7¼ square feet, which was reduced to 2½ square feet during the trial. The tubes were 2¾ inches diameter and 39 in number.

With steam-pressure at 80 pounds per square inch and at about 150 revolutions per minute, the engine developed 20½ indicated and 16⅞ dynamometrical horse-power, and consumed less than 2½ pounds of picked coal per indicated horse-power per hour, the boiler evaporating 10 pounds of water per pound of coal. The amount of water used was 24 pounds per indicated horse-power per hour, and burned at the rate of over 20 pounds per square foot of grate per hour. The engine was of the type above described, but the governor was attached to a right and left hand screwed stem, moving the cut-off blocks on the back of the main valve. With a powerful and yet delicate governor, this is an excellent arrangement. The governor has been connected to the cut-off valve of the portable engine by Mr. Hoadley also. The engine exhibited at Vienna was similar to that which gave this exceedingly creditable result on trial.

114. Messrs. MARSHALL, SONS & CO., of Gainsborough, exhibited portable engines of the class called in Great Britain "semi-fixed," in which the engine and boiler were mounted together, but were not carried on wheels as are the really portable machines. In design and in

Digitized by Google

construction and finish these engines were among the best shown in the British section. The Hartnell & Guthrie shifting-eccentric was used, and this by its adjustability to different extent of throw, gave the same flexibility of valve-adjustment attained by the better-known "Dodd motion."

115. Messrs. CLAYTON & SHUTTLEWORTH exhibited a large collection of engines and boilers. This firm, which was founded in 1848, is said to have constructed between 12,000 and 13,000 engines. They have had a large branch establishment at Vienna for many years, and now have a large share of the continental trade in this class of machinery. The principal characteristics of these engines were quite similar to those of other builders of the better class of engines, and they were equally admirable in design, construction, and finish.

116. Messrs. AVELING & PORTER were also exhibitors of most commendable engines. ROBEY & Co. exhibited engines remarkable for their fine finish. Some were fitted with Richardson's governor, mounted on the crank-shaft, and acting upon the cut-off valve through an eccentric with a modified Dodd motion. The device was said to work very satisfactorily.

Messrs. E. R. & F. TURNER, of Ipswich, exhibited an engine which, although not as highly finished as some others, was of excellent form and proportions, and was reported to be exceedingly economical. It had the Hartnell & Guthrie governor attached to a valve patented by the builders. The main valve is a piston-valve 6 inches in diameter, for a cylinder of 12 inches diameter, and resembles, in some respects, the Davis valve, used in the engine exhibited by the New York Safety Steam Power Company. The engine was reported, at Cardiff, in 1872, to regulate remarkably well, and to perform very economically, notwithstanding the use of but one valve instead of attaching an independent cutoff valve.

117. Messrs. RANSOME, SIMS & HEAD were large exhibitors of a considerable variety of machinery, including several steam-engines of the class here considered. One of these engines was adapted to burning straw and other vegetable refuse. It was exhibited at a public trial, and its performance was so satisfactory as to attract the attention of both engineers and agriculturists. This machine was especially designed to meet a demand which promises to become an important one, and particularly in many portions of continental Europe, where the raising of grain forms the principal business of the farming population. The plan is said to have originated with a Russian engineer, Mr. Schemioth, who was assisted in the development of the invention by Mr. Head, the junior partner of the firm.

As arranged at Vienna, the straw was driven into the furnace by feeding-rollers, moved by a belt from the crank-shaft, and hangs suspended above the grates a short time, while the flame rising from the half-consumed fuel on the bars, seizes it, and its combustion is partially

Digitized by Google

accomplished before it falls. The essential feature of success seemed to be the free supply of air thus secured for every portion of the combustible mass. The grates are liable to become choked by a mineral, silicious deposit—the ash formed—and a raking apparatus is provided, by means of which its removal is effected at intervals. To avoid danger from fire, the ash-pan is closed at the nearer end, and the ashes are kept moistened by a small stream of water from the feed-pump. The consumption of fuel is reported to be three and a half to four times the weight of coal usually required, and one sheaf of straw suffices to thresh twelve or fifteen sheaves of wheat. The combustion was very perfect and rapid.

The boiler is given a greater area of heating surface than is given for equal power when wood or coal is the fuel.

The engine exhibited at Vienna was rated at ten-horse power. Its cylinder was of 9 inches diameter, and the stroke of piston 1 foot; speed of piston 280 feet per minute, or 140 revolutions; the heating surface measured 210 square feet. It was said to develop 20 indicated horse-power.

The best portable engine of standard design exhibited by Ransome, Sims & Head was rated at 12 horse-power. It was 8.4 inches in diameter of cylinder, one-foot stroke; it was regulated for 140 revolutions per minute, and had 210 square feet of heating surface. Steam was carried at 90 pounds pressure per square inch.

The cylinders were steam-jacketed on both sides and ends; the inner "working-barrel" being made separately and forced into the main casting. Separate slide-expansion valves were used, worked by independent eccentrics, adjustable in position to give a range of expansion from one and one-half to five times. A feed-water heater, with an independent feed-pump, furnished water to the boiler nearly at the boiling point. The engine was stated to be capable of working up to 35-horse-power, with a consumption of 3½ to 3¾ pounds of coal per horse-power per hour. The point of cut-off was adjustable by the Brown arrangement of governor. It does very good work, and the indicator diagrams show a very fair distribution of steam.

These engines were beautifully finished, were well made, and evidently well prepared to do good work. In this, as in several other exhibits, the crank-shafts were *bent* to shape—an excellent practice. A *buckle* on the governor-belt to permit taking up slack showed careful attention to details on the part of the builders.

118. Messrs. John Fowler & Co. exhibited their agricultural machinery in great variety, and deserve credit for the excellence of design and workmanship and for their success in the field. The writer found their apparatus at work on the estate of Baron von Horsky, doing excellent work—plowing. The portable engine driving the plows was a strong, well-proportioned and well-built engine, and seemed capable of long service without serious expense for repairs.

Digitized by Google

119. There were several other portable engines exhibited at Vienna by British builders, some of which were hardly less creditable to their makers than those mentioned above, while, in one case at least, they were crude in design, rough in workmanship, and without finish.

As a rule, the British builders were without rivals in the exhibition in this branch of work. The American Engine Company, J. C. Hoadley, and possibly one other firm in the United States are rivaling the best of them, but the portable engine has not received the attention that it deserves in this country, and there remains ample room for other good builders in our markets. Although manufacturers may take a just pride in building large steam-engines on the most approved plans, with elaborate expansion-gear and with condensing apparatus, the more extended market is that for small engines, and for portable engines particularly. The market for small, simple, well-proportioned, and carefully-made engines will always be large, and it may always be relied upon as far steadier and safer than that for larger machinery. Our builders cannot do better than to follow, and, if possible, to excel, the British makers in this direction.

The French section contained three or four portable engines. That of M. HERMANN LACHAPELLE was well made, of very good design, and, in the absence of the magnificent show of British engines, would have been considered worthy of special mention. The other French engines were quite unworthy even of criticism.

The other continental builders of portable engines were, evidently, usually following in the track, although far in the rear, of the English makers, and their engines require no mention, except in the case of Sigl, of Vienna, whose exhibit was very creditable.

120. STEAM FIRE-ENGINES.—The Silsby Manufacturing Company, of Seneca Falls, New York, exhibited a well-built and finely-finished steam fire-engine, with rotary engine and pump, (Fig. 55.) The superiority of a rotary motion for a steam-engine is apparently so evident that it is not strange that many attempts have been made to overcome the practical difficulties to which it is subject. One of these difficulties, and the principal one, has been the packing of the part which performs the office of the piston in the straight cylinder. Robert Stephenson expressed the opinion, a few years ago, that a rotary engine would never be made to work profitably on account of this difficulty of packing. The most palpable of the advantages of the rotary engine are the reduction in the size of the engine, claimed to result from the great velocity of the piston, avoidance of great accidental strains, especially noticed in propelling ships, and a great saving of the power which is asserted to be expended in the reciprocating engine in overcoming the inertia while changing the direction of the motions. These advantages adapt the rotary engine, in an especial manner, to the driving of a locomotive or steam fire-engine. This application has been made, and all difficulties are claimed to have

Digitized by Google

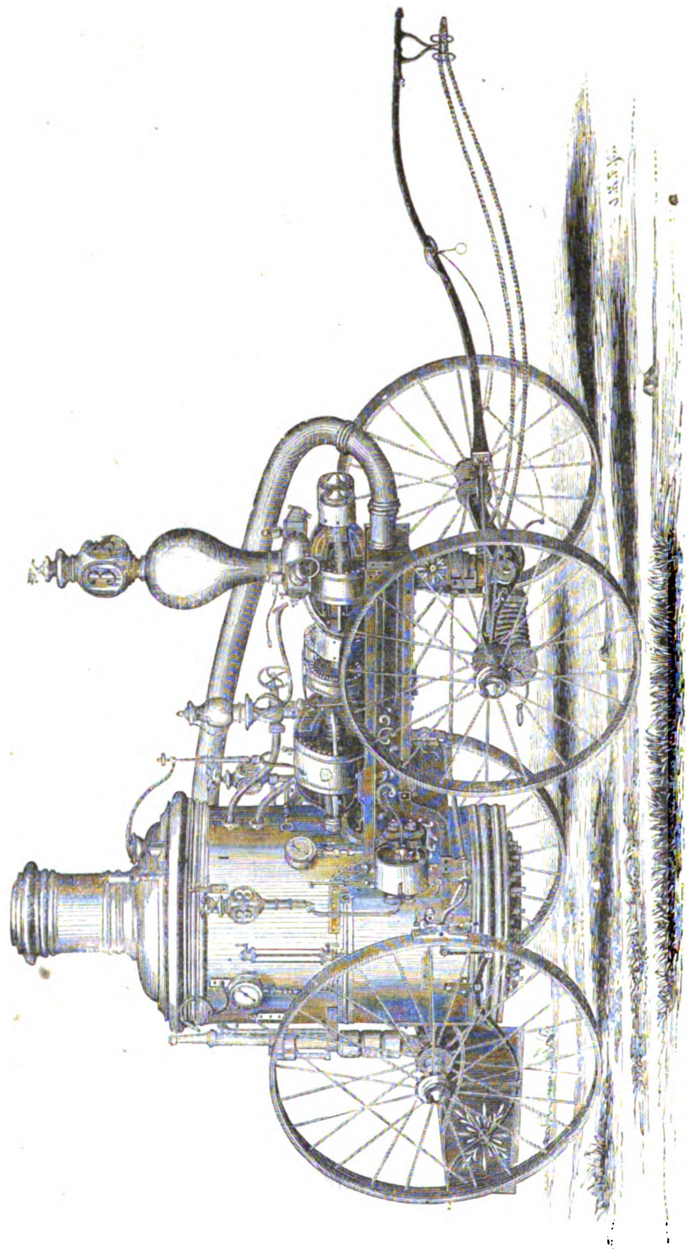


FIG. 55.—Steam fire-engine—Silsby Manufacturing Company, U. S.

Digitized by Google

been surmounted. The packing, after three years' trial, it is stated, has been found perfectly tight.

121. In these rotary engines and pumps (Fig. 56) all eccentrics and sliding cams, which are frequently used in rotary engines, and which are so objectionable on account of their great friction, are avoided. Corrugated pistons, or irregular cams, C D, are adopted, forming chambers within the cases. In the engine the steam enters at A, at the bottom of the case, and presses the cams apart. The friction in this engine is claimed to be very small, as the only packing used is in the ends of the long metal cogs, which are ground to fit the case and are kept out by the momentum of the cams, assisted by a slight spring back of the packing-

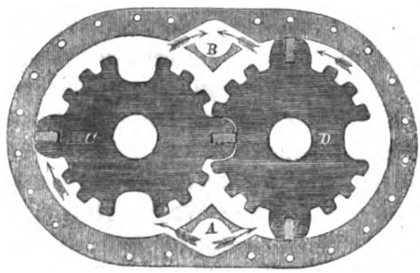


FIG. 56.

pieces. The friction on the pump is claimed to be less than in the engine. This is the reason given in support of the claim that the rotary engine forces water to a given distance with from one-fourth to one third the steam-pressure necessary to drive all reciprocating engines. The smaller amount of power necessary to do the work, the less strain and consequent wear and tear upon the whole machine, are said to make it more durable and reliable. The pump being chambered, its liability to injury by the use of dirty or gritty water is lessened, and it is stated that it will last for years, pumping gritty water that would soon cut out a piston-pump.

122. The advantages of the rotary engine are: The ease of its operation and the absence of the crank-motion which is found in all reciprocating machines. The high speed at which all engines must be driven in steam fire-engines makes it necessary that the reciprocating engine should be very strong and heavy to bear the jerking and straining to which they are subjected in passing the centers. The rotary engine has not that difficulty to contend against. The machine stands perfectly still when in operation. There is no necessity for blocking the wheels or jacking the boiler off the springs. There is no vibration of the hose, and the pressure being steady and uniform, it does not strain the hose, as happens from the blows of a piston. Hose that will not bear the pressure of the piston of the reciprocating-pump to force water 200 feet, it is said by these builders, will stand the uniform pressure of the rotary engine when

Digitized by Google

throwing the stream 230 feet. Hose used on a rotary engine will wear longer than that used on a piston-engine, as it lies perfectly still while the machinery is in operation, and consequently does not wear out by friction upon the ground or pavement. The pipe of a rotary engine is held more easily than that of a piston-engine. This is of great advantage to the fireman in ascending ladders to the upper portion of a building. Another advantage is claimed to be the low pressure of steam with which the rotary engine can be driven, it being seldom necessary to use over 40 pounds to do effective fire-duty. The suction-hose is, in this engine, always attached to the pump, and has only to be lifted out of the hooks on the side of the machine and dropped into the water or attached to a hydrant, and the leading hose being laid and attached, the machine is ready for operation. There are no valves in either engine or pump, and the whole arrangement is so simple that any careful man may be intrusted with the engine. They require two men, the engineer and fireman, while in operation. The engine has a feed-pump for supplying the boiler while the machine is in operation, and an independent donkey-pump. It also has an arrangement for supplying the boiler from the main pump, so as to insure supplying water, under any and all circumstances and for any length of time. The "Washington 8," of Mobile, a third-size engine, is reported by these exhibitors to have worked over 136 hours at a fire, merely stopping to change the location of the hose. Another advantage claimed for this machine is that the boiler is so constructed that impure or salt water can be used without causing it to foam or prime. This, they state, has been tested at Providence, R. I., one of the old and seven of the new styles being in use in that city, all of which have been used with salt water in their boilers while working at fires in the lower part of the city, where fresh water could not be obtained without difficulty. The boiler can easily be repaired, and every part is accessible without taking the machine apart. The advantage of the steam fire-engine over the hand-engine for the extinguishment of fires has now been long recognized. The experience of all cities and villages that have adopted a steam fire-department indicate they are more effective, less troublesome to manage, and also less expensive to maintain, than the hand-engine department.

123. Messrs. SHAND & MASON and Messrs. MEREWETHER, of London, exhibited heavy, but well-built steam fire-engines. It is unfortunate that several American firms, noted for their excellence of product in this class of machinery, had not exhibited their fire-engines.

124. AMERICAN STEAM FIRE-ENGINES.—There were no steam fire-engines exhibited by the best known American builders of engines with reciprocating engines and pumps, such as are in general use in the United States, and have become standard in general plan and arrangement of details. These are probably the best illustrations which have ever been produced of extreme lightness, combined with strength of parts and working power, which have ever been produced in any branch

Digitized by Google

of mechanical engineering. By using a small boiler crowded with heating-surface, very carefully proportioned and arranged, and with small water-spaces; by adopting steel for running-gear and working parts wherever possible; by working at high piston-speed and with high steam-pressure; by selecting fuel with extreme care; by all these expedients the steam fire-engine has been brought, in this country, to a state of efficiency far superior to anything seen in Europe. Steam is raised with wonderful promptness, even from cold water, and water is thrown from the nozzle at the end of long lines of hose to great distances.

But this combination of lightness with power is only attained at the expense of a certain regularity of action which can only be secured by greater water and steam capacity in the boiler. The small quantity of water contained within the boiler makes it necessary to give constant attention to the feed, and the tendency, almost invariably observed, to serious foaming and priming not only compels unintermitted care while running, but even introduces an element of danger which is not to be despised, even though the machine be in charge of the most experienced and skilful attendants.

The limited steam-space in these boilers also introduces another objectionable feature by producing such a tendency to variation of steam-pressure that even the most expert firing (stoking) cannot secure immunity from serious oscillations of steam-pressure. The skill with which these engines are usually handled is most remarkable, and it can only be the product of long practice and excessive care.

But even the greatest care, directed by the utmost skill, would not avail to prevent frequent explosions, were it not for the fact that it rarely, if ever, occurs that accidents to boilers occur from low water, unless the boiler is actually completely emptied of water. In driving them at fires, they frequently foam so violently that it is utterly impossible to obtain any clew to the amount of water present, and the attendant usually keeps his feed-pump on and allows the foaming to go on. As long as water is passing into the boiler it is very unlikely that any portion will become overheated and that accident will occur. Such management appears very reckless, and yet accident from such a cause is exceedingly rare, even if any such accident has been known.

Where it is uncertain whether there is sufficient water in the foaming boiler, a prudent engineer is careful to keep his feed-pump on and his engine running until he can find the water-level. If he finds himself actually caught with an overheated boiler, he promptly deadens his fire without stirring it, avoiding any other change of condition. The best way to proceed is probably to cover the fire with damp ashes or sand.

125. Historical sketch.—The steam fire-engine is peculiarly an American production; although previously attempted, their permanently successful introduction has only occurred within the last fifteen years.

As early as 1830, Braithwaite, of London, Great Britain, built an

Digitized by Google

engine with steam and pump cylinders of 7 and 6½ inches diameter, respectively, with 16 inches stroke of piston. This machine weighed two and a half tons, and is said to have thrown 150 gallons of water per minute to a height of between 80 and 100 feet. It was ready for work in about twenty minutes after lighting the fire. Braithwaite afterward supplied a more powerful engine to the King of Prussia, in 1832.

The first attempt made in the United States to construct a steam fire-engine was probably that of Hodge, who built one in New York in 1841. It was a strong and very effective machine, but was far too heavy for rapid transportation.

The late J. K. Fisher, who throughout his life persistently urged the use of steam-carriages and traction-engines, designing and building several, also planned a steam fire-engine. Two were built from his design by the Novelty Works, New York, about 1860, for Messrs. Lee & Larned. They were "self-propellers," and one of them, built for the city of Philadelphia, was sent across on the highway, driven by its own engines. The other was built for and used by the New York fire department, and did good service for several years. These engines were heavy, but very powerful, and were found to move at good speed under steam and to manœuvre well.

The Messrs. Latta, of Cincinnati, soon after succeeded in constructing comparatively light and very effective engines, and the fire department of that city was the first to adopt steam fire-engines definitely as their principal reliance. This change has now become general.

A self-propelling engine by the Amoskeag Company had the following dimensions: Weight, four tons; speed, eight miles per hour; steam-pressure, 75 pounds per square inch; height of stream from 1¼-inch nozzle, 225 feet; 1¾-inch nozzle, 150 feet; distance horizontally, 1¼-inch nozzle, 300 feet; 1¾-inch, 250 feet.

The Fire-Extinguisher, which has now become an essential article of furniture in so large a proportion of the houses of people in good circumstances in the United States, was not shown. This modern representative of the "Fire Cart," introduced by Captain Manby, in Great Britain, a half century ago, is a very important modern device, and should have been exhibited in all its variety of construction and mounting. One of the Babcock Manufacturing Company's carriages would have been very interesting to European visitors, and its lightness, power, and handiness would have surprised all.

Digitized by Google

CHAPTER VI.

STEAM-BOILERS AND ATTACHMENTS.

PITKIN BROTHERS' BOILER; THE GALLOWAY BOILER; TRIAL OF GALLOWAY BOILER; DATA AND RESULTS; HOWARD'S AND OTHER SECTIONAL BOILERS; HISTORICAL SKETCH OF SECTIONAL BOILERS; THEIR ADVANTAGES AND DISADVANTAGES; TEST OF THEIR ECONOMICAL PERFORMANCE; METHOD OF MAKING UP DATA; TABULAR EXHIBIT OF RESULTS; DETERMINATION OF PERCENTAGE OF PRIMING; FINAL RELATIVE STANDING; DESCRIPTION OF THE HOWARD BOILER; SPECIAL ADVANTAGES; THE SINCLAIR BOILER; ADAMSON'S BOILERS; THE BOILERS OF DAVEY & PAXMAN; THE BELLEVILLE BOILER; BOILERS OF MEYER, EHRHARDT, BERGMAN, PAUCKSCH & FREUND; SIGL'S BOILER AND LEH'S GRATE; BOLZANO, TEDESCO & CO.'S BOILERS; BOLZANO'S GRATE; BERRYMAN'S HEATER AND FEED-WATER REGULATOR; GREEN'S AND TWIBIL'S ECONOMIZERS; INJECTORS OF SELLERS, FRIEDMAN, AND KORTING; PHILOSOPHY AND HISTORY OF THE INJECTORS; PRINCIPLES OF STEAM-BOILER CONSTRUCTION.

126. The steam-boilers exhibited at Vienna were not remarkable for their number, their novelty of design, nor, generally, for exceptionally fine workmanship. One boiler only was exhibited in the United States section, by Pitkin Brothers & Co., of Hartford, Conn.* It was a tubular

* The following extract from a letter from Mr. Pickering, engineer of the United States Department at the Vienna Exhibition, gives interesting information concerning the Pitkin boiler here alluded to. It was 54 inches in diameter, 16 feet long, with 59 tubes 3 inches in diameter and 15 feet long:

"Your boiler was subjected to the customary hydrostatic test, and it was declared by the officer in charge to be the only one of the entire collection at this Exposition which stood the cold-water test without leaking. And now the boiler has been in constant use nearly two and a half months, and has, to the surprise of every one, (including myself,) supplied our department with all the steam we need, and that with very easy firing and very poor coal. We are running daily four steam-engines: one 30, two 8, and one 3 horse-power; one 650-pound steam-hammer, one steam puddling-machine engine, of 5 horse-power, three steam-pumps, and other machinery, and supplied steam, when wanted, for the sand-blast exhibit of Tilghman, of Philadelphia. The main steam-pipe furnished by the Austrian General Commission is of very thin iron, 6 inches in diameter and 150 feet long. From this pipe all the steam is supplied, except through 48 feet of 1½-inch pipe continued from the end of the 6-inch pipe, making a total distance of this last engine from boiler 238 feet, as there are 40 feet of 3-inch pipe connecting boiler to the 6-inch main pipe. This steam piping is not covered, and consequently condenses much steam; so much, in fact, that it was necessary to place a straw-trap about the middle of the length of this pipe to relieve it of the water of condensation. The exhaust-pipes of these engines and pumps are so far from the boiler that it was found impracticable to use the exhaust steam for heating the feed-water; consequently, we feed cold water. I am now more than ever impressed with the economy and safety of this style of boiler, and our present and previous commissioners, as well as myself, desire to express our thanks for your liberality and promptness in furnishing, for use of the American department of this Exposition, so good a boiler, and one which is so true a sample of a style of boiler now so much in use in the United States.

"Very truly yours,

"T. R. PICKERING,

"*Engineer United States Department, Vienna Exposition.*"

Digitized by Google

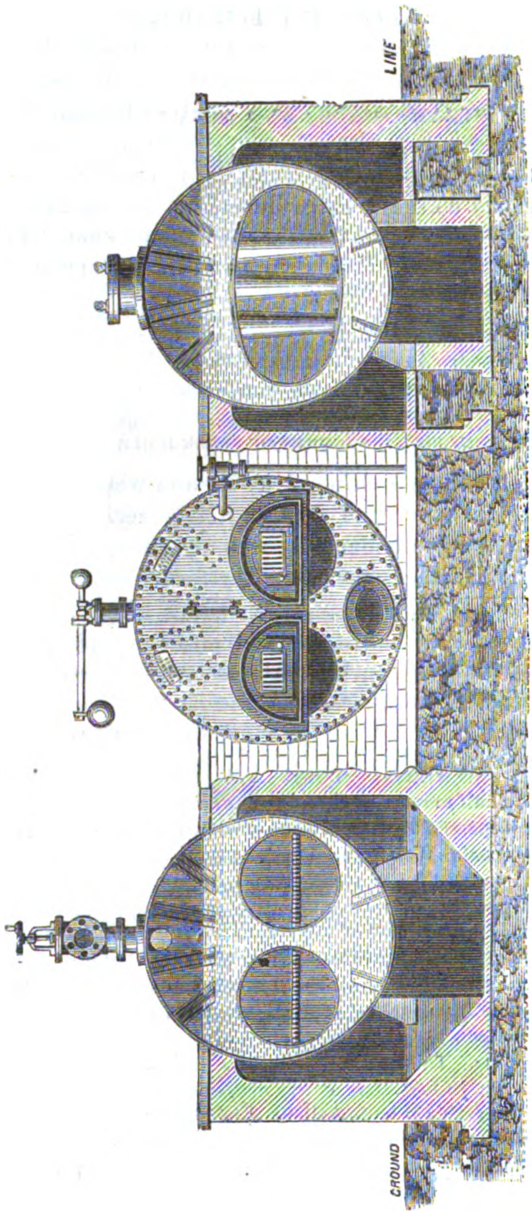


FIG. 57.—The Galloway steam-boiler—front elevation and section.

Digitized by Google

boiler of small size, of good proportion, and of excellent material and workmanship. The furnace was below the boiler, the gases passing back under the shell and returning through the tubes. The boiler did good work throughout the period of the Exhibition.

127. In the British section, the exhibit of Messrs. W. & J. GALLOWAY & SONS is interesting as illustrating the use of their conical tubes, (Fig. 58.) These are very largely used in Great Britain, but are seldom if ever seen in the United States. The Cornish boiler, to which they are usually applied, consists of a large cylindrical shell, 6 feet or more in diameter, containing one tube of about one-half as great dimensions, or sometimes two of one-third the diameter of the shell each. Such boilers have a very small ratio of heating to grate surface, and their large tubes are peculiarly liable to collapse.

To remove these objections, the Messrs. Galloway introduced stay-tubes

FIG. 58.

(Figs. 58, 59, 60) into the flues, which tubes are conical in form, and are set in either a vertical or an inclined position, the larger end uppermost. The area of heating-surface is thus greatly increased, and, at the same time, the liability to collapse is reduced. It is stated that more than 100,000 of these tubes are in use. The same results are obtained by another device of Galloway, which is sometimes, as at Vienna, combined with that just described in the same boiler. Several sheets in the flue are worked in "pockets" which project into the flue-passage.

The Galloway boilers exhibited are shown in elevation, plan and sections, (Figs. 57, 59, and 60,) and had each two furnace-flues, of 34 inches diameter each, opening into one large elliptical flue 69 inches wide by 36 inches high, its inner axis vertical, which was stayed by 24 Galloway tubes, (Fig. 59,) and by six side-pockets, as seen in Fig. 60. The gases issued from the rear end of the boiler, and thence passed underneath it to the chimney. The shell was 24 feet long and 7 feet in diameter.

128. TRIAL OF A GALLOWAY BOILER.—The following report of a trial of a Galloway boiler at the mill of C. R. Collins, esq., at which were present the editor of "Engineering," C. R. Collins, esq., Byron Donkin, esq., engineer, London, and Chas. J. Galloway, Manchester, was handed the writer by the exhibitors.

The boiler was rated by the makers as a 55-horse-power boiler, was 26 feet long by 7 feet in diameter, and was made of $\frac{3}{8}$-inch plates, double-riveted at the longitudinal seams. The two front flues were each 2 feet 10 inches in diameter and 7 feet long; they were made of $\frac{3}{8}$-inch plates, with welded

Digitized by Google

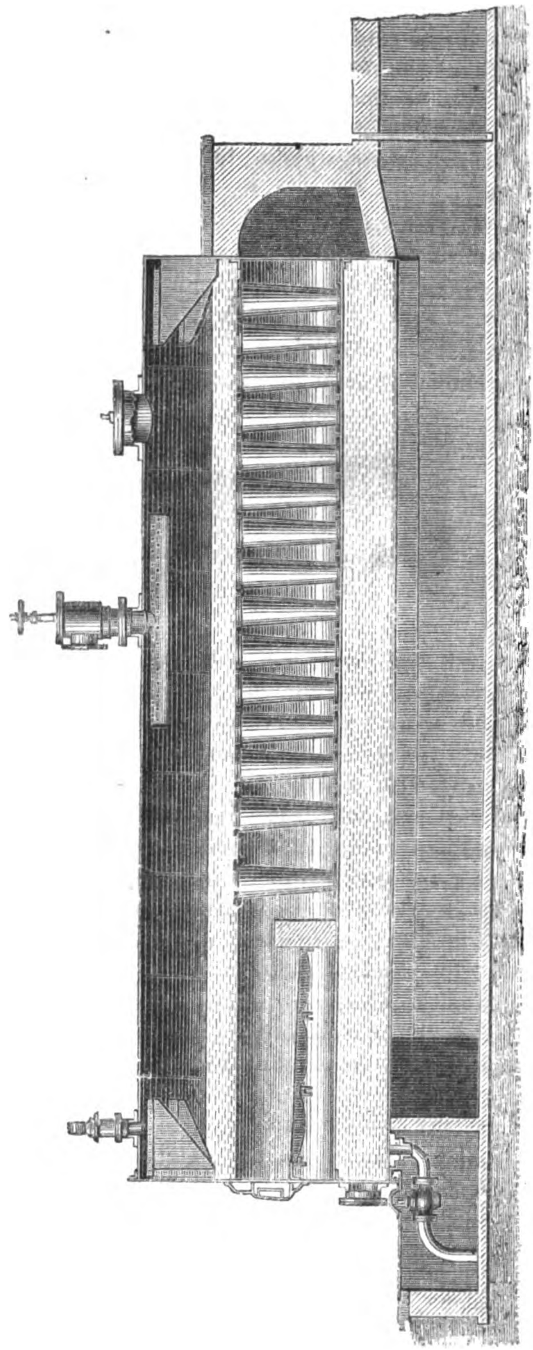


FIG. 59.—The Galloway steam-boiler—vertical section.

Digitized by Google

seams, and were strengthened by T-iron rings, while the back flue, which was of elliptical section, had a horizontal diameter of 5 feet 8 inches and a vertical diameter of 3 feet. This back flue was traversed by 27 Galloway tubes, each 10½ inches diameter inside at the top and 5½ inches at the bottom, while it was also made with a pair of side "pockets," these "pockets" causing the mixture of the gases coming from the two front flues. The fire-bars of each grate were in three 2-feet lengths, and the fire-grate area is 33 square feet. The hot gases, on escaping from the back flue, are led along the two sides of the boiler and then back under the bottom of the latter to the chimney.

The total heating-surface of the boilers was as follows:

	Square feet.
Fire-boxes	72
Over-flue	240
Twenty-seven cone-tubes and two pockets	144
Side-flues	220
Bottom-flue	72
Total	748

The boiler had been thoroughly cleaned out and the flues swept prior to the trial, and it had, in fact, only been lighted up about twenty-one hours when the trial commenced, so that the brickwork setting was scarcely thoroughly warmed through. This was slightly against it, as was also the fact that it was worked very much below its real power, so that the constant losses due to radiation, &c., went far to balance any advantage due to the slow combustion and the very moderate evaporation per square foot of heating-surface. The boiler was fed by a small donkey-pump, this pump being, during the experiment, supplied with steam from an adjacent boiler, so that its use should not affect the results obtained from the main engine. The boiler under trial was situated at the end of a range of boilers to which the steam-pipe was connected. To do away with any chance of leakage through the one connecting stop-valve, however, the adjacent boiler was kept at the same pressure as that under trial during the whole of the experiment, so that there should not be the slightest tendency to leak either way. The boiler was carefully lagged, as was also the steam-pipe which connected it with the engine.

The boiler was fed from a small cast-iron tank, situated by its side, and to which the donkey-pump already mentioned was attached. This tank was fitted with a gauge showing the water-level, and at the end of the experiment the water was brought to precisely the same level as that at which it stood at the commencement. The water used was filled into the tank by two cylindrical cans, each closed at the upper end, with the exception of a small opening, so that they could be accurately filled. The number of can-fulls of water used was noted by two observers, whose records were found to agree, and the cans themselves

Digitized by Google

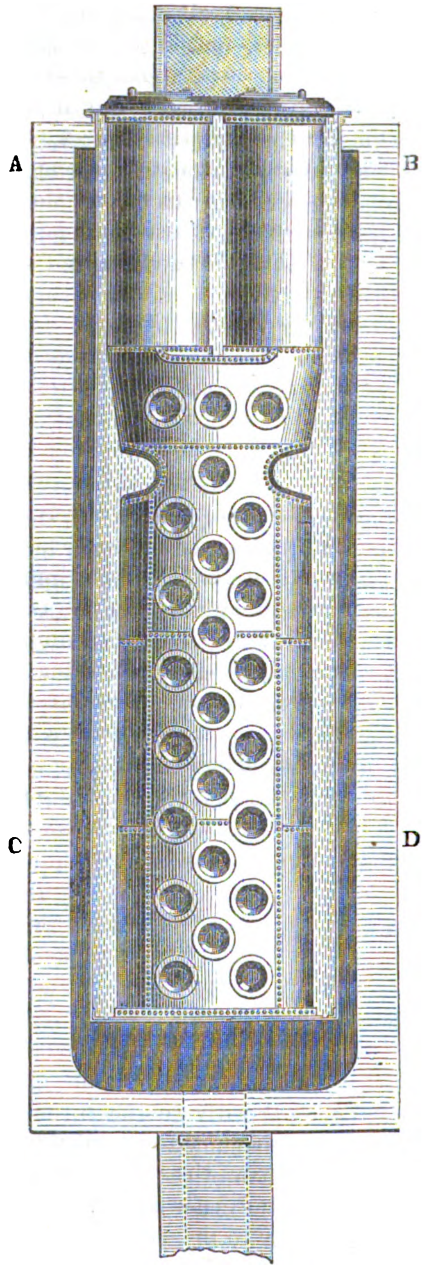


Fig. 60.—The Galloway steam-boiler—plan and section.

carefully weighed full and empty, and the weight of water used thus ascertained. The temperature of the feed-water was also taken at intervals of about 20 minutes.

Before the experiment commenced, all coals were cleared completely away from the front of the boiler, and into the space thus made the coals to be used on the trial were weighed, under the supervision of Mr. Collins. The coals used were Powell's Duffryn, and were of excellent quality. In commencing the experiment at 9.30 a. m., on a signal being given from the engine-house, the water-level in the boiler was marked on a scale fixed to the glass of the water-gauge, the pressure of steam was noted, and both fires were drawn at once, with the exception of about a shovel-full left in each furnace for re-lighting. About 12 pounds of wood were then thrown in, and the firing commenced with the weighed coal, the drawn fires being cleared away. When the fires were drawn, the steam stood at 50 pounds per square inch, in five minutes it had fallen to 49 pounds, but in fifteen minutes it had risen again to 49½ pounds, and in twenty-five minutes it was at 54 pounds. During the day it was kept almost constantly at 53 pounds, scarcely ever varying from this pressure more than a couple of pounds, and the mean of forty-nine observations, taken at intervals of twelve minutes, showed the pressure last mentioned to be the average throughout the experiment. At 6.45 p. m., when the experiment was approaching a close, the pressure was 51½ pounds, while at the end of the trial it was 49¾ pounds, or almost exactly the same as at the beginning, while the water-level was also precisely the same. On notice being given from the engine-house that the trial was completed, both fires were drawn, and the coal, cinders, &c., taken out and set on one side to cool, while at the same time the ash-pits were cleaned out.

129. When cool, the materials drawn from the fires were passed over a sieve with ¼-inch meshes, and the clinkers picked out by hand, and the weights were then found to be as follows:

	Cwt.	Qr.	Lbs.
Cinders	2	0	15
Siftings	0	0	26
Clinkers	0	0	10
Dirt from ash-pit	0	1	25
Total	2	3	20

The total amount of coal charged into the furnaces during the trial was 12 cwt., and the quantity consumed was thus 9 cwt. 0 qr. 18 lbs.= 1,016 lbs. plus its proper proportion of the dirt. Of the siftings, one-half was judged to be good fuel and the other half dirt, and the total quantity of dirt was thus 13 lbs. siftings+10 lbs. clinkers+53 lbs. from ash-pit= 76 lbs. in all, or almost exactly 5.66 per cent. Of this 76 lbs. of dirt, 12 lbs. (a quantity rather below the proper percentage) was taken as belonging to the 239 lbs. of cinders drawn from the fire, and the re-

Digitized by Google

mainder, 64 lbs., was added to the fuel actually consumed, thus raising the latter to 1,080 lbs.

The quantity of water fed into the boiler during the trial was 11,691 lbs., and the evaporation, therefore, took place at the rate of $\frac{11691}{1080}=$ 10.82 lbs. of water per pound of coal. Considering that the mean temperature of the feed was 61¾°, this was a remarkably high evaporation, and affords good testimony as to the efficiency of the boiler.* We may add that the experiments made on the engine prove decisively that the quantity of water above mentioned was really evaporated, and that none of it passed away in priming.† This is an important point, and it is one of many in favor of the system of engine-testing adopted on the occasion of which we are speaking. It will be noted that during the trial the boiler was worked far below its real power, the rate of evaporation being but 1.56 pounds per square foot of total heating-surface per hour. There can be no doubt that this contributed to the economical results obtained; but at the same time, for reasons to which we have before referred, the advantage gained by this very slow rate of evaporation was not so great as might at first sight be supposed. In February, last year, the same boiler was tested with an evaporation of 28,087 pounds of water in ten hours, (a quantity nearly two and a half times as great as that evaporated during this trial,) and this weight was evaporated with a consumption of 2,919 pounds of coals, containing 2.8 per cent. of dirt, the evaporation being thus rated at 9,622 pounds per pound of coal. In this instance the temperature of the feed was 75°, and the general conditions and arrangements for ascertaining the results were

* It may be convenient for comparison with data derived from other experiments to reduce the results above stated to the equivalent evaporation from a temperature of 212°, and under the ordinary atmospheric pressure.' To do this we may employ the convenient and well-known formula of Professor Rankine to determine what he has termed the factor of evaporation. This formula is—

$$\text{Factor} \times \frac{0.3\ (T_1 - 212°) \times (212\ T_2)}{966}$$

in which T_1 = the temperature at which evaporation takes place, and T_2 = the initial temperature of the feed. In the case of experiments above recorded, T_1 = 310.2°, that being the temperature of steam at a pressure of 53 pounds above the atmosphere, while T_2 = 61¾°. The factor was thus:

$$1 \times \frac{0.3(310.2 - 212) \times (212 - 61.75)}{966} = 1 \times \frac{179.71}{966} = 1.186$$

Multiplying now the evaporation obtained during the experiments by this factor, we get 10.82 × 1,186 = 12.83 pounds, as the equivalent evaporation which would have been obtained if the feed had been supplied at 212°, and the water boiled off under ordinary mean atmospheric pressure.

† Unfortunately, it remains uncertain how much of this was water actually evaporated and how much was "primed."

The remark, made above in regard to determining this by experiments upon the engine, can hardly be accepted as decisive on this point. See Art. 136 for the method adopted by the author in determining accurately the extent to which priming occurs.—R. H. T.

Digitized by Google

similar to those adopted at the more recent trial. For convenience of reference we give here, in a tabular form, a comparison of the principal data derived from this trial and from that of February, 1871.

	Trial February 8, 1871.	Trial October 11, 1871.
Quantity of coals burned per hour .... pounds..	291.9	108
Quantity of coals burned per square foot of grate .... do....	8.85	3.27
Quantity of coals burned per square foot of heating-surface .... do....	0.39	0.144
Quantity of water evaporated per hour from above temperature.... do...	2,808.7	1,169.1
Quantity of water evaporated per pound of coal .... do....	9.622	10.82
Quantity of water evaporated from temperature of feed per square foot of heating-surface per hour .... pounds..	3.75	1.56
Equivalent quantity of water which would have been evaporated from a temperature of 212°, and under atmospheric pressure for each pound of coal consumed, (by Professor Rankine's formula) .... pounds..	11.28	12.83
Percentage of dirt and clinkers .... per cent..	2.8	5.66
Temperature of feed .... degrees..	75	61.75

RESULTS OF THE TRIAL OF A GALLOWAY BOILER, OCTOBER 11, 1871.

	Square feet.
Heating-surface, fire-boxes	72
oval flue	240
27 cone-tubes and two pockets	144
side flues	220
bottom flues	72
Total	748
Fire-grate area	33

Results of trial.

Duration of trial, from 9.30 a. m. to 7.30 p. m .... 10 hours.

Mean pressure per square inch of steam in boiler-house, average of 49 observations made at intervals of about 12 minutes .... 53 pounds.

Initial temperature—mean of 28 observations .... 61.75°

		Pounds.
Feed-water.	Quantity evaporated during 10 hours = 108 cans, weight of each can 108¼ pounds	11,691
	Quantity evaporated per hour	1,169.1
	Quantity evaporated per minute	19.48
	Quantity evaporated per indicated horse-power per hour	20.55
	Quantity evaporated per pound of coal consumed	10.82
Coal.	Description: Powell's Duffryn.	
	Quantity consumed during ten hours	1,080
	Quantity consumed per square foot of fine-grate per hour	3.27
	Quantity consumed per indicated horse-power per hour	1.91
	Percentage	5.66 per cent.

Average temperature of outer boiler .... 57°

Average temperature in boiler .... 63°

Digitized by Google

From the above experiment it will be seen that the "Galloway" boiler evaporated 10.82 pounds of cold water per pound of Welsh coal. Had the temperature of the feed been raised to 212° (which is often exceeded where an economizer is used) and the water evaporated at atmospheric pressure, the result would have been 12.83 pounds of water per pound of coal, an evaporation which has perhaps never been exceeded by any other form of boiler.*

The boiler in this case was worked much under its ordinary power, as, with a condensing-engine, in good working order, it would drive 250 indicated horse-power with a pressure of 50 pounds or 60 pounds of steam.

130. Messrs. HOWARD, of Bedford, England, exhibited a boiler of a type which, in the United States, is largely known as the sectional boiler. In this class, of which there are many different kinds in the market, the water-space of the boiler is contained in a large number of small compartments, each of which is very strong, and the explosion of any one of which is not likely to produce that destruction of property and that great loss of life which so frequently follow the explosion of the more common kind of boiler.

131. HISTORICAL SKETCH OF SECTIONAL BOILERS.—The earliest boiler of this class was probably that of Col. John Stevens, of Hoboken, N. J., still preserved and now in the possession of the Stevens Institute of Technology. Dr. Alban forty years later attempted to bring this type into general use, and constructed a number of such boilers. Their introduction, like that of all radical changes in engineering, has been but slow, and it has been only recently that their manufacture has become an important branch of industry.

A committee of the American Institute, of which the writer was chairman, in 1871, examined several boilers of this and the ordinary type very carefully, and reported that they felt "confident that the introduction of this class of steam-boilers will do much toward the removal of the cause of that universal feeling of distrust which renders the presence of a steam-boiler so objectionable in every locality. The difficulties in thoroughly inspecting these boilers, in regulating their action, and other faults of the class are gradually being overcome, and the committee look forward with confidence to the time when their use will become general, to the exclusion of older and more dangerous forms of steam-boilers."

132. VALUE OF SECTIONAL BOILERS.—The economical performance of these boilers with a similar ratio of heating to grate surface should be equal to that of other kinds. In fact they are usually given a somewhat higher ratio, and their economy of fuel frequently exceeds that of the other types. Their principal defect is their small capacity for steam and water, which makes it extremely difficult to obtain steady steam-pressure.

Where they are employed, the feed and draught should be, if possible,

* See preceding foot-note.—R. H. T.

Digitized by Google

controlled by automatic attachments, and the feed-water heated to the highest attainable temperature. At best, their satisfactory working depends, more than in other cases, on the skill of the fireman, and can only be secured by the exercise of both care and skill.

133. ECONOMY OF SECTIONAL BOILERS.—The comparative economical efficiency of this class of boilers is well exhibited by the report of the committee above alluded to; and their report is the more interesting from the fact that it embodies the results of trials in which the actual evaporative powers of boilers were determined, evading the error which is usually produced where the water passing off with the steam, as in the last-described trial, is not measured and its weight deducted from the apparent weight of steam formed.

Digitized by Google

Results of a competitive trial of Sectional and other Steam-Boilers.

Boiler.	Square feet.		Ratio of heating-surface to grate-surface.	Total weights.					Ratio of water primed to water evaporated.	Mean temperatures.						
	Grate-surface.	Heating-surface.		Coal.	Combustible.	Feed.	Steam.	Primed water.		Injection.	Feed.	Water of condensation.	Discharge.	Steam.	Super heat.	Flues.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.	P.
A	27	876½	32.5	3,800	3,185.5	27,896	27,896	0.	0.	45°.94	45°.94	58°.31	143°.1	334°.6	16°.08	416°.6
B	32¼	920	28.5	5,375	4,527	39,670	39,670	0.	0.	45°.5	45°.5	63°.48	154°.76	330°.63	13°.23	345°.87
C	23	600	26.1	2,800	2,274	20,428	19,782.94	645.06	3.26	45°.65	45°.65	54°.38	120°.83	321°.06	0°.	503°.76
D	37¾	913	24.2	4,400	3,705	34,000	31,663.35	2,336.65	6.9	45°.0	45°.0	54°.8	131°.5	319°.48	0°.	389°.6
E	8½	440	51.8	1,232	1,047.5	10,152.5	9,855.6	296.9	3.	44°.4	44°.4	49°.49	106°.14	323°.75	0°.	221°.67

Boiler.	Total British thermal units.	Total units per pound of combustible.	Apparent evaporation.				Actual evaporation.		Equivalent evaporation of water at 212° Fahr. and atmospheric pressure.	Square feet of heating-surface required to evaporate one cubic foot of water per hour.	Coal, lbs. per square foot, grate-surface per hour.	Efficiency; actual evaporation of fuel divided by theoretical.
			Per pound of coal.	Per pound of combustible.	Per square foot of grate-surface per hour.	Per square foot of heating-surface per hour.	Per pound of coal.	Per pound of combustible.				
	Q.	R.	S.	T.	U.	V.	W.	X.	Y.	Z.	Z 1.	Z 2.
A	32,751,834.34	10,281.53	7.34	8.76	86.09	2.65	7.34	8.76	10.64	23.59	11.73	0.709
B	46,387,827.1	10,246.92	7.38	8.76	102.51	3.59	7.38	8.76	10.60	17.41	13.88	0.707
C	23,060,685.39	10,143.66	7.26	8.95	73.70	2.83	7.07	8.70	10.49	22.74	10.13	0.699
D	37,228,739.072	10,048.24	7.68	9.12	75.06	3.10	7.20	8.55	10.40	21.63	9.71	0.693
E	11,485,777.35	10,964.94	8.24	9.69	99.53	1.92	8.00	9.41	11.34	33.48	12.10	0.756

Digitized by Google

The boilers tested were A and B, true "sectional boilers;" C, a semi-sectional, and D and E, boilers which were tubular boilers of more nearly the ordinary type. All of the steam formed was condensed in a surface-condenser of 1,100 square feet area of refrigerating-surface. The coal used was anthracite, of excellent quality, containing 91 per cent. carbon, and capable of affording, if perfectly utilized, 13,197 British thermal units of heat per pound of coal, and of evaporating 13.65 pounds of water at the boiling-point.

The preceding table, exhibiting the results of the trials, which were of twelve hours' duration each, affords valuable information not readily obtainable:

135. In calculating the results from the record of the logs, the committee first determined the amount of heat carried away by the condensing water by deducting the temperature at which it entered from that at which it passed off. To this quantity is added the heat which was carried away by evaporation from the surface of the tank, as determined by placing a cup of water in the tank at the top of the condenser at such height that the level of the water inside and outside the cup were the same, noting the difference of temperatures of the water in the cup and at the overflow, and the loss by evaporation from the cup. The amount of evaporation from the surface of the water in the cup and in the condenser, which latter was exposed to the air, was considered as approximately proportional to the tension of vapor due their temperatures, and was so taken in the estimate. The excess of heat in the water of condensation over that in the feed-water also evidently came from the fuel, and this quantity was also added to those already mentioned.

The total quantities were, in thermal units, as follows:

A	34,072,058.09
B	48,241,833.60
C	24,004,601.14
D	38,737,217.57
E	11,951,002.10

These quantities, being divided by the weight of combustible used in each boiler during the test, will give a measure of their relative economical efficiency; and, divided by the number of square feet of heating-surface, will indicate their relative capacity for making steam. But as it was the intention of the committee to endeavor to establish a practically-correct measure that should serve as a standard of comparison in subsequent trials, it was advisable to correct these amounts by ascertaining how and where errors had entered, and introducing the proper correction. There were two sources of error that are considered to have affected the result as above obtained. The tank being of wood, a considerable quantity of water entering it, leaked out again at the bottom, without increase of temperature, instead of passing through the tank and carrying away the heat, as it is assumed to have done in the above

Digitized by Google

calculation. The meters also registered rather more water than actually passed through them, and this excess assists in making the above figures too high. The sum of these errors the committee estimated at 4 per cent. of the total quantity of heat carried away by the condensing water. The other two quantities were considered very nearly correct.

Making these deductions, we have the following as the total heat, in British thermal units, which was thrown into the condenser by each boiler:

A	32,751,835.34
B	46,387,827.10
C	23,066,685.39
D	37,228,739.07
E	11,485,777.35

That the figures thus obtained are very accurate is shown by calculating the heat transferred to the condenser by A and B, (both of which superheated their steam,) by basing the calculation on the temperature of the steam in the boiler, as given by the thermometer, the results thus obtained being 32,723,681.76 and 46,483,322.5, respectively.

Dividing these totals by the pounds of combustible consumed by each boiler, we get as the quantity of heat per pound, and as a measure of the relative economic efficiency:

A	10,281.53
B	10,246.92
C	10,143.66
D	10,048.24
E	10,964.94

Determining the weight, in pounds, of water evaporated per square foot of heating-surface per hour, we get as a measure of the steaming capacity:

A	2.65
B	3.59
C	2.83
D	3.10
E	1.92

The quantity of heat per pound of combustible, as above determined, being divided by the latent heat of steam at 212° Fahrenheit, (966°.6,) gives as the equivalent evaporation of water at the pressure of the atmosphere, and with the feed at a temperature of 212° Fahrenheit:

A	10.64
B	10.60
C	10.49
D	10.40
E	11.34

For general purposes, this is the most useful method of comparison for economy.

The above figures afford a means of comparison of the boilers,

Digitized by Google

irrespective of the condition (wet or dry) of the steam furnished by them. All other things being equal, however, the committee considered that boiler to excel which furnished the driest steam; provided that the superheating, if any, did not exceed about 100°.

In this trial the superheating was as follows:

A	16°.08
B	13. 23
C	0.
D	0.
E	0.

136. As the boilers C D E did not superheat, it became an interesting and important problem to determine the quantity of water carried over by each with the steam. This we are able, by the method adopted, to determine with great facility and accuracy.

Each pound of saturated steam transferred to the condensing water the quantity of heat which had been required to raise it from the temperature of the water of condensation to that due to the pressure at which it left the boiler, *plus* the heat required to evaporate it at that temperature. Each pound of water gives up only the quantity of heat required to raise it from the temperature of the water of condensation to that of the steam, with which it is mingled. The total amount of heat is made up of two quantities, therefore, and a very simple algebraic equation may be constructed, which shall express the conditions of the problem:

Let—

H = heat units transferred per pound of steam.
h = heat units transferred per pound of water.
U = total quantity of heat transferred to condenser.
W = total weight of steam and water, or of feed-water.
x = total weight of steam.
$W - x$ = total weight of water primed.

Then—

$$Hx + h(W - x) = U;\ \text{or}\ x = \frac{\frac{U}{h} \quad W}{\frac{H}{h} - 1}$$

Substituting the proper values in this equation, we determine the absolute weights and percentages of steam and water delivered by the several boilers, as follows:

	Weight of steam.	Weight of water.	Percentage of water primed to water evaporated.
A	27, 896.	0.	0.
B	39, 670.	0.	0.
C	19, 782. 94	645. 06	3. 26
D	31, 663. 35	2, 336. 65	6. 9
E	9, 855. 6	296. 9	3.

Digitized by Google

And the amount of water, in pounds, actually evaporated per pound of combustible—

A 8.76
B 8.76
C 8.70
D 8.55
E 9.41

137. Comparing the above results, the committee were enabled to state the following order of capacity and of economy, in the boilers exhibited, and their relative percentage of useful effect, as compared with the economical value of a steam-boiler that should utilize all of the heat contained in the fuel:

	Steaming capacity.	Economy of fuel.	Percentage of economical effect.
A	No. 4	No. 2	0.709
B	1	3	0.707
C	3	4	0.699
D	2	5	0.693
E	5	1	0.756

The results obtained, as above, and other very useful determinations derived from this extremely interesting trial, were given in the table, as a valuable standard set of data with which to compare the results of other trials, and as a useful aid in judging of the accuracy of statements made by boiler-venders in the endeavor to effect sales by presenting extravagant claims of economy in fuel.

As some authorities consider the evaporation of one cubic foot per hour to be the equivalent of one horse-power, column Z was introduced into the above table to give the area of heating-surface required in each boiler, per horse-power, on this basis. A good modern steam-engine ought not to require more than one-half the specified amount.

This class of boilers is thus seen to be very economical. The boiler E should be expected to excel, in consequence of its immense area of heating-surface.

138. THE HOWARD BOILER.—The boiler of Messrs. Howard, as exhibited at Vienna, (Fig. 61,) was of the same class as boiler A above, and with similar proportion should give equally good results. It consisted of 20 tubes, of 9 feet length and 9 inches diameter each, a size about twice as great as those of the boilers just referred to. They were placed in a position slightly inclined from the horizontal, very much as in the boiler known in the United States as the Root boiler. The steam-drum was formed by a larger cylinder placed above the tubes and set in a line at right angles to that of the smaller tubes. A similar but smaller cylinder at the lower part of the back end of the boiler received the feed-water and distributed it to the several sets of tubes. The tubes were lapwelded. Their front ends were plugged with iron screw-caps, and the rear ends, which were slightly raised, were screwed into a set of ver-

Digitized by Google

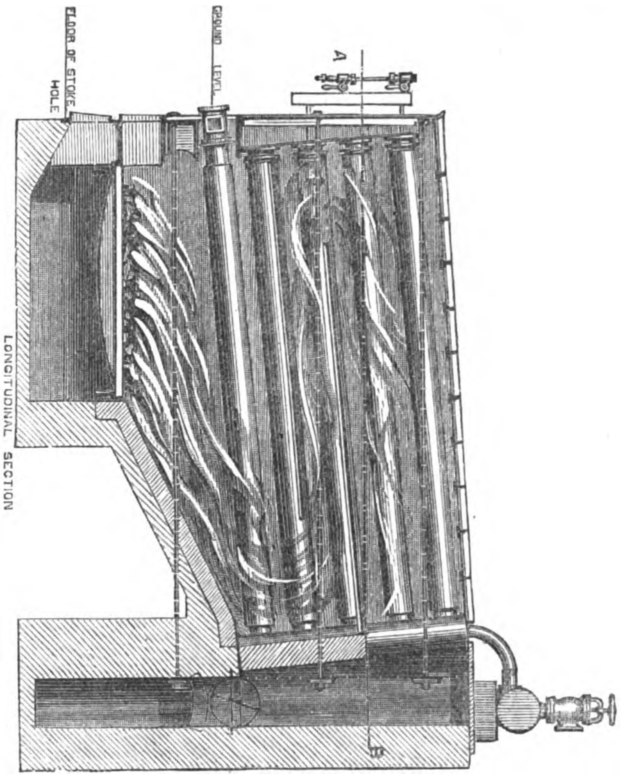


FIG. 61.—The Howard boiler—longitudinal section.

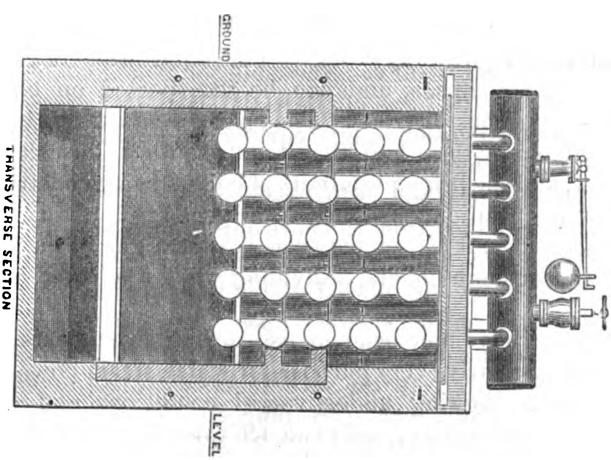


Fig. 61*a*.—The Howard boiler—transverse section.

tical tubes, which formed the only communication between them. The water-line in this boiler crossed the second row of tubes, leaving the top row and a part of that next below as a reservoir for steam and a super-heater, or, more properly, a "steam-drier." The grate is below the tubes and the gas is caused to wind among them, pursuing a rather circuitous course to the chimney by means of baffle-plates laid horizontally between the layers of tubes. Messrs. Howard were said to give about 20 square feet of heating-surface and one-half square foot of grate for each horse-power. As the term "horse-power" applied to a steam-boiler has no definite meaning, it is uncertain whether this is a liberal allowance or not. Assuming the horse-power to represent the evaporation of one cubic foot of water per hour, as in the table above given, this allowance would seem none too great.

The boiler is simple in construction, very strong, and injured tubes can be quite readily replaced. It is said to make steam freely and quite steadily, and is looked upon as a good example of this class of steam-boiler.

139. The Messrs. Howard state that every boiler is tested to three times its working pressure, and that the bursting pressure of the tubes is at least 1,500 pounds per square inch. They claim for it great simplicity of parts, facility of repairs, and durability, as well as safety. They add that in the Howard boiler there are neither seams nor rivets, and no joint is exposed to the direct action of the fire; the tubes are counterparts of each other, and every part is made on the interchangeable principle, and it is more readily accessible, both internally and externally, for thorough inspection and cleaning than almost any other form of boiler; and that, with their boiler, a pressure of 120 to 140 pounds per square inch is more secure than ordinary boilers working at 50 pounds; while experience has shown that, on the great question of economy of fuel, the hopes entertained that the higher pressure of steam would, under proper conditions, lead to an important saving of coal, have been realized. This boiler in many instances, on a large scale, is working with great economy. The boiler can be taken to pieces and carried in ordinary railway-trucks. For exportation it can be packed in a very small compass, and can be transported on bad roads and through mountainous districts. The space occupied by the boiler when fixed is little more than half that required for a Cornish boiler of the same power, and the principle admits of boilers being constructed so as to suit almost any position. The brick-work setting is plain. Where there is only one boiler, it is set between two straight brick walls; where there are two or more boilers, a dividing wall is all that is required in addition.

These boilers have now been in use nearly seven years. They have been applied to nearly every purpose for which steam-power is required, and have been working under varied conditions and management. These facts are offered as good evidence that the principle of the boiler

Digitized by Google

has been appreciated, and as proof that a large amount of practical success has been achieved.

Messrs. J. & F. Howard constructed in January, 1866, for their own works, a boiler of 40 horse-power, upon the tubulous principle. After many experiments with both vertical and horizontal tubes, conducted with care, and after some improvements had been effected, other boilers on the same principle were fixed, replacing Cornish boilers previously in use. The results of their working were so satisfactory that they were led to direct public attention to this form of boiler, and the experience of the last six years has, as they affirm, confirmed their expectations and proved the utility of the boiler for almost every purpose for which steam-power is used. Many engineers and manufacturers, both at home and abroad, have adopted them on a large scale.

140. A somewhat similar steam-boiler, called the "SINCLAIR boiler," exhibited by McNicol, of Glasgow, is made up of smaller tubes, and resembles still more the boiler of the Root Steam-Engine Company.

141. The finest boiler-work in the collection was seen in the boilers of Messrs. ADAMSON & Co. They were similar in size to the Galloway boilers, each 24 feet long and 7 feet in diameter. Two were set and were at work. One is of iron and the other of steel. The shell of each is riveted, but the flues have welded longitudinal seams, and are made by flanged joints, which serve as both expansion-joints and strengthening-rings. The main flue is stayed, like the Galloway boilers, with cross-tubes, which are welded in place instead of being riveted. Specimens of these tubes, welded in a short length of flue, were exhibited separately, and were extraordinarily fine pieces of work. It was in some cases very difficult to find the weld. All of the work on these boilers was most excellent, and is such as is rarely seen, either in Europe or America. Thoroughly good boiler-work is rarer than good machine-work, and deserves especial commendation when found.

142. THE DAVEY-PAXMAN BOILER, (Figs. 63, 64,) exhibited with a portable engine, (Fig. 62,) is worthy of notice. It is a vertical boiler, having a set of bent and tapering tubes in the fire-box, as shown in the sketch. The London Engineer, to which we are referred by the exhibitors, thus describes a trial of this boiler:

"The engine being a 4 horse-power, nominal, it was determined that, to make the test fair, the boiler should be fired as though the engine were working at 6 horse-power, and it was calculated that such an engine would use about 40 pounds of steam per horse-power per hour, therefore that the boiler must be called upon to evaporate 240 pounds of water per hour. The experiment actually lasted 3.5 hours, and the total evaporation was 798 pounds, which, divided by the running time, gives the hourly evaporation as 222.25, very nearly. * * * The boiler evaporated 9.5 pounds of water per one pound of coal, a result which we believe to be almost unprecedented with a vertical boiler of these dimensions. * * *

Digitized by Google

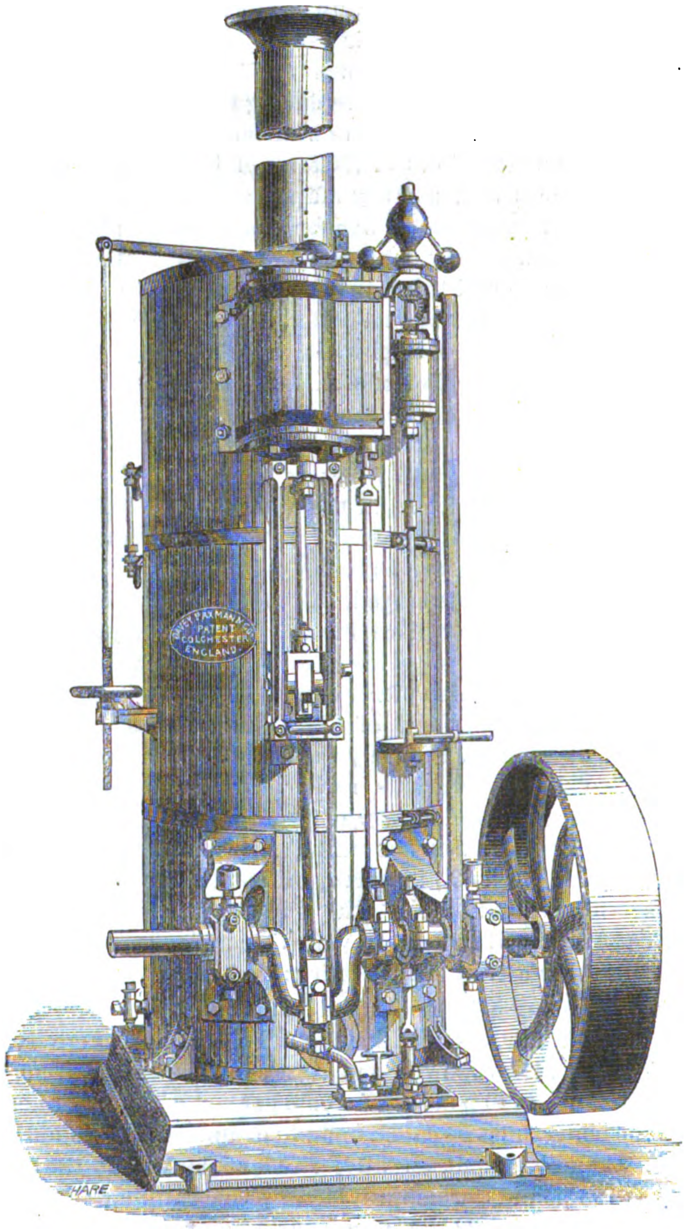


FIG. 62.—The Davey-Paxman engine and boiler.

Digitized by Google

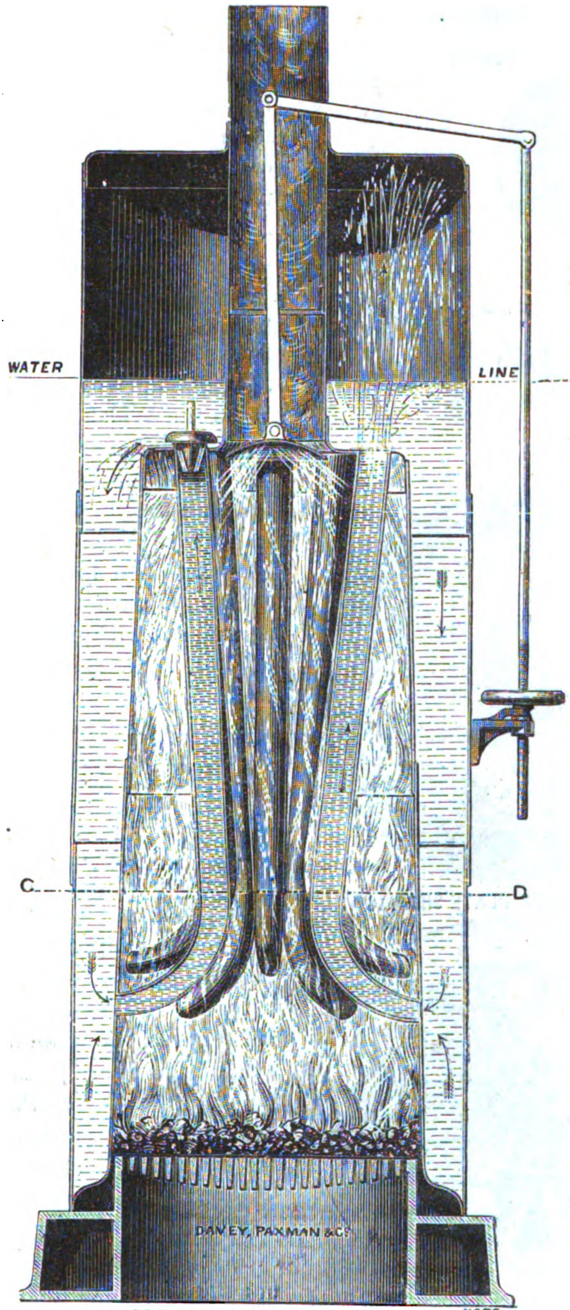


FIG. 63.—Davey-Paxman boiler.

Digitized by Google

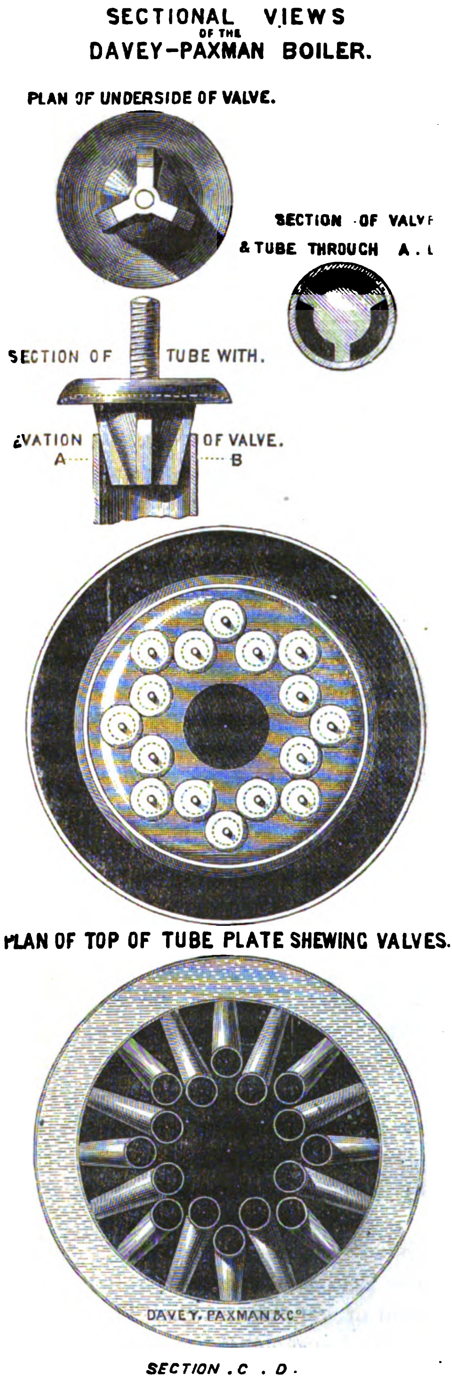


Fig. 64.—Davey-Paxman boiler.

"We confess that this experiment tends to modify the views we have already expressed concerning vertical boilers. We have here a vertical boiler doing better than the Royal Agricultural Society's boiler, generally admitted to be very good. It will be seen from the judges' report that this last evaporated, with excellent Welsh coal, only 9¼ pounds of water per pound of coal, while the Davey-Paxman boiler evaporated 9½ pounds with common coal. With the Welsh coal we have no doubt whatever that it would have evaporated 10 pounds of water, a result which we do not hesitate to say has seldom, if ever, been attained in any experiment conducted with small boilers, and carried out with the care bestowed on the trial, the particulars of which are just given."

London Engineering of October 14, 1870, speaking of the best vertical engines at the trial at the Royal Agricultural Society's show at Oxford, says: "The evaporation of water per square foot of heating-surface was 1.48 pounds, a rate of evaporation less than one-half as great as that obtained with the Davey-Paxman boiler. As regards the amount of water evaporated per pound of fuel burned, the Davey-Paxman and the Royal Agricultural Society's boilers are almost exactly equal. These results show that the Davey-Paxman boiler possesses an evaporative efficiency equalled by but few boilers of any class whatever, and we certainly have no authentic records of any other approaching at all closely to the vertical boiler having given a result duty we have recorded."

Digitized by Google

The Mechanics' Magazine of December 9, 1871, remarks: "It will be seen that the merits of this boiler are due to the bent and taper water-tubes and the deflector inserted in the top of each tube. The water in these tubes, being exposed to the full heat of the furnace, soon acquires a much higher temperature than in the other parts of the boiler, and rises rapidly. The water from all the other parts rushes into the tubes, and thus keeps up a constant and perfect circulation. The taper form at the lower end adds greatly to the velocity and the scouring action that takes place in the tubes and all parts of the boiler. So great is the velocity of the water through these tubes that it rises in jets completely up to the crown-plate. This would of course render the boiler useless, but for an ingenious contrivance invented to keep the water perfectly smooth on the surface. This is the patent deflector, plan, section, and elevation of which are shown in the engraving. These deflectors, placed at the top of each tube, arrest the jets of water, divert them downward with increased velocity, and cause the water to impinge upon the sides of the boiler and tubes. This latter contrivance effectively prevents priming, hitherto a great drawback to the use of vertical boilers. There is a baffle-plate, adjustable by hand on the outside of the boiler, which regulates the heat and throws it back among the water-tubes just where it can be most profitably utilized. These boilers not only contain nearly twice the heating-surface of an ordinary boiler, but this heating-surface is of the most advantageous kind, consisting largely, as it does, of thin tubes exposed to the extreme heat of the furnace. Their thinness has a great advantage. They permit the free transition of heat, and are less affected thereby; and as no incrustation takes place, they will last as long as the shell boiler."

This boiler is not a novel device. The writer had his attention called to this form of tube and fire-box by an American steam fire-engine manufacturer fifteen years ago.

143. The BELLEVILLE BOILER, exhibited in the French section, is another form of sectional boiler, and seems to be the only one which has become well known in that country. It is, with the exception of the Root boiler, the only sectional boiler which has been well tried at sea with fairly satisfactory results, as far as the writer can learn. It has been used to some extent in the French navy. In general construction, this boiler resembles somewhat the Howard boiler. It consists of a mass of water-tubes, connected together at each end by cast-iron boxes, through which circulation may take place. The tubes are 6 or 7 feet long, 2½ to 3 inches in diameter, and usually of about No. 3 gauge.

A Belleville boiler was exhibited in the Belgian section. These boilers seemed well proportioned, well built, and of good material. They have given excellent results where they have had sufficiently prolonged trial to justify a report.

144. Germany was represented in this department by eight exhibits. J. C. C. Meyn's boilers are made with two cylindrical shells, the one

Digitized by Google

superposed on the other. The two exhibited at work had the following dimensions: Diameter of shell, 75 inches in the lower and 52 inches in the upper portion; length of shell, 8½ feet in the lower, 6½ feet in the upper boiler; heating-surface, 431½ square feet; grate area, 15½ square feet. The grate was 6⅜ feet long; the tubes were flattened vertical water-tubes below, 74 in number, with 66 cylindrical tubes above, of 2½ inches diameter. The pressure proposed for these boilers was 60 pounds per square inch. They were well made, machine-riveted, and seemed of good iron. The exhibitors gave as the results of trial of a somewhat smaller boiler, using coal containing about 80 per cent. carbon, and 3½ per cent. hydrogen, and making 15 per cent. ash, an evaporation equivalent to from 7¾ to 9½ pounds from the boiling-point, or an efficiency, estimated as in the trials of the American Institute, already given, of 55 to 65 per cent. The agent of M. Krupp, at Vienna, stated that these boilers were in use at Essen, and were found to perform very satisfactorily.

145. EHRHARDT'S BOILER.—The designer of the so-called "Dingler engine," Herr Ehrhardt, exhibited a steam-boiler, built also by the manufacturers of his engine, the Dingler'sche Maschinen-Fabrik, of Zweibrücken. This, too, is a double construction, two shells connected by vertical cylinders, one at each end; the larger was 3½ feet in diameter, 11½ feet long; the upper and smaller was 3 feet in diameter. The heating-surface was given at about 350 square feet; grate-surface 11½ square feet. A feed-water heater was attached, containing about 65 square feet of surface. A "mud-drum," about 20 inches in diameter and 15 inches deep, is placed beneath the boiler. The inventor presented members of the International Jury with a little pamphlet-circular, in which he explained very fully his ideas with reference to the practice of steam-boiler construction. He is a believer in slow combustion, small boilers, and many of them, where it is necessary to obtain a large quantity of steam. He proposes burning but nine or ten pounds of coal per square foot of grate per hour in stationary boilers, and prefers not to construct boilers having more than from 300 to 400 square feet of heating-surface, considering several small boilers better than the same amount of heating-surface in a less number of larger boilers. He thinks two meters too long for a grate-bar and a meter to be a maximum width. About one square meter is his best area of grate. He prefers to make fire-box boilers.

The boiler exhibited furnished steam to the compound engine already described. (Art. 41.) It was designed for a pressure of 150 pounds per square inch, or ten atmospheres, as pressures are reckoned in Europe.

146. JULIUS BERGMAN, from Haltingen, Westphalia, exhibited two steam-boilers, each composed of an upper and a lower cylindrical shell, with a detached furnace of brick-work. The upper shell was about 4½ feet in diameter, and 5½ feet high, and from its lower head a set of vertical dependent water-tubes were carried down around the lower shell, which was but about 2½ feet in diameter, and was 10 feet high. These

Digitized by Google

tubes, 45 in number, were 3 inches in diameter and 4 feet 8 or 9 inches long. Brick-work surrounded the boiler, and guided the gases *en route* to the chimney. The advantages claimed for the boiler were economy, durability, accessibility for repairs, and great strength of form. Its economy, however, was not established by any results of trial furnished the jury; in durability it might claim advantages were it not for the unfortunate arrangement of setting incident to its form, which certainly did not justify a claim of accessibility. Its strength is simply a question of thickness of iron and diameter of shell. The boiler introduced by Corliss in the United States possesses some features resembling the details of this boiler, but is far superior to the German design in most respects.

147. PAUCKSCH & FREUND are the German patentees of another boiler, of which type two were exhibited in the German section. They were 7½ feet in diameter and 17 feet long. Each contained 90 tubes 3½ inches in diameter, and fastened in place by Berendorf's apparatus. The boiler was externally fired, the furnace having a brick arched top, which separated it from the boiler. There were some peculiarities of construction which should be noted, as interesting and sometimes evidently commendable. Flanging was resorted to wherever other builders usually introduce angle-iron connecting-pieces; the holes in the tube-sheets were tapered, and the tubes were given a similar shape; the tubes were clustered in two sets to enable a workman to enter among them for cleaning. Accessibility was secured inside and out, most fully.

The agents state that, at a trial in Silesia, one of these boilers with a heating-surface of between 1,300 and 1,400 square feet area, a grate-surface of one-fiftieth that extent, an evaporation of over 8 pounds of water per pound of coal was obtained, where a Cornish boiler of usual proportions evaporated but 6 pounds. In another case an evaporation of about 10 pounds was reported. The latter, if correct, is creditable the former is not remarkable.

148. SIGL'S BOILERS.—In the Austrian section, SIGL, of Vienna, exhibited three well-made boilers of the form familiar to all engineers who have studied French designs, as the "Chaudiére à Bouilleurs." They consisted of a large cylindrical shell 4½ feet in diameter and 35 feet long, beneath which were a pair of "bouilleurs," each 2½ feet in diameter and running nearly the whole length of the longer portion, to which they were attached by vertical connecting-pipes 1½ feet in diameter. The heating-surface measured about 700 square feet; the grate-surface, 20 feet. The pressure proposed for them was 5 atmospheres. They were fitted with Zeh's mechanically fired furnaces. In this arrangement th grates are inclined, and the fuel glides down them from a hopper, urged by gravity and aided by a motion given by eccentrics or a shaft driven by the donkey-pump. Some very favorable testimony was given in regard to the action of these grates.

BOLZANO, TEDESCO & Co., of Prague, exhibited a double boiler

Digitized by Google

consisting of a lower multitubular boiler, about 6 feet in diameter and 10½ feet long, containing 85 tubes of 3 inches inside diameter, and of an upper plain cylindrical shell 3 feet in diameter and 15 feet long. The grate was of Bolzano's patent, 27½ square feet area, 6½ feet long, and 4¼ wide.

These boilers were in brick settings, which were somewhat expensive in character, and in arrangement were capable of improvement.

Bolzano's grate and furnace door attracted much attention, and deserve notice from that fact, even if not proven to be of exceptional excellence. The former consists of a double set of grate-bars inclined at an angle of 12° or 15°, and a third set lying beyond and below them some 30 inches below the boiler in a horizontal position. The latter are cast in one piece. In the inclined sets, alternate bars are movable and may be raised a short distance, at the inner ends, by means of a properly adjusted lever, thus breaking up the cinder and cleaning the fire.

The horizontal grate may be drawn out by means of an attached rod whenever it is desired to remove the cinder. The furnace-door carries on its upper part a kind of hopper or trough, into which coal is thrown, and where it remains until required on the grate. The fire being started, and the fuel worked down by shaking with the lever attached to the inclined bars until it reaches the horizontal grate, it is allowed to burn until so far consumed that it becomes necessary to add fresh fuel. The fuel already placed in the hopper is then thrown upon the upper set of inclined grates by tilting the hopper on the horizontal spindle which carries it, and the hopper, falling back into its usual position, is again charged with fresh coal. The fuel is thus worked down until it is finally completely consumed, the cinder forming a deposit in the lower horizontal grate and the ashes falling through the grates into the ash-pit. The cinder is finally removed by withdrawing the flat grate and dumping it into the ash-pit. Thus, it is claimed, a uniform temperature and a clear fire, with rapid and regular combustion, are secured with fuel of very inferior quality. The apparatus is simple, inexpensive, and, with a little experience and care on the part of the attendant, is said to be very efficient.

149. FEED-WATER HEATERS.—The use of feed-water heaters in connection with non-condensing engines is very usual in the United States. It is less frequently seen in Great Britain, and still less often on the continent. They are of many forms, but may be divided into two classes: those in which the steam comes directly into contact with the feed-water, as in the "open heater" generally used in some parts of the country, and those in which the heat is transferred by conduction through metallic walls separating the steam from the feed-water. The former are the least expensive, usually, and are the most efficient as simple transferrers of heat; but they allow all grease and impurities coming over with the steam to be mingled with the feed-water, and they give some trouble frequently, in consequence of the difficulty of

Digitized by Google

Digitized by Google

Digitized by Google

drawing from them and forcing into the boiler the heated water. The feed-pump must be placed so low as to have a sufficient head of water to open its valves; or the temperature of feed must be kept low enough to permit the formation of a partial vacuum and the lifting of the valves by atmospheric pressure; or they must be operated automatically, with a head on the pump sufficient to produce the flow of water through the induction-passages at the speed required for the prompt filling of the pump at each stroke. The closed heater gives less effectyive heating; but it preserves the feed-water pure, and the pump ma draw in the usual manner and force through the heater, thus avoiding the objections to the open heater.

The economy due to the use of a heater for the feed-water is not always fully appreciated either by designers, manufacturers, or users of steam-boilers. It is so easily calculated, however, that no one need remain in doubt as to the advisability of their use in any given case.

If T represents the total heat of steam at the boiler-pressure, estimated from 0°, t=the temperature of the feed-water entering the heater, t'=the temperature of the feed-water leaving the heater and entering the boiler, the economy secured by the use of the heater is—

$$E = \frac{t' - t}{T - t}$$

For example: If the total heat, T, is 1,200° Fahr., and the temperatures of the feed before and after entering the heater t and t' are 50° and 200°, respectively, the gain is—

$$E = \frac{200^\circ - 50^\circ}{1,000^\circ} = 0.15, \text{ or 15 per cent.}$$

This is a fair illustration of the gain to be obtained by the use of a good heater in cases of very common occurrence, and 15 per cent. of the coal-account is usually a very important item.

The BERRYMAN HEATER (Fig. 65) was one of the best, if not the very best, exhibited at Vienna. It is illustrated in the accompanying plate, as attached to the exhaust-pipe of a Corliss engine.

It represents the heater with a portion of the shell broken away, so as to show the position of the steam-pipes within. A cylinder contains the feed-water, E being the induction and F the eduction pipe. The exhaust steam enters one side of the chamber through the pipe A; it is thence conveyed by the tubes to the other side of the chamber, and passes out through the pipe E. D is a blow-off cock, connected with the feed-water cylinder, and two drip-pipes are connected with the exhaust-chamber E. The construction of the water-cylinder, which is made strong enough to withstand the working-pressure of any steam-boiler, will be understood readily from the engraving. The tubes used are seamless brass of the best quality. They do not pass through the sheet, but rest upon a shoulder formed in boring it, and are there ex-

Digitized by Google

panded or set up. A sufficient number of tubes are employed in each heater to obtain an area in the aggregate twenty per cent. greater than that of the exhaust-pipe of the engine for which it is intended.

Among the advantages claimed for this form of heater are the following:

The ability of the steam-tubes to expand and contract with varying temperatures without causing the damaging strains to which heaters that are constructed with tubes fastened in both heads are subject.

The capacity of the heater for containing a large quantity of water, which insures sufficient time for it to become settled and thoroughly heated before being fed to the boiler.

The arrangement of the supply-pipe and feed-pipe, (the first being near the bottom of the heater, but far enough distant from the constantly collecting sediment to create no disturbance in it, and the second near the top,) which results in supplying the boiler with pure water at a maximum heat.

The facilities for cleaning the heater.

The advantage of requiring but one pump, when open heaters require two, which occurs in all places where there is no water-pressure; it avoids the constant trouble and risk of overflowing into the exhaust-pipe to which all open heaters are subjected.

The feed-water reaches the boiler at a temperature nearly equal to 212° Fahr., and this high result is due to the large amount of heating-surface obtained and the constant passage of the exhaust steam through the tubes, which takes place whether the boiler is being fed or not. There is no place in which the water of condensation can lodge in the tubes, and there is therefore no loss of power, which would otherwise be incurred in driving it through them.

The steam and feed-water not coming in contact with each other, the arrangement prevents injury to the boilers. By carrying so large quantity of water heated to nearly a boiling-point, it adds largely to the steam-producing capacity of the boilers. It purifies impure water.

The apparatus is simple, and a vast amount of testimony was presented indicating its efficiency. The advantage claimed of freedom from liability to leakage of joints produced by irregular expansion is a very important one. The makers recommend with propriety the use of a large heater, and its expense is usually fully compensated by its superior efficiency. Surfaces are rarely too greatly extended in either boilers, heaters, superheaters, or surface-condensers. Its greater capacity also permits the settlement of mechanically-suspended impurities and the precipitation of those lime-salts which are thrown out of solution by raising the temperature of the water in which it is dissolved.

The BERRYMAN FEED-PUMP REGULATOR was also exhibited and received very general commendation. Its positive and invariable action and the evidently common-sense principles upon which its design is founded were alike subjects of favorable comment. It is simply a cast

Digitized by Google

iron sphere of moderate capacity, suspended from a steelyard balance. It is connected with the water-space by two pipes of small diameter, one of which terminates just above and the other just below the proposed water-line. When the water falls, steam enters the upper pipe and fills the globe. The weight of the unloaded vessel is insufficient to counterbalance the opposite weight, and it falls, putting on the feed as it descends. When the feed has entered in sufficient quantity to raise the water-level above the mouth of the upper tube, water ascends through that tube into the globe, taking the place of the steam as the latter condenses, and the weight of the now filled vessel causes it to descend, shutting off the supply of feed.

There is evidently some loss by condensation of steam, but that can well be afforded when safety is so well insured. The only risk of failure of the apparatus occurs when the pipes become choked by sediment, or when the friction of the feed-attachments becomes so great as to prevent motion. Either would be a consequence, in exceptional cases, of want of care. The writer has had gauge-cocks attached to the pipes of such arrangements, and they serve the double purpose of furnishing an independent means of determining the position of the water-level and of keeping the pipes clear.

H. N. WATERS'S FEED-WATER HEATER, another American invention, was also exhibited by the inventor, a resident of Hartford, Conn. This consists of a tank, closed and fitted with pipes leading into it the exhaust steam and the feed-water, and affording exit to the latter and to waste steam or water. The steam is guided by a deflecting plate, and the cold water, as it enters, is sprinkled by a rose or a perforated pipe; a very complete intermingling is thus secured. The water stands within at a height which is indicated by a gauge-glass on the exterior of the tank. The eduction-pipe, leading to the pump, is cut short a few inches above the bottom in order that the sediment may not be disturbed by the issuing current. The pump draws air when the water-level falls below this point. This is, as seen, an open heater, and cannot be safely used when the water contains matters in suspension or solution which are likely to injure the boiler. These heaters were both exhibited in the British section.

Several "economizers," as their inventors call them, were also exhibited as original inventions by British exhibitors. The economizers of Green and of Twibil are collections of pipes, which seem to be usually made of cast iron, and look much like what would be called in the United States sectional boilers, which have been inverted in application. They are heated by waste gases from the boiler, and are intended to be used to increase the economy of the less efficient forms of boiler. They are provided with scrapers to remove the deposits of soot from the exterior of the tubes, which are so liable to form wherever bituminous coal is used as fuel. The apparatus of both inventors is well made and well put together, can be conveniently kept clean, and are said by those who have used them to be very valuable accessories.

Digitized by Google

Such apparatus may very frequently be used with great advantage in cases in which the boiler is deficient in heating-surface or in which the surface is badly arranged, wherever, as is not unusual, the gases escape from contact with the boiler at temperatures much above that of the boiler itself, and where, at the same time, the draught is amply sufficient to produce the required rapidity of combustion after the addition of such a retarding influence.

The economy to be derived by its application is calculated as in the case of exhaust feed-heaters. Mr. W. A. Miller and other engineers in the United States have for many years adopted this method of increasing economy. The writer, in the course of professional work, has often found their use to make an utterly inefficient steam-boiler quite as economical as the best known types.

150. INJECTORS.—FRIEDMANN'S INJECTOR was one of the most important attachments to steam-boilers exhibited. It was attached to several locomotives, and is in extensive use all over Europe. The proprietors state that over 12,000 are in use in Europe, and that Messrs. Nathan & Dreyfus, of New York, are now introducing them into the United States. They urge in their favor the advantages that they start punctually, do not reduce the steam-pressure when at work, feed either warm or cold water, and have no movable parts to get out of order.

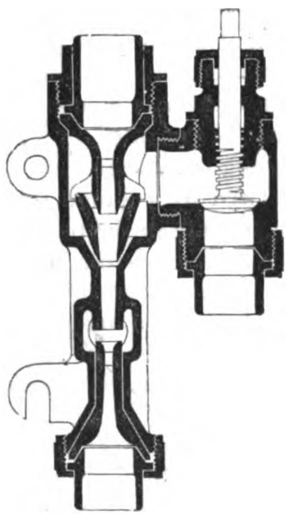
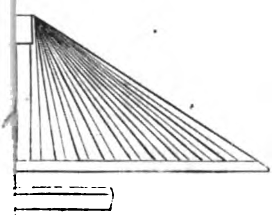


Fig. 67.—Friedmann's non-lifting injector—section.

Fig. 66 represents one of these injectors as attached to a locomotive. A is the starting-valve; B, the steam-pipe; C, the water-supply pipe; D, the water-delivery pipe; E, the overflow pipe; F, the check-valve; G, the water-regulating handle; H, the overflow-valve handle; O, the overflow-valve; W, the water-valve.

One of the peculiarities of this form of injector is the intermediate nozzle, seen in Fig. 67, which permits the water to be supplied to the steam-jet in two annular streams, giving a smoother reciprocal action

Digitized by Google



Digitized by Google

Digitized by Google

of the two currents upon each other. Another merit of the device is that the overflow from the one nozzle flows down outside, already warmed, and forms a part of the supply to the second. Acting upon the cur-

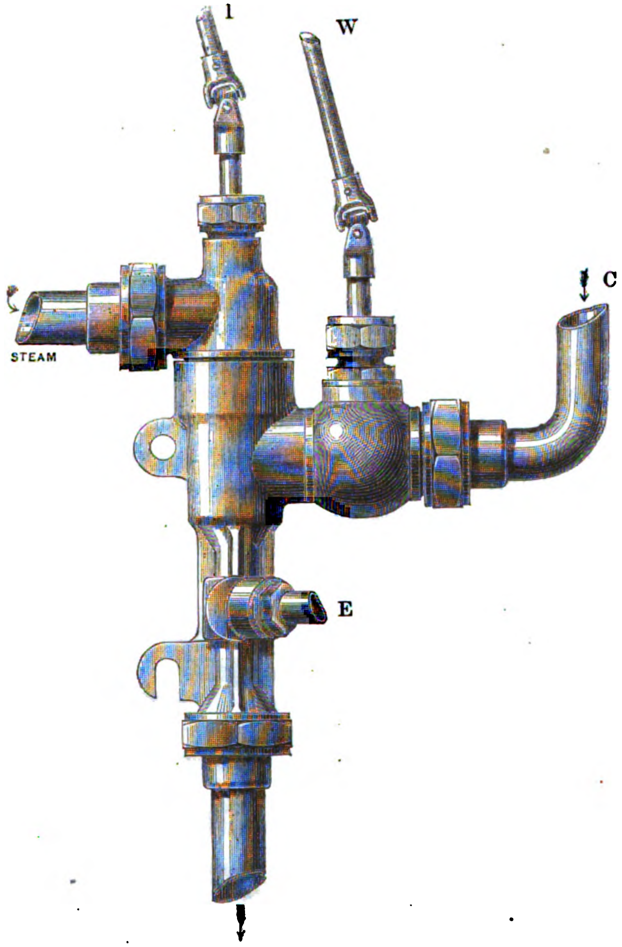


Fig. 69.—Friedmann's lifting injector.

rent of water at two points, the steam imparts its energy very equably, and itself becomes perfectly condensed.

The non-lifting form of injector is placed before the source of supply. It is sometimes used as a heating-cock, simply by closing the overflow and permitting the steam to flow into the tank. In attaching this, as with all injectors, the pipes must be made as short, large, and direct as possible. In working, the overflow-valve is opened by the handle seen in the engraving; the starting-valve is opened, first gradually, then as rapidly as may be; the overflow is then adjusted until no waste of water occurs, and the machine is in full operation.

The lifting injector is shown attached to a locomotive in Fig. 68. It

Digitized by Google

is placed horizontally instead of vertically, and may be used for lifts of 8 or 10 feet. This form has been set up to lift 18 feet vertically. The exterior is shown in Fig. 69, in which I is the steam and W is the water-valve; E, the overflow; C, the water-supply, the upper nozzle the steam and that at the bottom the boiler attachment.

Fig. 70 exhibits the interior of this instrument, in which I is the steam and W the water valve; B the steam, C the water, and D the boiler-pipe nozzles.

Fig. 71 illustrates one of these injectors as proposed for stationary boilers. It stands vertically, and will work up to a temperature of feed-water of 140° Fahr.

Fig. 72 is a style used for portable, stationary, and small marine boilers. It is similar in general internal construction to the others. It is intended to be capable of lifting readily from 8 to 10 feet.

THE GIFFARD INJECTOR, invented a quarter of a century ago by Henri Giffard, of Paris, was the first of this class of instruments. Its remarkable power of taking steam from one point in a steam-boiler and returning it to the boiler again at another point, loaded with many times its weight of water, and without the movement of any one of its own organs, was at first a paradox to many, even well informed, engineers. It is now well understood, and is recognized as one of the most beauti-

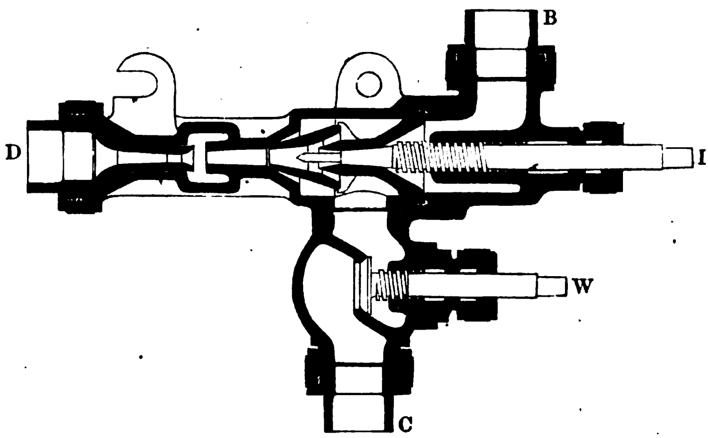


FIG. 70.—Friedmann's lifting injector—section.

ful known adaptations of scientific principles to practical purposes. This principle may be easily understood: If an opening is made into the steam-space of a boiler, the steam will issue with a velocity due the pressure; and, were its motion reversed, it would be just able to return into the boiler. But suppose all the energy of the rapidly-flowing current concentrated upon a fractional portion of the section of the opening, the resisting pressure remaining constant, the stream of fluid would re-enter and would have a surplus of *vis viva* sufficient to carry with it a load of water. This is precisely what occurs in this injector. The great stream of steam issuing from the boiler is condensed in the

Digitized by Google

instrument with a comparatively small mass of water and expends its surplus energy in carrying into the boiler the water by which it was condensed. Steam taken from one boiler has been known thus to carry

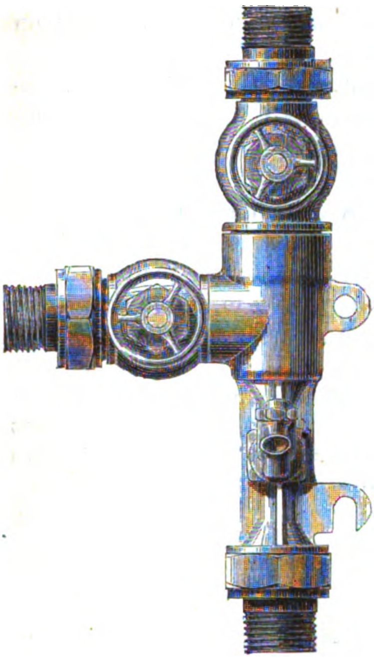


FIG. 71.—Friedmann's injector for stationary boilers.

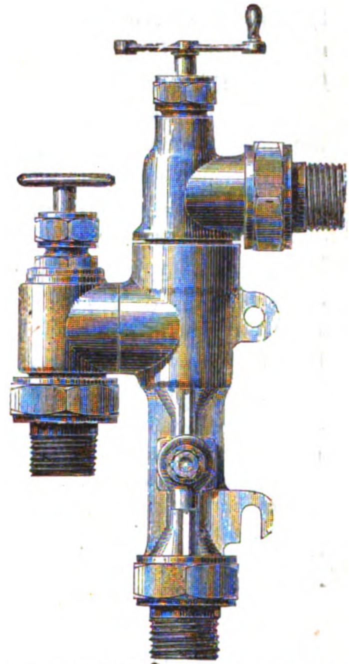


FIG. 72.—Friedmann's injector for portable boilers.

its load of water into another boiler under double pressure. The amount of this surplus is indicated by the fact that a pound of steam at a pressure of 60 pounds per square inch, occupying a space of 5½ cubic feet, condenses into $\frac{1}{350}$th of its volume, forming but 27½ cubic inches of water.

The injector is rarely used to the exclusion of the pump, but in some portions of the United States the Giffard injector, made by Messrs. Sellers & Co., with their beautiful and ingenious improvements, is sometimes found in use alone. Injectors have some decided advantages over pumps. With good water, they are far less liable to get out of repair; they are independent steam-pumps, and can be started whenever there is steam on the boiler; they warm the feed-water; they waste no steam; all that is used in them returns to the boiler again with the feed-water. They are compact, light, handy, and may be placed in any convenient place and in any desired position.

EFFICIENCY OF THE INJECTOR.—Bourne* made a series of experiments to determine the economic efficiency of the injector. As the result of over sixty trials, he remarks: "As, then, these experiments show the quantity of water evaporated from the boiler under

* Steam, Air, and Gas Engines, 4to, London, 1869.

Digitized by Google

a determinate pressure, and also the quantity of water lifted against a determinate pressure, or head, by the volume of steam answering to the quantity of water evaporated, the duty of the instrument, in any experiment, can easily be deduced, and it will be found to be very low."

London Engineering, referring to these experiments,* takes exception to this conclusion, and shows, by a very simple calculation of duty based on Bourne's data, that the injector, although an excellent feed-pump, for the reasons given above, is not adapted to other purposes, where the heat communicated to the current is not subsequently economically applied. In feeding the steam-boiler, it is a matter of little consequence whether the quantity of steam used by the instrument in heating is small or great, as all heat not expended in mechanical work is returned to the boiler. In other cases, all heat not changed into mechanical energy is wasted.

In the examples selected for calculation, the data were the following:

Length of trial, minutes	12	9	16
Steam-pressure, pounds	30	10	30
Resisting pressure, pounds	30	10	90
Water evaporated, gallons	5	6	6
Water drawn from tank, gallons	90	94	96
Water delivered, gallons	100	100	100
Water, initial temperature, degrees Fahr	52	60	52
Water, final temperature, degrees Fahr	117	116	114
Heat consumed, thermal units	50,266	60,245	60,320
Heat transferred to fuel, thermal units	......	52,175	57,776
Heat expended, thermal units	......	8,070	2,554

Giffard presents a brief analysis of the theory of the injector † which may properly complement the general explanation already given.

---

*Engineering, July 30, 1869.

† *Notice théorique de l'injecteur automatique;* also Sonnet's *Dictionnaire des mathématiques appliquées.*

If p = the weight of steam escaping per second, P = the weight of water drawn into the instrument, m and M = their masses; ϖ = the area of cross-section of the orifice; V = the velocity of the steam at the orifice; v = the velocity of the water; a = the least cross-section of the expanding nozzle; θ = the time of mutual reaction. Then the increase of energy becomes

$$E = (m + M)\,\theta\, v - m\theta V.$$

R represent the resultant external force in line of the axis,

$$(m + M)\,\theta\, v - m\,\theta\, V = R\,\theta$$

and—

$$(m + M)\, v - m\, V = R.$$

When $R = o$, $(m + M)\, v - m\, V = o$, and, substituting weight for mass,

$$(P + p)\, v - p\, V = o$$

and—

$$p = (P + p)\frac{v}{V}$$

in which $P + p$ is the weight of water fed into the boiler per second.

Considering density unchanged, and letting S = the weight of steam per cubic meter, N = the pressure in atmospheres,

$$V = \sqrt{\frac{2g\ 10{,}334\ n}{S}}$$

If H = the height due the pressure, and if W = the weight of the water in the instru-

The history of the injector may be stated in few words.

The principle of the *entrainement*, by a current of one fluid issuing under pressure from an orifice, of the fluid surrounding the vessel was known as early as 1870 by Philibert de Lorme. It was applied to the locomotive blast-pipe more than a half century ago. Gurney, forty years ago, used the steam-jet as a ventilator; Nagel & Kaemp, Thomson, and others afterward employed it in engineering practice.

Giffard finally applied it, in combination with the principle already explained by the writer, to the introduction of feed-water into the steam-boiler.

Del Peche, Koch, Schaeffer & Budenburg, and Messrs. Dreyer, Rosenkranz & Droop, all produced modifications of the instrument.

Krauss, Körting, Schau, and Friedmann brought out auxiliary details, or simplified the injector for the purpose of reducing first cost and liability to derangement.

The most beautiful and ingenious modifications, looking to economy of steam and quantity of discharge, were made in the United States.

Messrs. Sellers & Co. secured the right to manufacture, and by careful and intelligent efforts soon increased the delivery to nearly double that given by the instrument of Giffard. They reduced its weight and cost, improved its details, and attained a comparatively high efficiency. They finally introduced their self-adjusting injector, in which the water-supply is regulated automatically by the action of the overflow, its suction increasing the area of the annulus through which the water enters, and its pressure, when the supply is in excess, throwing back the exterior nozzle, which is made movable, and reducing the supply.

The Mack, the Rue, and other forms recently introduced in the United States are Giffard injectors, having fewer moving parts. They are less costly, and less liable to derangement by bad water, but are usually much less readily adapted to a wide range of supply.

ment per cubic meter, usually about 500 kilograms, as the expenditure of energy in propulsion and resistance are the same,

$$V = \sqrt{2 g H}$$

In view of the fact that in actual practice the density is not that assumed, Giffard proposes the formula,

$$V = \sqrt{2 g k \frac{10{,}334\ n}{1{,}000}}$$

in which k is a co-efficient to be determined, and usually varying between 2 and 2.25.

Again—

$$p = a V d$$

and—

$$P + p = a v W$$

In determining temperature of feed, according to Regnault, the loss in passing from the temperature T to the temperature t is

$$H = p\,(606.5 + 0.305^{*}\,T - t) = P\,(t - t')$$

where $t' =$ is the temperature of feed-water before entering.

* Recent experiments seem to indicate this co-efficient to be slightly less than given by Regnault.—R. H. T.

Digitized by Google

Morton, of Glasgow, has applied the injector on a larger scale as an air-pump and condenser for steam-engines. In the United States, Mr. H. W. Bulkley and Mr. Ransome have introduced condensers, in which the stream of condensing water is made by the adoption of a similar law to act the part of the air-pump.

KORTING'S STEAM-JET is illustrated in the accompanying sketch, (Fig. 73,) as it was exhibited in this class of apparatus at Vienna, with a number of modifications adapted to use as "ejector-condensers," injectors, bilge and ashes pumps, and other such applications.

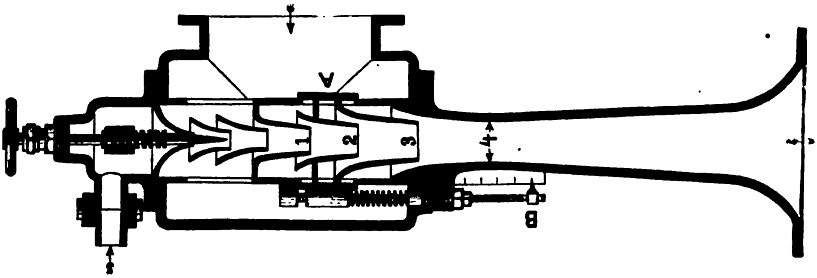


FIG. 73.—E. Korting's steam-jet.

In this instrument* the sliding collar A and cones 1, 2, and 3 are adjustable in relative position by the screw B, which is set at the exact point required for maximum efficiency by means of a scale and pointer. The steam enters at the small nozzle seen at the upper right-hand corner of the figure, and is admitted into the cones by the use of the hand-wheel shown. The air-current enters from below, passes between the cones at A, and emerges as shown by the arrow on the left. The same disposition to which the efficiency of the Friedmann injector is attributed gives effectiveness here. The adjustment of A permits the use of one or more openings between the cones, and determines the capacity of the instrument while working. This form of jet is used as a gas-exhauster.

151. THE PRINCIPLES OF STEAM-BOILER CONSTRUCTION are exceedingly simple, and although attempts are almost daily made to obtain improved results by varying the design and arrangement of heating-surface, the best boilers of nearly all makers of acknowledged standing are practically equal in merit, although of very diverse forms.

In making boilers the effort of the engineer should evidently be:

1st. To secure complete combustion of the fuel without permitting dilution of the products of combustion by excess of air.

2d. To secure as high temperature of furnace as possible.

3d. To so arrange heating-surfaces that, without checking draught, the available heat shall be most completely taken up and utilized.

4th. To make the form of boiler such that it shall be constructed without mechanical difficulty or excessive expense.

* Lately introduced into the United States by Messrs. Schütte & Goehring, of Philadelphia.

Digitized by Google

5th. To give it such form that it shall be durable, under the action of the hot gases and of the corroding elements of the atmosphere.

6th. To make every part accessible for cleaning and repairs.

7th. To make every part as nearly as possible uniform in strength and in liability to loss of strength by wear and tear, so that the boiler when old shall not be rendered useless by local defects.

8th. To adopt a reasonably high "factor of safety" in proportioning parts.

9th. To provide efficient safety-valves, steam-gauges, and other appurtenances.

10th. To secure intelligent and very careful management.

In securing complete combustion; the first of these desiderata, an ample supply of air and its thorough intermixture with the combustible elements of the fuel are essential; for the second, high temperature of furnace, it is necessary that the air-supply shall not be in excess of that absolutely needed to give complete combustion. The efficiency of a furnace is measured by

$$E = \frac{T-T'}{T-t}$$

in which E represents the ratio of heat utilized to the whole calorific value of the fuel; T is the furnace-temperature; T′ the temperature of the chimney, and t that of the external air. Hence the higher the furnace-temperature and the lower that of the chimney, the greater the proportion of available heat.

It is further evident that, however perfect the combustion, no heat can be utilized if either the temperature of chimney approximates to that of the furnace, or if the temperature of the furnace is reduced by dilution approximately to that of the chimney. Concentration of heat in the furnace is secured, in some cases, by special expedients, as by heating the entering air, or as in the Siemens gas-furnace, heating both the combustible gases and the supporter of combustion. Detached fire-brick furnaces have an advantage over the "fire-boxes" of steam-boilers in their higher temperature; surrounding the fire with non-conducting and highly-heated surfaces is an effective method of securing high furnace-temperature.

In arranging heating-surface, the effort should be to impede the draught as little as possible, and so to place them that the circulation of water within the boiler should be free and rapid at every part reached by the hot gases.

The directions of circulation of water on the one side and of gas on the other side the sheet should, whenever possible, be opposite. The cold water should enter where the cooled gases leave, and the steam should be taken off farthest from that point. The temperature of chimney-gases has thus been reduced by actual experiment to less than 300° Fahr., and an efficiency equal to 0.75 to 0.80 the theoretical is attainable.

The extent of heating-surface simply, in all of the best forms of

Digitized by Google

boiler, determines the efficiency, and the disposition of that surface seldom affects it to any great extent. The area of heating-surface may also be varied within very wide limits without greatly modifying efficiency. A ratio of 25 to 1 in flue and 30 to 1 in tubular boilers represents the relative area of heating and grate surfaces in the practice of the best-known builders.

The material of the boiler should be tough and ductile iron, or, better, a soft steel containing only sufficient carbon to insure melting in the crucible or on the hearth of the melting-furnace, and so little that no danger may exist of hardening and cracking under the action of sudden and great changes of temperature.

Where iron is used it is necessary to select a somewhat hard, but homogeneous and tough quality for the fire-box sheets or any part exposed to flames.

The factor of safety is invariably too low in this country, and is never too high in Europe. Foreign builders are more careful in this matter than our makers in the United States. The boiler should be built strong enough to bear a pressure at least six times the proposed working-pressure; as the boiler grows weak with age, it should be occasionally tested to a pressure far above the working-pressure, which latter should be reduced gradually to keep within the bounds of safety. In the United States, the factor of safety is seldom more than four in the new boilers, frequently much less, and even this is reduced practically to one and a third by the operation of our inspection-laws.

Digitized by Google

CHAPTER VII.

AIR AND GAS ENGINES.

STEAM COMPARED WITH GAS AS A MOTOR; COMPARISON OF STEAM AND GAS ENGINES; THE HOT-AIR ENGINE; ITS DISADVANTAGES; ERICSSON'S ENGINE; STIRLING AND CAYLEY'S ENGINES; HENDERSON'S THEORY OF THE AERO-STEAM ENGINE; CALCULATION OF ITS EFFICIENCY; EXAMPLES; LEHMAN'S HOT-AIR ENGINE; THE BRAYTON GAS-ENGINE; TRIAL OF THE BRAYTON ENGINE; RESULTS; DETAILED DESCRIPTION OF THE BRAYTON ENGINE; CONCLUSIONS FROM RESULTS OF TRIAL; ADVANTAGES OF NON-EXPLOSIVE GAS-ENGINES; THE OTTO & LANGEN GAS-ENGINE; TRIAL BY MON. H. TRESCA; RESULTS OF TRIAL; CAUSE OF THE EXCEPTIONAL ECONOMY OBSERVED; RANKINE'S THEORY OF GAS-ENGINES.

152. STEAM COMPARED WITH AIR AS A MOTOR.—Air and gas engines are expected by many engineers to compete, ultimately, with the steam-engine as economical, if not otherwise highly efficient, motors.

The actual standing of the best steam-engine of the present time, as an efficient heat-engine, is really very high. The sources of loss are principally quite apart from the principles of design and construction, and even from the operation of the machine, and it may be readily shown* that, to secure any really important advance toward theoretical efficiency, a radical change of our methods must be adopted, and probably that we must throw aside the heat-engine in all its forms, and substitute for it some other apparatus by which we may utilize some mode of motion and of natural energy other than heat.

The mechanical equivalent of heat is reckoned at 772 foot-pounds per thermal unit, that unit being the quantity of heat necessary to raise one pound of water one degree in temperature.

A pound of pure carbon yields, in burning, 14,500 units of heat, equivalent to $14,500 \times 772 = 11,194,000$ foot-pounds of energy. A pound of good coal containing 91 per cent. carbon, as shown in the report of the committee of the American Institute testing steam-boilers in 1871, produces about 13,200 units of heat, and its mechanical equivalent is $13,200 \times 772 = 10,190,400$ foot-pounds of work.

The very best classes of modern steam-engines very seldom consume less than two pounds of coal per horse-power per hour, and it is a good engine that works regularly on three pounds. A horse-power raises 1,980,000 pounds one foot high per hour, consequently a pound of coal, in our very best engines, develops but $\frac{1980000}{2} = 990,000$ foot-pounds,

* See Scientific American, vol. xxviii; No. 2; p. 16.

Digitized by Google

instead of the 10,190,400 which it would give us were there no loss of power.

The first-class steam-engine, therefore, yields less than 10 per cent. of the work stored up in good fuel, and the average engine probably utilizes less than 5 per cent.

A part of this loss is unavoidable, being due to natural conditions beyond the control of human power, while another portion is, to a considerable extent, controllable by the engineer or by the engine-driver.

Scientific research has shown that the proportion of heat stored up in any fluid, which may be utilized by perfect mechanism, must be represented by a fraction, the numerator of which is the range of temperature of the fluid while doing useful work, and the denominator of which is the temperature of the fluid when entering the machine, measured from the "absolute zero"—the point at which heat-motion is supposed to cease entirely—461°.2 Fahr. below the zero of the common scale.

Thus, steam, at a temperature of 320° Fahr., being taken into a perfect steam-engine, and doing work there until it is thrown into the condenser at 100° Fahr., would yield $\frac{320-100}{320+461}=0.28+$, or rather more than one fourth of the 10,190,400 foot-pounds of work which it should have received from each pound of fuel.

The ratio, $\frac{990{,}000}{2849842}=0.34=\frac{1}{3}$, of the work done by our best class of engines, to this possible performance of a perfect engine using 75 pounds of steam, shows us how much we have to hope for in improving the steam-engine.

The proportion of work that a non-condensing but otherwise perfect engine, using steam of 75 pounds pressure, could utilize would be $\frac{320-212}{320+461}=0.14=\frac{1}{7}$; and, while the perfect condensing-engine would consume two-thirds of a pound of good coal per hour, the perfect non-condensing engine would use $1\frac{1}{3}$ pounds per hour for each horse-power developed, the steam being taken into the engine and exhausted at the temperatures assumed above. Also, were it possible to work steam down to the absolute zero of temperature, the perfect engine would require but 0.19 pound of similar fuel.

It may therefore be stated, with a close approximation to exactness, that of all the heat derived from the fuel about seven-tenths is lost through the existence of natural conditions over which man can probably never expect to obtain control, two-tenths are lost through imperfections in our apparatus, and only one-tenth is utilized in even good engines.

Boiler and engine are intended to be included when writing of the steam-engine above. In this combination, a waste of probably three-tenths at least of the heat derived from the fuel takes place in the boiler and steam-pipes, on the average, in the best of practice, and we are therefore only able to anticipate a possible saving of $0.2\times0.75=0.15$, about one-sixth

Digitized by Google

of the fuel now expended in our best class of engines, by improvements in the machine itself.

The best steam-engine, apart from its boiler, therefore, has 0.85, about five-sixths, of the efficiency of a perfect engine, and the remaining sixth is lost through waste of heat by radiation and conduction externally, by condensation within the cylinder, and by friction and other useless work done within itself. It is to improvement in these points that inventors must turn their attention if they would improve upon the best modern practice by changes in the construction of the steam-engine.

To attain further economy, after having perfected the machine in these particulars, they must contrive to use a fluid which they may work through a wider range of temperature, as has been attempted in air-engines by raising the upper limit of temperature, and in binary vapor engines by reaching toward a lower limit, or by working a fluid from a higher temperature than is now done down to the lowest possible temperature. The upper limit is fixed by the heat-resisting power of our materials of construction, and the lower by the mean temperature of objects on the surface of earth, being much lower at some seasons than at others.

In the boiler the endeavor must be made to take up all the heat of combustion, sending the gases into the chimney at as low a temperature as possible, and securing in the furnace perfect combustion without excess of air-supply.

The best engines still lack 15 per cent. of perfection, and the best boilers, as an average, over 30 per cent.

The hot-air engine seems to be the most promising of known expedients for increasing economy by widening this range of temperature, and among hot-air engines the furnace gas-engine would seem most probably the form of highest efficiency.

153. STEAM AND GAS ENGINES COMPARED.—Yet, for medium and high powers, the steam-engine stands to-day, as it has stood from the time of Watt, without a rival as a prime mover. The high pressure which can be obtained by the evaporation of water without excessively high temperature, the compactness of the machine itself, and incidental advantages, place it beyond comparison in advance of all other heat-engines for powers exceeding, at the highest, two or three horse-power in ordinary cases.

For extremely small powers, however, the necessity of having a skilled attendant makes the steam-engine too expensive where, as with small powers, the cost of attendance becomes a large proportion of the total running expense. The difficulty of finding a proper location for the steam-engine and its boiler; the danger which must always attend, in a greater or less degree, its use; the first cost of so complicated and nice a piece of apparatus; the expense of repairs, and other less apparent objections, seriously interfere with its introduction and general use.

A "domestic motor," as this class of machine here considered is fre-

Digitized by Google

quently called, should, so far as possible, be perfectly safe, healthful, inexpensive in first cost and in maintenance, compact, cleanly, and durable, and should not require specially-trained attendants.

Such a prime mover has not yet been produced; but the hot-air, electric, and gas engines are finding their way into use gradually in some such situations as are here referred to, and are becoming of some importance even as compared with the steam-engine. Some examples of these machines were shown at Vienna, although not representing the best of that practice with which our own mechanics are already familiar.

154. THE HOT-AIR ENGINE has been long known, and many varieties exist. The readiness with which its working-fluid is obtained from the surrounding atmosphere, its efficiency as a heat-engine, its manageableness, and its safety from danger of explosion at high temperatures, have made this a favorite field with inventors. The greatest difficulty met is that of rapidly transferring heat to and from the mass of air employed—a consequence of its nearly perfect non-conduction—and that of using a much larger cylinder with the low pressures at which it is worked than is found necessary where, as in the steam-engine, high pressure is attainable. The theoretic efficiency of this form of heat-engine is very great, in consequence of its wide range of temperature; and it is also practically quite high. A perfect air-engine working between temperatures of 650° and 150° F., would have an efficiency of 0.45 when expanding twice. It would have a mean pressure of 8.33 pounds per square inch, and would require a large volume of working-cylinder—$\frac{27\frac{1}{2}}{S}$ cubic feet per horse-power where $S =$ the number of strokes per minute.

155. THE ERICSSON ENGINE.—The form of air-engine most familiar to American engineers is the Ericsson so-called "caloric" engine, in which the change of temperature occurs at an approximately constant pressure. It consists of a working-cylinder, placed above a furnace, and containing a piston which works within the upper portion. The piston is protected from the direct heat of the furnace by a non-conducting mass suspended from its lower side.

Air is compressed in a compressing-pump, and is forced through a check-valve into a receiver, where it remains under pressure until it passes into the working-cylinder. *En route* to the working-cylinder, it passes through a regenerator—a vessel filled with wire-gauze, or some other metallic porous mass—which has been heated by the exhaustion through it of air which has done duty in the cylinder. Reaching the lower part of the working-cylinder, it is in direct contact with the furnace, and is rapidly heated by convection. Expanding, it forces up the piston, and on the return-stroke is exhausted through the regenerator, where it leaves a portion of its heat to be transferred again to the next entering charge of air.

The air-engines of the steamer Ericsson, by far the largest ever con-

Digitized by Google

structed, were found by Professor Norton to consume 1.87 pounds of coal per horse-power per hour, and gave an efficiency equal to 0.10.

156. STIRLING'S ENGINE.—In another form of engine, invented by Dr. Robert Stirling in 1827, the temperature of air changes under approximately constant volumes, the same mass of air being sent alternately into and out from the heater, its change of pressure producing the movement of the piston in the working-cylinder. Such an engine, working between the limits of temperature already above assumed, gives an efficiency of 0.3, with a mean pressure of $37\frac{3}{4}$ pounds per square inch, consuming about $1\frac{2}{3}$ pounds of coal per horse-power per hour.

157. CAYLEY'S ENGINE.—A later form of air-engine, and one which promises well in the opinion of some able engineers, is the furnace-gas engine, in which the furnace-gases and products of combustion pass into the working-cylinder and are utilized as the working-fluid. The earliest engine of this class was that of Sir George Cayley, invented about 1830. A well-known example of this type is that of the American engineer Stephen Wilcox. The difficulties met with in this engine are the burning-out of the piston and working-cylinder under the intense heat, and the "cutting" of surfaces by the dust carried over in the working-fluid. The former difficulty has been at least partially overcome by the use of a water-jacket. The latter will very possibly be avoided by the use of a combustible which, like the petroleums, contains no gritty constituent.

158. THE AERO-STEAM ENGINE is a modification of the furnace-gas engine, in which the working-fluid is a mixture of the furnace-gases with steam from a steam-boiler within which the fuel is burned; it has recently excited much attention from engineers. This engine was experimentally fitted to the steamer Novelty, in the United States, many years ago, and has since been brought into notice by several inventors, among the latest of whom is Mr. Warsop, a British engineer.

The theory of this engine is similar to that of other air and gas engines in many respects, and has been given by Mr. J. Augustus Henderson, in a graduating thesis at the Stevens Institute of Technology.

His method and results are as follows:

THE THEORY OF AERO-STEAM ENGINES.—The case to be discussed is restricted to that of a high-pressure aero-steam boiler and engine of the following general description:

The boiler would be provided with an inclosed furnace, from which the whole products of combustion under pressure would be injected into the water, and there so lowered in temperature, at the expense of further formation of steam, that when thoroughly mixed with all of the steam formed, a given final temperature of superheating would be produced. The engine would consist essentially of a main working-cylinder using this mixture expansively to atmospheric pressure, an air-compressing pump to supply air to the imprisoned fuel under the boiler-pressure, and of the mechanism by which the two would be connected and the excess of work delivered.

Before making any numerical calculations, the general formula applicable to such an engine and boiler are introduced as embracing the main points of importance or of interest, and as serving for a common basis from which the several examples may be

Digitized by Google

worked out by direct substitution. The principal authority referred to for the constants used in calculation was Professor Rankine, and his nomenclature and fundamental equations were applied when practicable. The majority of the formula, however, and more especially those relating to the determination of the proportion of steam and air by weight, and by volume before mixture, their tension when mixed, and to the determination of the value of the constant γ for the mixture, are here deduced, as no such formula could be found in published works. All of the formulas, other than those whose results are ratios, apply to such quantities as are produced by the entrance of one pound of air through the compressing-pump, this mode of treatment greatly simplifying the relations between them. The general method adopted for obtaining the effective work developed per pound of air admitted, by computing the work of expansion and compression from the theoretic forms of the diagrams, and taking the difference, was found to be the most satisfactory and direct under the circumstances. It should be observed that the word *air*, owing to its shortness, is commonly employed to denote the *products of combustion*, except, of course, in those statements where the use of the more specific term becomes necessary.

Below is given the general notation to be used in the formulas:

Pressures, measured absolutely in pounds per square foot:

P_a = pressure of atmosphere.

p_1 = pressure in boiler and during admission in main cylinder.

p_2 = pressure of exhaust = P_a when back pressure above atmosphere is not considered.

P_a, P_1, &c., the same measured in pounds per square inch, and above the atmosphere, except when otherwise stated.

Temperatures, in degrees Fahrenheit:

t_a = temperature of atmosphere.

t_b = temperature after compression in pump.

t_c = temperature upon leaving the fire.

t_1 = temperature of mixed air and steam.

t_2 = temperature of exhaust.

t_f = temperature at which feed-water is supplied.

τ_a, τ_b, &c., the same as measured from the absolute zero $-461{\cdot}2^\circ$ F.

Weights in pounds per pound of air admitted:

w_c = weight of products of combustion.

w_s = weight of steam formed.

w = weight of mixture of the two.

Volumes in cubic feet per pound of air admitted:

v_a = volume of one pound air when first admitted to compressing-pump.

v_b = volume of the same when compressed.

v_c = volume of products of combustion at temperature of mixture.

v_s = volume of steam at the same temperature.

v_1 = volume of air and steam after mixture.

v_2 = volume of mixture when expanded to atmospheric pressure.

Ratios:

r = ratio of expansion in main cylinder.

r_c = ratio of compression in pump.

r_p = ratio of boiler to atmospheric pressure.

q_w = ratio of weight of steam to products of combustion.

q_v = ratio of volume of steam to products of combustion.

q_h = ratio of heat absorbed by steam to that remaining in air *above heat of compression*,

The quantities usually assumed as *data* are P_a, P_1 and P_2, t_a, t_1 and t_f, from which p_a, p_1, p_2, and r_p, τ_a and τ_1 may be directly found; also H the total heat of combustion in foot-pounds, per pound of fuel, and N the number of pounds of air supplied for the same.

Digitized by Google

The points to be determined are taken up in the order in which they naturally present themselves, beginning with the *heat of compression and ratio of compression in pump.*

Since the air is compressed without gain or loss of heat,

$$\frac{\tau_b}{\tau_a} = \left(\frac{p_1}{p_a}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$$

and

$$\frac{r_a}{r_b} = \left(\frac{p_1}{p_a}\right)^{\frac{1}{\gamma}} = r_p^{\frac{1}{\gamma}}$$

where $\gamma = 1.408$ for air. From these two equations it follows that

$$\tau_b = \tau_a \, r_p^{\frac{\gamma-1}{\gamma}} \quad \text{and} \quad r_c = r_p^{\frac{1}{\gamma}}$$

in which substituting the value of γ, and adapting to the use of logarithms, we get

$$\log \tau_b = \log \tau_a + 0.29 \log r_p \quad \text{.......... (1)}$$

$$\log r_c = 0.71 \log r_p \quad \text{.......... (2)}$$

from which t_b and r_c may be computed.

Initial temperature t_c of gases leaving fire.—In finding this, t_h, the temperature directly added by combustion, is first obtained by the formula

$$t_h = \frac{H}{772\,(1+N) \times 0.238} \quad \text{.......... (3)}$$

the numbers 772 and 0.238, being Joule's equivalent and the specific heat of the products of combustion under constant pressure.

This temperature being added to that of the air leaving the pump, gives

$$t_c = t_b + t_h \quad \text{.......... (4)}$$

Ratio of heat of combustion absorbed in gasifying steam, to that remaining in air, above heat of compression.—On account of the transfer of heat in the boiler taking place at constant pressure, the quantities of heat are proportional to the changes in temperature, as is seen in the equation giving the desired ratio,

$$q_h = \frac{0.238\, w_c\,(t_c - t)}{0.238\, w_c\,(t_1 - t_b)} = \frac{t_c - t_1}{t_1 - t_b} \quad \text{.......... (5)}$$

The percentage of heat entering steam and air might, if necessary, be obtained from the formulas

$$h_s = \frac{100\ q_h}{1 \times q_h} \quad \text{and} \quad h_c = 100 - h_s.$$

Weight of products of combustion per pound of air admitted.

$$w_c = \frac{1+N}{N} \quad \text{.......... (6)}$$

Proportions by weight of steam and air.

Since the steam is to be in such quantity that the heat required to form it in the gaseous state at t_1° from the feed-water shall leave the air at the same temperature, and since the heat lost by the air is wholly taken up by the steam, we must have

$$0.238\, w_c\,(t_c - t_1) = w_s \times h$$

where h is equal to the total heat of gasification per pound of steam for any constant pressure, and has the empirically determined value of

$$1092 + 0.475\,(t_1 - 32) - (t_1 - 32)$$

Digitized by Google

thermal units. By substituting this in the previous equation and reducing, is obtained the following:

$$q = \frac{w_s}{w_c} = \frac{0.238\,(t_c - t_1)}{1124 + 0.475\,(t_1 - 32) - tf} \quad (7)$$

$\therefore$ $$w_s = w \times q_w \quad (8)$$

and $$w_1 = w_c + w_s = w_c\,(1 + q_w) \quad (9)$$

Proportion by volume of steam and air.

For one pound of any gas we must have

$$\frac{p\,v}{\tau} = \frac{p_0\,v_0}{\tau_c} \text{ or } v = \frac{p_0\,v_0}{\tau_0} \times \frac{\tau}{p}$$

in which $\frac{p_0\,v_0}{\tau_0}$ is constant, and has for its value the difference between the dynamical specific heats under constant pressure and under constant volume of the gas considered.

For air, $\frac{p_0\,v_0}{\tau_0}$ is equal to 53.15, and for steam 85.00 foot-pounds.

Since the volume of the products of combustion is known to be almost exactly the same as that of the air supplied, for the same pressure and temperature, in the present case v_c will be the volume of one pound of air at the pressure and temperature of superheating, or

$$v_s = 53.15\,\frac{\tau_1}{p_1} \quad (10)$$

The volume of the steam will be that of a weight, w_s, at the same pressure and temperature, or

$$v_s = 85\,\frac{\tau_1}{p_1} \times w_s \quad (11)$$

From v_s and v_c are directly obtained

$$q_v = \frac{v_s}{v_c} \quad (12)$$

and $$v_1 = v_c + v_s \quad (13)$$

Here, v_s, v and q_v, of course apply only to the volumes before mixture, as after mixture v_s and v_c each equal v_1 and $q_v = 1$. This diffusion of the air and steam to the same volume v_1, is accompanied by a corresponding fall in tension of each, but the sumof the two tensions remains equal to the pressure p_1 before mixture, and neither the resultant pressure, volume, nor temperature is affected.

Determination of the value of γ, proper for mixed air and steam.

The general equation of adiabatic curves for any gas is

$$p = \text{constant} \times v^{-\gamma}$$

where γ is constant, and has for its value the ratio of the specific heat at constant pressure, to that at constant volume, of the gas under consideration.

Denoting by C^p_a and C^v_a, C^p_s and C^v_s, the specific heats at constant pressure and constant volume of air and steam, respectively, we thus have

for air $$\gamma_a = \frac{C^p_a}{C^v_a} = \frac{0.238}{0.169} = 1.408$$

and for steam $$\gamma_s = \frac{C_s}{C^v_s} = \frac{0.480}{0.370} = 1.3$$

very nearly.

Digitized by Google

It should be mentioned that the specific heats of the products of combustion of all ordinary fuels are stated by Rankine not to differ sensibly from those of pure air, and accordingly no distinction is here made.

To find γ_m, the value proper for air and steam mixed in the proportions already found, we may determine the two specific heats C^p_m and C^v_m the mixture, and take their ratio.

As the weights w_s and w_c bear to each other the ratio q_w, and have w_1 for their sum,

$$C^p_m = \frac{(C^p_a + q_w C^p_s)\, w_c}{w_1} \quad \text{and} \quad C^v_m = \frac{(C^v_a + q_w C^v_s)\, w_c}{w_1}.$$

$$\therefore \gamma_m \frac{C^p_m}{C^v_m} = \frac{(C^p_a + q_w C^p_s)\, w_c}{w_1} \times \frac{w_1}{(C^v_a + q_w C^v_s)\, w_c} = \frac{C^p_a + q_w C^p_s}{C^v_a + q_w C^v_s}$$

in which, substituting the values of the several specific heats,

$$\gamma_m = \frac{0.238 + 0.48\, q_w}{1.169 + 0.37\, q_w} \quad \text{.......................} \quad (14)$$

To use γ_m as thus calculated, it is necessary that the mixture be sufficiently superheated above the point of saturation of the steam, to keep the latter in the truly gaseous state, a condition that would probably be realized in most actual examples.

Ratio of expansion in main cylinder and temperature of exhaust.

It is here assumed, owing to the insulation action of the air in mixture, and to the cylinders being properly clothed to prevent conduction and radiation, that no appreciable quantity of heat is lost, and consequently that the curve of expansion will be truly adiabatic, in which case, analogous to that of the compressing-pump,

$$\tau_2 = \tau_1 \left(\frac{p_2}{p_1}\right)^{\frac{\gamma_m - 1}{\gamma_m}} \quad \text{and} \quad r = \left(\frac{p_1}{p_2}\right)^{\frac{1}{\gamma_m}}$$

or taking the atmospheric pressure for p_2, since $\frac{p_2}{p_1}$ reduces to $\frac{p_a}{p_1} = r_p - 1$,

$$\tau_2 = \tau_1\, r_p^{-\frac{\gamma_m - 1}{\gamma_m}}, \quad \text{and} \quad r = r^{\frac{1}{\gamma_m}};$$

from which follow:

$$\log \tau_2 = \log \tau_1 + \frac{\gamma_m - 1}{\gamma} [\text{a. c. } \log r_p] \quad \text{........................} \quad [15]$$

and

$$\log r = \frac{1}{\gamma_m} \log r_p \quad \text{....................................} \quad [16]$$

Volumes of main and pump cylinders per pound of air admitted.

Main cylinder, $$v_2 = r\, v_1 \quad \text{...........................} \quad [17]$$

Pump-cylinder, $$v_a = 53.15 \frac{\tau_a}{p_a} \quad \text{.........................} \quad [18]$$

Ratio in which the space swept by the pump-piston is less than that swept by main piston.

$$q_c = \frac{v_a}{v_2} \quad \text{...} \quad [19]$$

Mean forward absolute pressures on main and pump pistons.

In the main cylinder, where the curve of expansion has for its equation

$$p = \text{constant} \times v^{-\gamma_m}$$

it may be demonstrated by the integral calculus, according to the general method set forth in Rankine, that q_m, the ratio of the mean forward pressure p_m to the initial pressure p_1, is given by the formula—

$$q_m = \frac{p_m}{p_1} = \frac{\gamma_m r^{-1} - r^{-\gamma_m}}{\gamma_m - 1} = \frac{\frac{\gamma_m}{r} - \frac{1}{r^{\gamma}}}{\gamma_m - 1} \quad \text{...................} \quad [20]$$

Digitized by Google

from which

$$p_m = q_m p \quad \text{[21]}$$

For the pump, denoting the ratio by q_n, and the mean pressure by p_n, we have in a similar manner,

$$q_n = \frac{p_n}{p_1} = \frac{\overline{\gamma_a - 1}}{\frac{r_c \quad r_p}{\gamma_a - 1}} \quad \text{[22]}$$

and

$$p_n = q_n p_1 \quad \text{[23]}$$

Gross work in main cylinder.

$$U_m = (p_m - p_a) \times v_2 \quad \text{[24]}$$

Work of resistance of pump.

$$U_n = (p_n - p_a) \times v_a \quad \text{[25]}$$

Effective work developed, per pound of air admitted.

$$U_e = U_m - U_n \quad \text{[26]}$$

Heat of combustion used for the same, in foot-pounds.

$$H_1 = \frac{H}{N} \quad \text{[27]}$$

Heat rejected in exhaust, in foot-pounds.

$$H_2 = H^1 - U_e \quad \text{[28]}$$

Mean effective pressure, or pressure in main cylinder, equivalent to performance of work.

$$P_e = \frac{U_e}{V_2} \quad \text{[29]}$$

When given in pounds per square foot, as directly computed from this formula, P_e further represents the effective energy developed per cubic foot swept through by the main piston.

Pressure equivalent to expenditure of heat.

$$P_h = \frac{H_1}{V_2} \quad (30)$$

Efficiency of fluid.

$$E = \frac{U_e}{H_1} = \frac{P_e}{P_h} \quad (31)$$

This also includes the efficiency of the furnace, which for the given form of boiler is unity, because of there being no waste heat up the chimney.

Weight of fuel used, per effective horse-power per hour.

Since the work performed per pound of fuel is $N \times U_e$, and there are 1,980,000 feet pounds to be performed by the desired weight C of that fuel, it follows that

$$C = \frac{1{,}980{,}000.}{N \times U_e} = \frac{1{,}980{,}000}{E \times H.} \quad (32)$$

The numerical examples, six in number, are given in tabular form and in the order in which they were originally worked out, as being applicable to the plan of aero-steam engine considered, while working under several conditions, relative to the higher limiting pressures and temperatures, and with varying supplies of air, above the amount necessary for complete combustion. These quantities were chosen to fall within the limits of possible practice, and at the same time to give those results most likely to be applied with advantage to this form of engine.

In the first example given, the temperature t_2 of exhaust was chosen at 212° F. to make a more direct comparison with the common high-pressure steam-engine, and the boiler pressure p_1 afterward calculated, but in the other five it was found best to place p_1 among the data instead of t_2, the order of all the determinations remaining as in the general formulas.

The following data are common to all of the examples, and therefore are here introduced, to be referred to when needed.

Digitized by Google

Common data.

$P_a = P_2 = 14.7$ pounds per square inch, or $p_a = p_2 = 2,116.4$ pounds per square foot.

$H = 10,000,000$ foot-pounds, or somewhat less than 13,000 British thermal units, a fair value for good coal, whether bituminous or anthracite.

$t_a = 50°$, being roughly assumed as about the average atmospheric temperature in this climate.

$t_f = 100°$, a value that is supposed to be reached by the use of a feed-water heater attached to the exhaust of the engine.

The least quantity of air practically required for the complete combustion of one pound of average coal or coke was taken at 18 pounds, being about 1.5 times the amount theoretically necéssary to furnish the oxygen for combination.

Following is given the table of examples, arranged as far as possible with reference to compactness. The horizontal row of figures on the top of the table refers to the example, and the vertical one on the left to the general formulas as is there indicated.

The numerical calculations are only carried out so far as to prevent any practically considerable errors from arising. For ratios having values near unity, three places of decimals is considered to be amply sufficient.

The value of q_h in the third and fifth examples is caused to come out negative by the fact of t_b exceeding t_1 in which case it should be defined as the ratio of the combined quantities of heat supplied to the steam, both from the fire and the excess of heat of compression, to this latter excess, lost from the air by its fall in temperature from $t_b°$ to $t_1°$.

Table of numerical calculations on aero-steam engines.

	Number of formula.	Symbol for quantity.	Denomination of quantity.	Number of example.					
				1	2	3	4	5	6
Data		P_1	Above atmosphere, pounds square-inch.	32.63	60.	100.	106.	100.	60.
		t_1	Degrees Fahr	450.	450.	450.	600.	450.	600.
		N	Pounds	19.	18.	18.	18.	54.	54.
Results per pound of air admitted.	1	t_b	Degrees	256.1	357.9	466.4	466.4	466.4	357.9
	2	r_c	Ratio	2.294	3.172	4.301	4.301	4.301	3.172
	3	t_h	Degrees	2864.5	2864.5	2864.5	2864.5	989.6	989.6
	4	t_c	Degrees	3120.6	3222.4	3330.9	3330.9	1456.0	1347.5
	5	q_h	Ratio	13.773	30.102	−175.7	20.440	−61.34	3.088
	6	w_c	Pounds	1.056	1.056	1.056	1.056	1.019	1.019
	7	q_w	Ratio	0.519	0.540	0.561	0.502	0.196	0.137
	8	w_s	Pounds	0.547	0.570	0.592	0.530	0.200	0.140
	9	w_1	Pounds	1.603	1.636	1.648	1.586	1.219	1.159
	10	v_c	Cubic feet	7.106	4.503	2.932	3.418	2.932	5.246
	11	v_s	Cubic feet	6.218	4.104	2.759	2.897	0.957	1.174
	12	q_v	Ratio	0.875	0.911	0.941	0.848	0.326	0.223
	13	v_1	Cubic feet	13.324	8.607	5.691	6.315	3.889	6.420
	14	γ_m	Ratio	1.349	1.348	1.347	1.349	1.375	1.383
	15	τ_2	Degrees	212.0	137.9	75.1	162.1	58.8	215.2
	16	r	Ratio	2.380	3.336	4.593	4.584	4.454	3.239
	17	v_2	Cubic feet	31.71	28.71	26.14	28.95	17.32	20.80
	18	v_a	Cubic feet	12.84	12.84	12.84	12.84	12.84	12.84
	19	q_e	Ratio	0.405	0.447	0.491	0.444	0.741	0.612
	20	q_m	Ratio	0.734	0.596	0.476	0.476	0.482	0.601
	21	p_m	Pounds square foot	5004.9	6410.8	1861.8	7861.8	7960.9	6464.6
	22	q^n	Ratio	0.732	0.606	0.488	0.488	0.488	0.606
	23	q_n	Pounds square foot	4989.3	6518.3	8060.0	8060.0	8060.0	6518.3
	24	U_m	Foot-pounds	91597.	123296.	150179.	166306.	101227.	90429.
	25	U_n	Foot-pounds	36888.	51516.	76310.	76310.	76310.	56516.
	26	U_e	Foot-pounds	54709.	66790.	73869.	89996.	24917.	33913.
	27	H_1	Foot-pounds	555555.	555555.	555555.	555555.	185185.	185185.
	28	H_2	Foot-pounds	500846.	488775.	481686.	465559.	160268.	151272.
	29	P_e	Absolute pres., lbs. sq. ft	1729.2	2326.0	2825.9	3109.1	1438.6	1630.6
	29	P_e	Absolute pres., lbs. sq. in	11.98	16.15	19.63	21.59	9.99	11.33
	30	P_h	Absolute pres., lbs. sq. ft	17520.	19350.	21253.	19192.8	10692.0	8904.4
	31	E	Ratio	0.098	0.120	0.133	0.162	0.135	0.183
	32	C	Pounds	2.011	1.647	1.489	1.222	1.471	1.082

In order to give a clearer idea of the precise mode of obtaining the results given in this table, the calculations in the case of example two are below indicated in full, as they were originally worked out by direct substitution of the data in the formulas.

Digitized by Google

EXAMPLE TWO.

Data.

$P_1 = 60$ pounds, $t_1 = 450°$ and $N = 18$ pounds.

$\therefore p_1 = 144 \times 60 + 2116.4 = 10756.4$ pounds per square foot.

$r\,p = \frac{10756.4}{2116.4} = 5.082$ and $\tau_1 = 450 + 461.2 = 911.2°$

RESULTS.

$\log \tau_b = \log 511.2 + 0.29 \log 5.082$

$\therefore \tau_b = 819.1$ and $t_b = 357.9°$ .... (1)

$\log r_c = 0.71 \log 5.082$

$\therefore r_c = 3.172$ .... (2)

$t^b = \frac{10{,}000{,}000}{772(1+18) \times 0.238} = 2864.5°$ .... (3)

$t^c = 2864.5 + 357.9 = 3222.4°$ .... (4)

$q_b = \frac{3222.4 - 450}{450 - 357.9} = 30.102$ .... (5)

$w_c = \frac{1+18}{18} = 1.056$ pounds .... (6)

$q_w = \frac{0.238\,(3222.4 - 450)}{1124 + 0.475 \times 418 - 100} = 0.540$ .... (7)

$w_s = 0.540 \times 1.056 = 0.570$ pounds .... (8)

$w_1 = 0.570 + 1.056 = 1.626$ pounds .... (9)

$v_a = 53.15\ \frac{911.2}{10756.4} = 4.503$ cubic feet .... (10)

$v_s = 85\ \frac{911.2}{10756.4} \times 0.57 = 4.104$ cubic feet .... (11)

$q_v = \frac{4.104}{4.503} = 0.911$ .... (12)

$v_1 = 4.503 + 4.104 = 8.607$ cubic feet .... (13)

$\gamma_m = \frac{0.238 + 0.48 \times 0.54}{0.169 + 0.37 \times 0.54} = 1.348$ .... (14)

$\frac{1}{\gamma_m} = 0.731$ and $\frac{\gamma_m - 1}{\gamma^m} = 0.258$

$\log \tau_2 = \log 911.2 + 0.258$ (a. c. log. 5.082)

$\therefore \tau_2 = 599.1°$ and $t_2 = 137.9°$ .... (15)

$\log r = 0.741 \log 5.082$

$r = 3.336$ .... (16)

$v_2 = 3.336 \times 8.607 = 28.71$ cubic feet .... (17)

$v_a = 53.15\ \frac{511.2}{2116.4} = 12.84$ cubic feet .... (18)

$q_c = \frac{12.84}{28.71} = 0.447$ .... (19)

$q_m = \frac{\frac{1.348}{3.336} - \frac{1}{5.082}}{0.348} = 0.596$ .... (20)

$p_m = 0.596 \times 10756.4 = 6410.8$ pounds per square foot .... (21)

$q_n = \frac{\frac{1.408}{3.172} - \frac{1}{5.082}}{0.408} = 0.606$ .... (22)

Digitized by Google

$p_n = 0.606 \times 10756.4 = 6518.3$ pounds per square foot .... (23)

$U^m = (6410.8 - 2116.4)\ 28.71 = 123,296$ foot-pounds .... (24)

$U_n = (6518.3 - 2116.4)\ 12.84 = 56,516$ foot-pounds .... (25)

$U_e = 124296 - 56516 = 66,780$ foot-pounds .... (26)

$$H_1 = \frac{10,000,000}{18} = 555,555 \text{ foot-pounds} \quad \ldots\ldots (27)$$

$H_2 = 555,555 - 66,780 = 488,775$ foot-pounds .... (28)

$$P_e = \frac{66,781}{28.71} = 2,326 \text{ pounds per square foot,}$$

or 16.15 pounds per square inch .... (29)

$$P_h = \frac{555,555}{28.71} = 19,350 \text{ pounds per square foot,}$$

or 134.4 pounds per square inch .... (30)

$$E = \frac{66781}{555,555} = 0.120 \quad \ldots\ldots (31)$$

$$C = \frac{1,980,000}{18 \times 66781} = 1.647 \text{ pounds} \quad \ldots\ldots (32)$$

It might be well to give an application of the last set of formulas upon condensation, to illustrate the manner of their use, though the results were not thought of sufficient importance to be tabulated.

$$q_d = \frac{0.540}{0.911} \times \frac{85}{53.15} = 0.98 \quad \ldots\ldots (33)$$

$$p_s = \frac{0.98}{1.98} \times 21164. = 1030.7 \text{ pounds per square foot,}$$

or 7.16 pounds per square inch .... (34)

The required value t_d corresponding to this absolute pressure, was found by reference to tables to be 177.84° Fahrenheit.

The only other example in which these calculations were made was the third, where $q_d = 0.954$, $p_s = 7.17$ pounds per square inch, and $t_d = 178.35°$, the departure from the results of the previous case being but slight.

It should be stated that almost all of the general formulas from which these examples were worked out are also applicable to aero-steam engines using any smaller proportions of air than the whole of the products of combustion; only those relating to the determination of the separate weights of the air and steam would have to be altered.

In addition to the formulas and examples thus far given, several other problems were investigated, whose general conclusions only need be referred to. The most important of them relate—

(1.) To the effect which would be had upon the work and efficiency of an aero-steam engine, were the air and steam conceived to expand in separate cylinders, their weights, initial pressures and temperatures, and final pressures, being the same as in the mixture; and

(2.) To the determination of the size of the lifting air-pump for a condensing-engine.

In regard to the second of these problems, enough has been already said while the practicability of using condensation was being considered.

As the result of the first, it may be stated that in calculations made with the data of several of the previous examples, the work developed by the separate expansion of the weight w_a of air and w_s of steam, from the common initial temperature t_1 and pressure p_1 to the atmospheric pressure p_2 was in every case the same as the work already found for the weight w_1 ($= w_c + w_s$) of the mixture, expanding with the same values of p_1 t_1 and p_2.

The following are the conclusions arrived at concerning the most advantageous use of mixed air and steam in the engine under discussion:

(1.) When t_1 is required to have a moderate value, so that the effects of heat need not be provided for, comparatively high values of P_1 with the least possible supply of air N, are the most advantageous as yielding the highest efficiency consistent with the given temperature, in addition to high mean effective pressures, with moderate size of pump. The case is well illustrated by the third example. When preparations are made for the use of high temperatures, two additional cases arise.

(2.) If at the same time with high efficiency a high mean effective pressure and small pump are desired to be retained, P_1 must remain at a high value and N be kept reduced as far as possible. This case is equivalent to the preceding one with an elevation of t_1, as in example four.

If the very highest efficiency be required at the expense of an increased bulkiness of the engine, P_1 may be reduced and N increased as was done in example six.

159. In order to impart more concise ideas as to the leading dimensions as well as gross consumption of fuel of aero-steam engines of this class, there may be here introduced with propriety a short application of the results of a few of these examples to as many cases of actual engines, while working according to their data and exerting different given amounts of power.

The best examples to illustrate are probably the third, fourth, and sixth, which have just been cited as being typical of the three courses open to advantageous change in the data:

(1.) A large single-cylinder marine engine, to exert 1,000 indicated horse-power, while making 50 revolutions per minute and working according to the data of example three;

(2.) A locomotive with two cylinders indicating a power of 200 horses and making 150 revolutions while fulfilling the conditions of example four; and

(3.) A small single-cylindered stationary engine, of 10 horse-power, running with a speed of 80 revolutions, as illustrative of example six.

The quantities to be determined are V_m and V_n, the respective volumes in cubic feet of the main and pump cylinders when both are double-acting, and C_1 and C_t the consumptions of coal by the engine in pounds per hour and tons per day, respectively.

Denoting by the symbols P and R, the number of horse-powers and rate of revolution per minute of the engine, and referring to the general formulas or examples, for the values of W_e, P_e, v_2, v_a, q_c and C, we may directly see that

$$V_m = \frac{33000\ P}{2R \times U_e} \times v_2 = \frac{33000\ P}{2\ R\ P_e} \text{ cubic feet} \quad \ldots\ldots (a)$$

$$V_n = \frac{33000\ P}{2R \times U_e} \times v_a = q_c V_m \text{ cubic feet} \quad \ldots\ldots (b$$

$$C = C \times P \text{ pounds} \quad \ldots\ldots (c)$$

$$C_t = C \times P \times \frac{24}{2240} = \frac{3 \times C \times P}{280} \text{ tons} \quad \ldots\ldots (p)$$

It should be noticed that the first common factor in the second members of both equations, (a) and (b,) is the number of pounds of air admitted to the engine for each stroke of the piston.

The table given embraces the application of these formulas to the three cases proposed, and includes besides their principal data and direct results of calculation, three additional columns of the equivalent dimensions of the main and pump cylinders, whose diameters d_m and d_n, and common stroke s, are expressed to the nearest inch.

TABLE OF APPLICATIONS OF EXAMPLES.

Case No.	Data of engine.			Data of corres. examp.			Results of prev. calculations.			Final results.						
	P	R	$\frac{s}{d_m}$	P_1	t_1	N	P_e	q_c	C	V_m	V_n	d_m	d_n	s	C_1	C_t
1	1000	50	1	100	450	18	2826	0.491	1.489	116.78	57.22	64	45	64	1489.	15.95
2	200	150	1.5	100	600	18	3109	0.444	1.222	3.538	1.571	17	11	26	244.4	2.62
3	10	80	3	60	600	54	1031	0.612	1.082	1.265	0.774	11	9	22	10.82	0.116

Digitized by Google

Both d_m and S were at once determined from V_m by assuming the ratio $\frac{s}{d_m}$, entered among the data in the table, while d_n was computed from V_n after having found S.

In the second case, that of the locomotive-engine, the calculated volumes and dimensions apply to one only of each of the two equal pairs of main and pump cylinders; the gross consumption of coal is that for the whole engine.

Where either the main cylinder or pump is to be single instead of double acting, in order to perform an equal amount of work at the same rate of revolution of the engine, its volumes obtained from this table must of course be doubled, or, if the ratio of the stroke to the diameter remains as before, these latter linear dimensions must be increased in the proportion of $\sqrt[3]{2}$ (= 1.26 nearly) to 1.

It will be observed by a comparison with the results of actual practice, that, in the aero-steam engines here illustrated, there are to a great extent combined both the economy in fuel of the furnace-gas-air engine and the compactness of the ordinary steam-engine. Boilers for such engines admit of being made much smaller than those required for steam-engines of the same power, not only because of the absence of waste chimney-heat, but also because of the greater facility for imparting heat to the steam by the direct injection of the products of combustion into the water.

The values of the resultant efficiencies of these aero-steam engines that can be practically obtained, will of course be less than those calculated by the formulas of this article, on account of the fact that the latter do not consider the efficiency of the mechanism together with such losses as are caused by external radiation of heat, back pressure, incompetent expansion, &c., but in well-constructed engines these losses may be so far reduced as not to seriously affect the efficiency—a conclusion that receives confirmation by the close approximation of the results of Professor Rankine's formulas on steam and air to the results of actual practice.

The large loss arising from condensation in the cylinders of common steam-engines, which is caused by the readiness with which wet steam imparts its heat to the cylinder-walls, is almost wholly prevented in the aero-steam engine. The prevention of such loss has been practically shown in Mr. Warsop's experiments to constitute one of the great advantages in the use of mixed air and steam. Regarding the condensation that is liable to occur in the latter part of the expansion of the mixture, even when there is no loss of heat whatever by external conduction, it may be further stated that in those cases where this liquefaction takes place at all, because of the initial temperature not being sufficiently high for the ratio of expansion, the liberation of latent heat would theoretically somewhat more than compensate the pressures and volumes of the mixture for the loss in weight of steam, and would thus cause the diagrams as calculated to be really a little smaller than the actual ones. The curve of expansion would be affected to a slight extent before the first actual condensation, as steam departs from the laws of a perfect gas before becoming saturated.

It may, at first sight, appear strange that the resultant efficiency is thus directly increased where this condensation occurs, but when it is remembered that the latter is brought about through an increase of the initial pressure of the mixture as compared with its initial temperature, and that such a change is advantageous to the efficiency, the fact may be fully accounted for.

This theory has been here presented at length, because it includes the theory of every modification of furnace-gas engine in use; and the attention which the subject is now receiving, and may be expected hereafter to receive, from engineers, as one of the most promising fields of exploration and invention, give it an importance to which its partial and restricted application, at the present time, is not at all commensurate.

The Ericsson hot-air engine was brought out by that distinguished engineer more than twenty years ago, and soon became quite well known in England and Germany, as well as in the United States. Wilcox's engine came into the market some ten years afterward. Mr. Shaw introduced his engine and obtained a considerable market for it a little later. This machine was exhibited at Paris in 1867, in successful competition with the Laubereau engine.

160. THE LEHMANN ENGINE.—At the Vienna Exhibition of 1873, this class of motors was represented by that of Lehmann, patented in 1869. In general appearance and the arrangement of its mechanism, it resembles somewhat the Ericsson engine. It has no regenerator. It is, however, a machine of the same class as that of Stirling, already described.

A brick furnace incloses about one-half of a long iron cylinder, the other portion of which is surrounded by a water-jacket. Within this cylinder moves another, which fits it so loosely as to permit air to flow freely past it, as it moves from one end to the other. The outside cylinder is closed at the furnace-end and has fitted at the other end a piston connected with a "vibrating lever" and crank-shaft, somewhat as in the Ericsson engine. The smaller cylinder has both ends closed, and acts simply as a displacing-piston. When the engine is in such a position that the inner cylinder is at the outer end and nearest the working piston, the air contained within the large cylinder is forced to the opposite end, and becomes heated by contact with the surfaces within the furnace. Expanding, it drives the working-piston to the limit of its throw, and at the same time is, by the movement of the displacing cylinder, driven back into the end of the working-cylinder nearest the piston, where the cold water-jacket absorbs its heat, and its contraction permits the piston to return unresisted. The air, flowing from the cold to the hot end of the cylinder, and *vice versa*, thus by transfer of heat expands and contracts, doing its work quite effectively. Regulation, unfortunately, is performed *by a brake*, the worst possible kind of regulation where economy is sought, since it simply converts excess of power into heat, and throws it away uselessly.

It is stated that during two years a hundred and thirty of these engines have been sold in Germany. No evidence was presented indicating its expenditure of fuel, or cost of maintenance or of repairs.

161. GAS-ENGINES, in which combustible gases are fired, and the products of combustion used as the working fluid, properly fall within the last-named class. They differ, usually, merely in the mode of combustion. Gas is introduced into the working-cylinder with the proper proportion of atmospheric air. The mixture being fixed, the resulting explosion develops gas under high pressure, and impels the piston. The working-cylinder and the furnace are, therefore, in this case, identical. The difficulties met in this class of engines are the same as with other furnace-gas engines, except that no trouble arises from the introduction of dust. The cost of gas is usually a more serious objection, and the high tem-

Digitized by Google

perature of the products of combustion gives more serious trouble than in the other form.

Two forms of gas-engine, constructed in Europe, were exhibited at Vienna—the Lenoir and that of Otto & Langen. The former was a French, the latter a German, invention.

The LENOIR GAS-ENGINE was the earliest brought into even limited use. It was patented in 1860, and several hundred have since been constructed. In that exhibited at Vienna, the gas was fired by means of the spark of the Rhumkorff induction-coil or "inductorium." The action of the machine is rendered quite smooth, in spite of the great fluctuation of working-pressure, by the use of a heavy fly-wheel. This engine did very good work, and was used for driving other machinery, apparently very satisfactorily. The general form of the engine was that of the ordinary horizontal direct-acting steam-engine. The cylinder was surrounded by a water-jacket to preserve the interior surface smooth and to prevent destruction of the lubricant. The induction of the mixed gases is produced by the movement of the working-piston, the engine thus acting as a pump during the early part of the stroke. The induction-valve next closes, the spark passes, firing the imprisoned gases, and the piston is impelled by a pressure which is at first very considerable, but which drops rapidly as the products of combustion cool by expansion, and as the steam, which forms a considerable proportion of the mass, condenses by contact with the cold sides of the cylinder.

162. *Defects of explosive gas-engines.*—This wide variation of pressure, and this loss by condensation, make a serious reduction of the efficiency of the gas-engine. In an American gas and air engine invented by Mr. C. P. Leavitt, and as constructed by him for the late W. F. Stearns, the second of these losses is avoided, with probably important economical results, by keeping the interior of the chambers in which expansion occurs at so high a temperature that condensation cannot take place.

The proportion of air and gas used are intended to be 13½ to 1; but it probably varies somewhat.

163. *Trial of the Lenoir engine.*—Referrring to the experiments of M. Tresca on the Lenoir engine, M. Claudel states:

"The velocity of the engine is variable.

"The failure to ignite a single charge will stop it.

"To start it, it is necessary to give it several revolutions by hand.

"Lubricant must be abundant and the amount of oil cannot be estimated at less than 0.5 kilogram (1.1 pound=1¼ pint) per day.

"To obtain the best effect, it is necessary to produce ignition before the complete closing of the valve."

A machine of $0^{m}.24$ (9.5 inches) diameter of cylinder was very nearly one horse-power.

The water circulating through the cylinder-jacket carried away 0.6 of the total heat of combustion.

Digitized by Google

These experiments were made several years ago, since which time, it is to be presumed, some increase of efficiency has been effected.

The HUGON GAS-ENGINE, in which the gases are fired by an ingeniously-arranged gas-jet, and in which the use of a voltaic battery, which is always an inconvenient and unsatisfactory attachment, is avoided, was not exhibited at Vienna.

164. The BRAYTON GAS-ENGINE (Fig. 74) was entered for exhibition in the United States section, but up to the time of the departure of the writer, at the close of the session of the juries, had not appeared. In some respects this is an important improvement upon the preceding forms, and the following description, written by the writer before leaving the United States, and after a brief but careful examination, indicates its construction and peculiarities. It is of interest also as giving an idea of the cost of fuel.

In construction this engine resembles the steam-engine, its cylinder and piston, its valves, and its connections being essentially similar. The principal difference consists in the addition of a compressing-pump and a reservoir for the purpose of compressing, and of retaining, a quantity of combustible gases, mixed with a proper proportion of air for its complete combustion, and at a pressure exceeding that which it is proposed to have exerted in the working-cylinder. The reservoir has precisely the same relation to the engine as has the steam-boiler to the steam-engine.

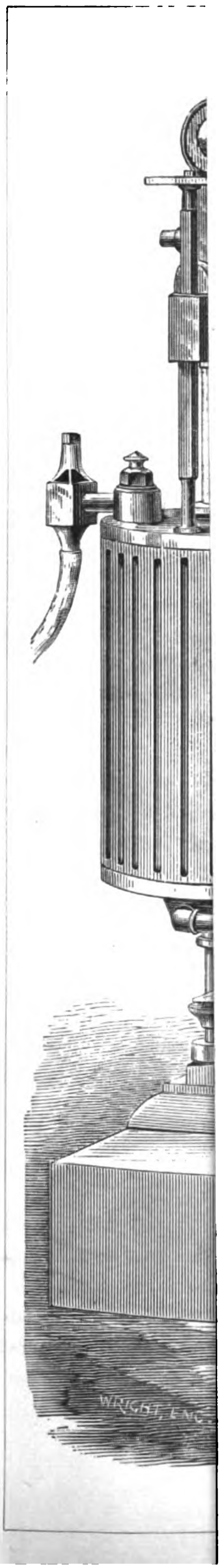
A jacket surrounds the cylinder, through which water is kept constantly circulating. The comparatively low temperature thus secured in the walls of the cylinder allows of the adoption of the same construction of piston, with metallic packing-rings, which has become standard in steam-engines. It also permits the use of the same methods of lubrication.

A diaphragm composed of several layers of wire-gauze, similar to that which gives the Davy safety-lamp its security, is placed at the openings through which the gaseous mixture enters the cylinder. This is of more closely woven material than that used in the safety-lamp, and is in several thicknesses instead of but one. It is probably an effective preventive of ignition of the mass of the gas inclosed in the reservoir. A similar diaphragm, but of much smaller area, allows a very small quantity of gas to stream continually into the cylinder, and as this current is not interrupted by the closing of the induction-valve, its little jet burns constantly and is always ready to ignite an entering charge.

Should a flame, by any accident, reach the reservoir, the expansion of the confined gas in consequence of its explosion simply opens the safety-valve, which is given considerable area, and no harm is done.

Where liquid hydro-carbons are used in place of gaseous fuel the reservoir is filled with air, and carburization takes place between the reservoir and the working-cylinder.

Digitized by Google



Digitized by Google

The induction-valve is protected from the action of the hot gases by the safety-diaphragm, which is interposed between it and the cylinder. The eduction-valve is unprotected, and to avoid serious injury it is made of well-fitted steel.

The operation of the engine is precisely similar, in the action of the engine proper and in the distribution of pressures, to that of the steam-engine. The action of the impelling-fluid is not explosive, as it is in every other form of gas-engine of which I have knowledge. Upon the opening of the induction-valve, the mixed gases enter, steadily burning as they flow into the cylinder, and the pressure, from the commencement of the stroke to the point of cut-off, as is shown by the indicator-diagrams, is as uniform as that observed in any steam-cylinder. The maximum pressure exerted during the experimental trial, and while the engine was doing somewhat more than its full rated power, was about 75 pounds per square inch at the beginning of the stroke, gradually diminishing to 66 pounds at the point of cut-off, where the speed was nearly a maximum, and thence declining, in accordance with the law governing the expansion of gases.

Complete combustion is insured by thorough mixture. This is accomplished by taking the illuminating-gas and the air, in proper proportions, into the compressing-pump together, and the mixture here made becomes more intimate in the reservoir and in its progress toward the point at which it does its work.

165. *Trial of the Brayton engine.*—The results of the trial were thus stated:

The engine rated at 5 horse-power developed, as a maximum, rather more than its rated power. Its mean power during the test, as determined by the dynamometer, was 3.986 horse-power, the indicator showing at that time 8.62 horse-power developed in the cylinder.

The amount of gas consumed averaged 32.06 cubic feet per dynamometrical horse-power per hour.

The excess of indicated over dynamometrical horse-power is to be attributed to the work of driving the compressing-pump and to the friction of the machine. The greater portion of this appears both on the debit and credit sides of the account, since, although expended in the compressing-pump, it is restored again in the driving-cylinder.

166. *Description of figures—Brayton's engine.*—Fig. 74 represents a single-acting engine of this class.

In the sectional view of the working-cylinder, (Fig. 75,) A is the cylinder, surrounded by a water-jacket to prevent overheating, and fitted with a piston. As this is exposed to the direct action of the ignited gases, it is protected by a separate plate of cast-iron, with a layer of asbestos intervening.

The upper end of the cylinder, used as a condensing-pump, is supplied with an induction-valve, *a*, and an eduction-valve, *b*. It is obvious that at each down-stroke of the piston the cylinder will be filled with the

Digitized by Google

gaseous compound through the valve *a*, and upon the up-stroke the same charge will be forced through the valve *b* into a reservoir.

At the bottom of the cylinder, and below the range of the down-stroke of the piston, is formed a chamber, in which are placed two or three dia-

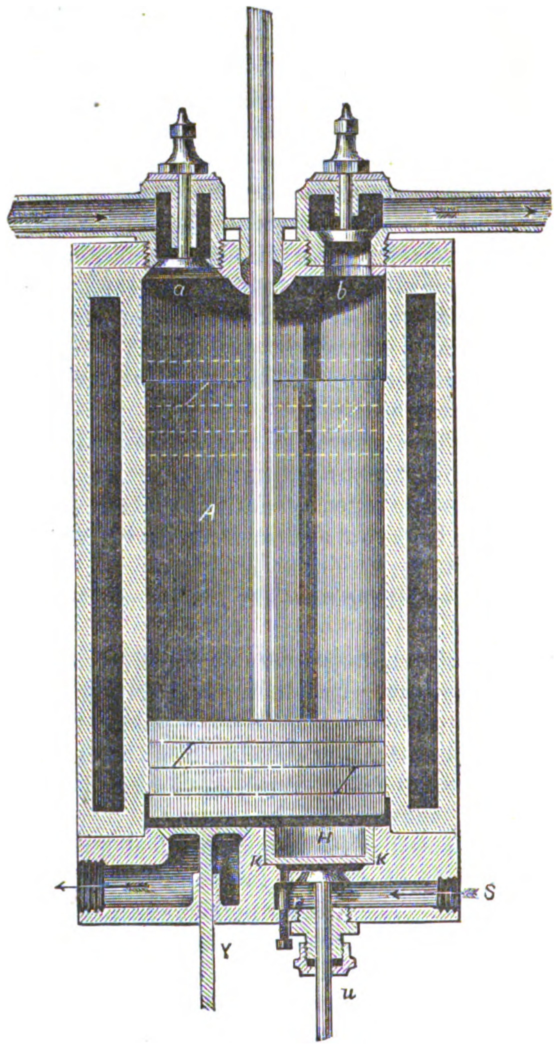


FIG. 75.—Section of Brayton's gas-engine cylinder.

phragms of fine gauze-wire, KK, kept in position by two outside plates which are perforated. This partition is called the intercepter, because it serves to guard the passage leading from the reservoir, and prevents the flame from communicating therewith. The partition is so located that all gases consumed in the engine must pass through it; a screw-valve, when open allows the gaseous compound to flow through the pipe

Digitized by Google

S to the valve-chest, which is similar to that of the steam-engine. The induction-valve *a* is opened for every up-stroke of the piston by means of a cam on a rock-shaft, thus admitting the compressed gases through the intercepter to the cylinder. As previously indicated, the gaseous compound is applied to drive the engine while it is undergoing expansion after ignition. It is, therefore, necessary to provide for maintaining a constant flame upon the surface of the intercepter. For this purpose a small aperture is made through the wall of the valve-seat, the area of which is regulated by means of the pointed screw *r*.

The most economical performance of a gas-engine previously recorded, so far as the writer is aware, is that of the Otto & Langen engine, exhibited at Paris in 1867.* This engine was reported by Prof. Karl Jenny, of Vienna, to have consumed 38.10 cubic feet of gas per horse-power per hour.

The best performance claimed for the Lenoir and Hugon engines is 70 and 74 cubic feet, respectively. M. Tresca reported from the *Conservatorie des Arts et Metiers*, Paris, a consumption of 95.28 cubic feet.

167. *Conclusions from results of trials of the Brayton engine.*—The conclusions based on the results of the trial of the American gas-engine just described were:

1st. That the method of utilizing the power obtainable from the combustion of gas as here adopted is, so far as the writer is aware, quite new, and is most advantageous in its results.

2d. That in this engine combustion is proven by the application of the indicator not to be explosive, but to occur in a progressive manner, developing a very uniform pressure, never equalling that in the reservoir, and varying in the driving-cylinder precisely as does steam-pressure in the cylinder of the steam-engine.

3d. That this method of utilizing gas-power is an exceptionally economical one.

4th. The liability of explosion within the reservoir, as well as of any danger arising from such explosion, should it ever occur, is very carefully provided against.

5th. That the interior surface of the cylinder presented no evidence of overheating, or of injury from any cause, at the termination of the experiments.

6th. The same remark applies to the safety-fuses or diaphragms.

7th. The valve-gear of this engine, with its variable cut-off, is an effective and valuable feature.

8th. That the mechanism and general design of the later style of this engine are excellent.

168. ADVANTAGES OF NON-EXPLOSIVE GAS-ENGINES.—The advantages claimed for this class of engines are well stated in an opinion of the late Charles M. Keller, after an examination of the Brayton gas-engine:

* See the very complete and valuable report of Dr. F. A. P. Barnard on machinery and processes.

Digitized by Google

"This gas-engine will occupy about the same space as a steam-engine of equal power, and hence will save all the space required for the boiler and its connections with the engine, which is much greater than the space occupied by the engine alone. It avoids all the risk attending the use of the steam-engine, such as fires and explosions. * * *

"This engine saves the expense of an engineer, as there is no boiler. * * * And what is of great importance in the question of economy, is the fact that it saves all the time and fuel required in the use of a steam-engine to get up steam."

To the above it may be added that the gas-engine is always ready for work, and stopping and starting, however often, involve no additional expense. They make no ashes, and are therefore cleanly and convenient in use. They are not, in any example yet produced, however, equally economical in cost of fuel with the hot-air or the steam engine, and are, therefore, not likely to be introduced with the rapidity which might be expected, were this point also in their favor. There are very many situations, however, in which they may be used where the use of the other heat-engines is entirely inadmissible, and quite a large market is open to them.

The adoption of the vapor of petroleum and of the naphthas as a combustible, in place of illuminating-gas, which has also been successfuly accomplished by the inventor of this engine, is a very important step in the direction of economy of cost of fuel, and makes it more certain that this or some similar form of gas-engine will find a wide range of application.

169. THE OTTO & LANGEN GAS-ENGINE.—Several of the engines of Otto & Langen above referred to were exhibited at Vienna. In these machines, the explosion of the gaseous mixture *shoots* the heavy piston and its attachments upward. When at the upper limit of its range, it is caught by a pawl, and its weight, while descending, turns the driving-shaft. The charge is fired by the electric spark. The machine is compact and works with great economy, but is rattling and very noisy, and it therefore impresses the professional observer, at least, as being unmechanical in design, and as likely to be expensive in repairs. It is claimed, however, to be a durable, as well as in other respects a satisfactory, motor, and it is stated that a considerable demand has arisen for them.*

170. *Trial of the Otto & Langen engine.*—In a note on the gas-engine of Messrs. Otto & Langen, and an account of experiments made on an engine of this kind, by M. Tresca, member of the council, which was published in the "*Bulletin de la Société d'Encouragement pour l'Industrie Nationale*," he reports in substance as follows:

The gas-engine of MM. Otto & Langen, which was in operation at the Exposition of 1867, was at the time the subject of numerous experiments. The report of those made by us is found in the *Annales du Con-*

*See Verhandlungen des Vereins fur Gewerbfleiss in Preussen, 1868.

Digitized by Google

servatoire, and in the *Memoires* of the Technical Society of Hanover. It there appears that the consumption per horse-power and per hour is reduced by the new arrangement to about 1,250 liters (46 cubic feet) of gas, *i. e.*, one-half less than that of similar engines constructed in France for some time past.

The diagrams taken from these engines exhibit the causes of this important improvement. In the atmospheric engine of MM. Otto & Langen, the stroke of the piston is variable, and this piston ceases to rise at the precise moment when the internal pressure ceases to be greater than the pressure of the atmosphere. In double-acting engines, on the contrary, it happens very frequently that toward the end of the stroke the internal pressure becomes considerably lower by the condensation resulting from the combination of the oxygen and the hydrogen, and that an expenditure of power is required to overcome the difference between the internal and external pressures during the latter portion of the stroke of the piston.

This negative work, which must be subtracted from the work developed during the period of expansion, exercises a visible influence; and the suppression of this cause of enfeebled action must necessarily be synonymous with an increase of useful effect.

An excellent work by M. Schmidt, the engineer of the Parisian company,* exhibits these advantages, and the company has for several years past been building engines of this kind for less than one horse-power.

M. Tresca availed himself of the first opportunity to institute regular tests with the engines purchased by M. Hardy for his shops, and we shall hereafter give the results obtained in this way at the beginning of 1870.

171. The engine experimented with was numbered 69, and its principal dimensions were:

	Meter.
Diameter of piston	0.222
Maximum stroke of piston	1.052
Diameter of water-jacket	0.400
Height of water-jacket	0.965

It is evident that the engine has very large dimensions compared with the work produced; but it economizes, on the other hand, the ordinary space of the boiler, which commonly takes up more room than the moving parts.

The following are the results of the different experiments which he was able to make.

First Experiment, March 27, 1870.—Pressure of gas, 30.5 millimeters.

Duration of experiment, 4 hours.

Number of revolutions during this time, 20,563.

* See Annuaire de la Société des anciens élèves des Écoles d'arts et métiers; 1867; XX^{e} année; p. 231.

Digitized by Google

Length of arm of brake, $0^m.75$.

Weight at extremity of arm, 10 kilograms.

$$T=\frac{628\times 0.75\times 10\times 20563}{4\times 3600\times 75}=0.896 \text{ horse-power.}$$

Consumption of gas during the four hours of the experiment, 4070 liters; or, per hour, 1017.5 liters.

Consumption per horse-power and per hour, $\frac{1017.5}{0.896}=1135.6$ liters, (39.4 cubic feet.)

In the following experiments, we estimate the consumption of gas by the burners at 60 liters per hour, which reduces the consumption corresponding to the work produced to $1^m.175-0^m.060=0^m.0575$.

If we estimate the heat disengaged by the combustion of each cubic meter of gas at 6000 calories, we perceive that total heat of combustion would be $0.9575\times 6000=5745$ calories.

We find in the water surrounding the cylinder of the engine an amount of heat represented by 1048.8 calories per hour. This amount of heat was determined by the rise of temperature of 110 liters of water from 23° to 64°, or 41° in 4 hours 18 minutes; total, $110\times 41=4510$ calories, and in one hour 1048.8 calories. By comparison with the amount expended, we find that the water carries off the fifth part of the amount produced by combustion. In fact, the proportion would be much greater if we took into account the loss occasioned by the cooling of the water-jacket.

Viewed with reference to the mechanical equivalent of heat, the total expenditure of 5745 calories, for a work of 0.896 horse-power, representing during one hour $270,000\times 0.896$, we have for each calorie a useful work of

$$\frac{270000\times 0.896}{5745}=42.1 \text{ kilogram-meters.}$$

To vary the velocity of the engine, a small cock is opened and closed so as to increase or diminish the flow of the gas; the distribution remaining the same, the proportions of the explosive mixture vary according to the opening of the supply-cock.

The engine is regulated so that, at each revolution, a volume of air and of gas is introduced, which is represented by $0.145\times\frac{\pi D^2}{4}=5.61$ liters; where $0^m.145$ is the distance from the bottom of the cylinder to the lower part of the piston at the moment when the supply is cut off.

During the four hours of the experiment, the gas-meter indicated a total consumption of 4070 liters, including that consumed by the burners; there remains, therefore, for the consumption of the machine $4070-(60\times 4)=3830$ liters. The total number of revolutions of the engine being 20,563, the volume of gas used per turn will be $\frac{3830}{20563}=0.1862$ liters. The total volume of the mixture of air and gas being 5.61 liters, it is

Digitized by Google

easy to determine the proportion of air, equivalent to $\frac{5.61}{0.1862} = 30.12$ times the volume of the gas.

172. *Second experiment*, April 3, 1870.—Pressure of gas, 36.00^{mm}.; determination of the work of the engine per minute:

Duration of the experiment, 1 hour, or 3600″.

Number of revolutions during this time, 4,917.

Arm of brake, $0^{m}.75$.

Weight of the extremity of arm, 10 kilograms.

$$T = \frac{6.28 \times 0.75 \times 10 \times 4917}{3600 \times 75} = 0.857 \text{ horse-power.}$$

Consumption in 1 hour, 1085 liters.

Consumption per horse-power and per hour, $\frac{1085}{0.857} = 1266$ liters, (44 cubic feet.)

In this experiment, the amount of gas used by the burners was directly determined during the experiment by employing a special meter. The consumption was as high as 65 liters an hour.

The amount of heat expended is $6000 \times 1.020 = 6120$ calories.

The amount of heat found in the water being 963.7 calories, determined by the rise of temperature of 107 liters of water from 33 to 2 degrees, or 9 degrees in an hour, the ratio of the amount of heat expended to the amount absorbed is $\frac{6120}{963} = 6.3$.

The work of one calorie is represented by the ratio

$$\frac{270000 \times 0.857}{6120} = 37.8.$$

The proportion of air is less than in the first experiment; the volume of gas is 1020 liters, the number of revolutions 4917; which gives $\frac{1020}{4917} = 0.207$ liters of gas per revolution. The volume of air and gas being always 5.61 liters, the proportion of the mixture represented by $\frac{5.61}{0.207} = 27.10$

173. *Third experiment*, April 3, 1870.—Presence of gas, 36.00 millimeters.

Determination of the work of the engine per second:

Duration of the experiment, 30 minutes, or 1,800″.

Number of revolutions during the time, 2,446.

Arm of the brake, $0^{m}.75$.

Weight at the extremity of the lever, 5 kilograms.

$$T = \frac{6.28 \times 0.75 \times 5 \times 2{,}446}{1{,}800 \times 75} = 0.426 \text{ horse-power.}$$

Consumption during 30 minutes, 280 liters, or 560 liters per hour.

Consumption per horse-power and per hour $\frac{560}{0.426} = 1314.5$ liters, ($45\frac{1}{2}$ cubic feet.)

Digitized by Google

In this experiment, the amount of heat expended is $6000 \times 0.506 = 3036$ calories; the heat absorbed by the water being 321 calories per hour, determined by the rise of temperature of 107 liters of water from 47° to 48°.5, or 1°.5 in thirty minutes; the rates of the heat expended to the heat absorbed is $\frac{3036}{321} = 9.4$.

The work of one calorie is represented by $\frac{270000 \times 0.426}{3036} = 37.8$ kilogram-meters.

To determine the proportion of air and gas in the explosive mixture, we have the following elements: 253 liters of gas for 2,446 revolutions of the engine, or $\frac{253}{2446} = 0.103$ liter of gas per revolution. Since the total volume of the mixture is always 5.61 liters, the proportion of the mixture will be represented by the ratio of $\frac{5.61}{0.103} = 54.46$.

174. *Fourth experiment*, April 3, 1870.

Determination of the work of the engine per second:

Duration of the experiment, 30 minutes, or 1,800″.

Number of revolutions during this time, 2,399.

Arm of the brake, $0^{m}.75$.

Weight placed at the extremity of the arm, 5 kilograms.

$$T = \frac{6.28 \times 0.75 \times 5 \times 2399}{1800 \times 75} = 0.418 \text{ horse-power.}$$

Consumption during 30 minutes, 280 liters, or 560 liters per hour.

Consumption per horse-power and per hour $\frac{560}{0.418} = 1339.7$ liters, (46 cubic feet.)

Heat expended, $6000 \times 0.5088 = 3052.8$ calories.

The amount of heat taken up by the water was not determined.

The work of one calorie is represented by—

$$\frac{270000 \times 0.418}{3052.8} = 36.96 \text{ kilogram-meters.}$$

The proportion of air and of gas in the explosive mixture is determined by the following elements: 280 liters of gas for 2,399 revolutions of the engine, or $\frac{280}{2399} = 0.116$ liter of gas per revolution. The proportion of the mixture is exhibited by the ratio $\frac{5.61}{0.116} = 48.36$."

175. *Results of trial of the Otto & Langen gas-engine.*—We will collect these results in the following table:

Digitized by Google

General table of results.

Dates of the experiments.	Numbers of the experiments.	Duration of experiments.	Velocity of the machine per minute.	Work developed.	Consumption per horse-power and per hour.	Ratio of the heat developed to the heat lost.	Work produced per calorie expended.	Proportion of gas in 100 volumes of explosive mixture.
		h. m.	*Revolutions.*	*Horse-power.*	*Gallons.*			
March 27, 1870	1	4 00	85.67	0.896	249.945	5.4	42.1	3.31
April 3, 1870	2	1 00	81.95	0,857	278.646	6.3	37.8	3.68
April 3, 1870	3	30	81.53	0.426	289.321	9.4	37.8	1.83
April 3, 1870	4	30	79.96	0.418	294.867		36.96	2.06
Mean	....	....	....	....	278.184	....	....	....
EXPERIMENTS OF SHORT DURATION MADE LATER BY M. HARDY.								
April —, 1870	1	15	76.6	0.80	286.120	....	....	....
April —, 1870	2	15	58.7	0.74	226.042	....	....	....
April —, 1870	3	15	65.9	0.69	255.095	....	....	....

NOTE.—The kilogram = 2.205 pounds avoirdupois; the meter = 3.281 feet = 39.372 inches; the liter = 61.0165 cubic inches = .0353 cubic feet = .264 gals. = 1.05 qts.; the calorie is the quantity of heat required to raise one kilogram of water one centigrade degree in temperature; the horse-power = 75 kilogram-meters per second, or 542½ foot-pounds, equivalent to 32,549 foot-pounds per minute.—R.H.P.

"It results from this table that the engine, No. 69, has never developed one horse-power; that the consumption of gas has never reached 1,350 liters per horse-power and per hour,* even when the proportion of gas in the explosive mixture was limited to 2 per cent. of the total volume; finally, that the utilization is still greater for a lower velocity, which would lead to the conclusion that the most favorable conditions correspond to 60 revolutions per minute.

Since the engine was put up, it has always worked well, and we may consider the reduction of the consumption of gas in atmospheric engines to one-half of what it formerly was, as a fact definitely accomplished by the invention of Otto & Langen. Many of the lesser industries may henceforward avail themselves economically and satisfactorily of these engines to within the limit of ¾ horse power, especially if the loss of water can be diminished by a well-conducted circulation, as indeed everything leads us to expect that it can. It would be very desirable if the noise made by the engine at every stroke could be lessened.

The above records of the experiments of M. Tresca are the best which have come into the hands of the writer, and the conclusions given are entitled to great weight as the opinions of one of the leading European authorities.

176. *Source of the economy of the Otto & Langen engine.*—The exceptional economy of fuel claimed, with probable justice, for this machine is, in the opinion of the writer, its only special recommendation. This

* Equivalent to 47.655 cubic feet per horse-power per hour.—R. H. T.

Digitized by Google

is probably due principally to the extreme rapidity with which the piston is projected upward at each explosion of gas, the work of expansion being thus utilized before sufficient time has elapsed for any serious amount of condensation to occur by contact with cold surfaces, or for any considerable cooling of the mass of the permanently gaseous products of combustion. High piston-speed is evidently a condition of economy with the gas-engine, as well as with the steam-engine, or wherever the expanding fluid is inclosed within a comparatively cool chamber or within one having walls of a material which is a good conductor of heat. Avoiding this loss by condensation within the working-cylinder, the efficiency of the gas-engine will be proportionably increased above 0.4 of that due the total heat of combustion.

177. Rankine on gas-engines.—In referring to gas-engines, Rankine gives the following as the theoretical treatment: Where p_0 = atmospheric pressure, p_1 = pressure above vacuum, immediately after explosion, p_2 = the final pressure measured from the same point, p_e = mean pressure effective, r = the ratio of explosion, H = the available heat of explosion per cubic foot of the explosive mixture, W = the indicated work per cubic foot, and W_1 = the work at maximum efficiency.

Then if $p_1 = 5$ atmospheres = 10,580 pounds per foot, $H_1 = 2.5\,(p_1 - p_0)$ = 21,160 = about $\frac{3}{8}$ *total heat* of explosion, $p_2 = p_1\, r^{\frac{7}{8}}$, nearly.

$$W = 2.5\,(p_1 - p_2) - 3.5\,(r - 1)\,p_2 + (r - 1)\,(p_2 - p_0)$$

$$p_e = \frac{W}{r}$$

$$W_1 = 2.5\,(p_1 - p_0) - 3.5\,(r - 1)\,p_0.$$

The theory of the gas-engine is as simple as that of any other heat-engine; but it is evident that the determination of constants and the collection of data are exceptionally difficult.

Digitized by Google

CHAPTER VIII.

HYDRAULIC MOTORS.

WATER-POWER AND STEAM-POWER COMPARED; CHARACTERISTICS OF HYDRAULIC MOTORS; THE TURBINE WATER-WHEEL; EFFICIENCY; COST; THE CAPRON WATER-WHEEL; GWYNNE & CO.'S GIRARD TURBINE; RIETER & CO.'S JONVAL WHEELS; ROY & CO.'S WHEELS WITH FREE-DISCHARGE; COLLADON'S "FLOATING WHEEL;" STRAUB'S VERTICAL WHEELS; NAGEL & KAEMP'S FOURNEYRON "PARTIAL TURBINES;" THEIR ARRANGEMENT; ESTIMATES OF THEIR EFFICIENCY AND POWER; THIME'S FOURNEYRON-JONVAL WHEEL; PRINCIPLES OF CONSTRUCTION OF WATER-WHEELS.

178. WATER AND STEAM-POWER COMPARED.—The hydraulic motors form a class of prime movers which had once far greater range of application than since they have been so extensively superseded by steam-engines. They still remain, however, second only in importance, as a class, to the heat engines.

Formerly, when steam-engines of even the best construction consumed ten pounds of coal or more per horse-power per hour, when the cost of manufacture was vastly greater than to-day, and when transportation and repairs were matters of vastly greater expense than now, water-power was so much less expensive that the location of mills and manufactories was determined by the availability of mill-privileges, rather than by proximity either to the source of supplies or to the market.

This is now all changed; steam-engines of the best construction, and of moderate power, may be obtained with a guarantee of an expenditure of not exceeding 2½ pounds of coal per horse-power per hour, and cost of maintenance has become comparatively slight. The usual dominant consideration in locating any manufacturing establishment is, consequently, proximity to the market and convenience of transportation.*

* The cost of the water-power equipment at Lowell was, for canals and dams, $100, and for wheels, &c., another $100, per horse-power. But this, as a first experiment, was more costly than a similar equipment need be. At Saco the expense incurred was $175 per horse-power; but at a later period, for turbines with high heads, the expense would be less. A construction and equipment, solidly carried out, with the latest improvement in wheels, would not cost over $200 per horse-power, and would, under favorable circumstances, cost less. An estimate at Penobscot was for $112.50 per horse-power. If the construction be with wooden dams, and the equipment with lower-grade wheels, then the cost would be about $50 per horse-power; and although the construction would be less permanent than the more solid, it would outlast any steam-apparatus. On the other hand, Fall River estimates of steam-equipment, exclusive of foundations and engine-houses, run from $100 to $115 per horse-power. A Boston authority gives $115 per horse-power for nominal 300 horse-power and upward, inclusive of

Digitized by Google

It thus happens that now only such privileges are sought along the banks of streams as fulfil this primary requisite, and large establishments are erected where, a few years ago, sharp competition by water-supplied localities forbade apparently a hope of success. It is this change which has built up such a wonderful cluster of great mills at Fall River, Mass., in spite of the rivalry of their long-established and well-known competitors along the Blackstone and Merrimac Rivers.

179. HYDRAULIC MOTORS.—It has by no means followed, as a consequence of the improvement of the steam-engine, that the water-wheel has been driven out of use. On the contrary, the latter has been vastly improved, especially in the United States, where the opening of the immense fields of the West and the growth of manufactures have caused the utilization of thousands of the best-located mill-sites along the many rivers and streams which intersect that part of our country. To supply that market, hydraulic motors have been demanded of which the requisites were primarily cheapness of first cost and repairs, and secondly, economy in consumption of water. But the second quality is, to a certain degree, associated with the first, since, where a given amount of water is available under a fixed head, a smaller and, other things being equal, a cheaper wheel can be put in to utilize that fall where great economy is secured than where the wheel chosen has a low efficiency. In the United States, where capital is far less concentrated than in Europe, and where it is worth something more than 7 per cent., these considerations have greater weight than there, where manufacturers are more frequently wealthy, and where the rate of interest on capital is but little more than one-half as great, while the fuel for steam-engines is more expensive also, and water-power less available, than in the United States.

The efforts of American inventors and of manufacturers have been long and earnestly directed to the cheapening of this class of motors, as well as to the increase of their efficiency, and their success has been most encouraging.

180. THE TURBINE WATER-WHEEL.—The most effective form of hydraulic motor for moderately high falls was formerly considered to be the overshot water-wheel; but recently, the turbine has been made to yield equally high efficiency, and its far lower cost, its higher speed, its freedom from difficulty arising from the presence of ice or of back-water, and its other advantages, have made it the only class now generally used. All of the three classes of turbine wheels, the outward, the inward, and the parallel flow, are constructed by builders of reputation, and give good results.

---

foundations and masonry. Similarly a Portland authority places it at $100 per horse-power. The actual cost of steam-equipment in the water-works of various cities of the United States varies from $150 to $300 per horse-power.

As to the cost of work done, it appears that in Philadelphia in 1867 the cost of raising water by water-power was only $2\frac{1}{4}$ cents per 1,000,000 gallon-feet; whereas the cost by steam-power was in four cities $8\frac{3}{10}$, $11\frac{1}{10}$, $19\frac{1}{10}$, and $29\frac{2}{10}$ cents, with coal at $5.50 per ton.—*The Water Power of Maine.*

Digitized by Google

181. *Efficiency and cost of turbines.*—The average performance of a well-designed and well-built wheel gives not far from 75 per cent. of theoretical power of the fall. This figure is, however, often exceeded. Thirty years ago, Mr. Uriah A. Boyden designed Fourneyron wheels, which gave 78 per cent., and in 1846 he was paid for 88 per cent. on a contract with the Appleton Company of Lowell, Mass.

Turbine wheels, to secure such very high efficiency, must be finished; as well as designed and constructed, with exceedingly great care. Cheap wheels are, however, made regularly for the market by builders in the United States, which, when set at work under favorable conditions, will yield a percentage quite up to the first figure given.

As an illustration, one of our manufacturing firms makes a wheel about 6 feet in diameter which sells for less than $1,800. Under a 9-foot-head, it is rated at over 110 horse-power, at about 55 revolutions per minute, and its builders present evidence that, driving a saw-mill, 60,000 feet of white-pine logs have been turned out in twelve hours, and an average made of 35,000 in eleven hours.

Another builder makes a 48-inch wheel for $550, and rates it, with probable correctness, at nearly 45 horse-power under 10 feet head and 80 revolutions, and at 80 horse-power at 20 feet head and 115 revolutions.

These wheels are made up in lots for the market, not singly and to order, as is done in other countries, and this fact of the adoption of what is known as the "American system" of manufacturing has an important influence in reducing cost.

The efficiency of those wheels at "part-gate" is very greatly affected by the method of regulation. In some cases the speed-governor is so attached as to adjust a set of slide-valves in the passages between guide-blades. In other cases, the blades themselves turn on axes near the inner ends, and in the standard Fourneyron turbine the gate usually consists of a drum between the wheel and the casing which is hoisted or lowered to increase or decrease the speed of the wheel. Rankine states the loss of efficiency for average practice as follows:

Ratio of actual to full gate........................ $\frac{1}{5}$, $\frac{2}{5}$, $\frac{1}{2}$.
Ratio of efficiency to maximum .... $\frac{1}{2}$, $\frac{2}{3}$, $\frac{5}{6}$.

The loss of efficiency will vary very greatly with the character of the regulating-apparatus. In some cases the loss is slight, while in others it is very great at the same degree of opening. A very large number of regulating-devices and forms of gate have been patented in the United States. These losses are least where the flow is adjusted by varying the size of the openings, or by changing properly the direction of the guide-blades, and they are greatest where the variations of velocity of the stream are greatest, or where sudden contractions of the channel are permitted. It is in this direction that some of the best work in the improvement of the turbine has been done.

182. THE CAPRON TURBINE.—The American section contained but one wheel of this class, a plain, well-finished turbine, exhibited by the Capron

Digitized by Google

Manufacturing Company, of Hudson, N. Y. It received some attention as illustrating the fact that builders in the United States were engaged in this class of work. It is unfortunate that so large an industry was so poorly represented in number and variety. The following improvements constitute the main features of this wheel: the buckets are detachable, being made with a V-shaped flange or bead upon their upper and lower edges, which fit into corresponding grooves on the upper and lower disks of the wheel. By this arrangement two important advantages are attained. The buckets may be polished before being inserted in the wheel, thus securing a considerable reduction in friction and a corresponding economy in power; and if one or more of the buckets should accidentally become broken, it may be replaced with little delay, and without rendering any of the other buckets or either of the disks useless. In many other wheels the breakage of a bucket makes it necessary to put in a new wheel or a section of a new wheel, occasioning long and expensive stoppages while the repairs are being made. The top of the mouth of the scroll is detachable, giving easy access to the wheel and scroll for removing obstructions that may get into the wheel; this also makes it possible to fit in a new gate, or to refit the old one, without removing the wheel from the scroll or detaching the scroll from the water-box.

183. GWYNNE & CO'S. GIRARD TURBINE.—The British section also contained but one wheel. This was a Girard turbine, built by Gwynne & Co., of London. Its most striking peculiarity consisted in the method of regulation. The circumference was divided into four quadrants, which were alternately provided with guide-curves and closed up. One-half of the wheel, therefore, did no work. The gate was so fitted that when the wheel was running at full power it lay between the wheel and casing at the blank quadrants. When regulation was necessary, it was swung around over the working quadrants, closing off a greater or less number of openings, according to the necessities of the moment. It is evident that this arrangement considerably increases the size of the wheel for a given power.

The arrangement is recommended for exceptionally great heads, or when the velocity of the ordinary wheel would be excessive. But as the efficiency of the wheel is so largely dependent upon the adjustment of its speed as a function of the height of fall, it is evident that reducing velocity will decrease efficiency. It would seem that a better plan would be to drive the turbine at the proper speed, providing against inconvenience or injury at such exceptionally high speeds by care in designing and skill in the construction of its bearings and of the machinery of transmission.

Wheels of the capacity of the American wheels above described are catalogued at £500 and £180, respectively, or not far from 50 per cent. higher price, notwithstanding the lower cost of labor and material in Great Britain. An efficiency of 80 per cent. is guaranteed. The prac-

Digitized by Google

tice of this firm is to make the steps of the shaft of lignum-vitæ, lubricating with water.

184. RIETER & CO.'S JONVAL TURBINE.—An interesting collection was shown by Messrs. T. Rieter & Co., of Winterthur, Switzerland. It consisted of machinery and plans of very fine work done by them during a few years past. These manufacturers build the Jonval wheel, and have constructed some of a size nearly equal to the largest turbines in use in the United States. Those constructed for Bellegarde, at the junction of the Rhône and Valerine, are 8 feet in diameter, and under a fall of 40 feet, making 90 revolutions per minute, as it was stated, develop a power of 630 horses. This firm adopt the "telodynamic" method of transmission of power, using wire rope running, at high speed, over very large pulleys. The method is that which has been introduced, with great success in some cases, by Messrs. J. Roebling's Sons, of Trenton, N. J.

185. Messrs. ROY & Co., of Vevay, presented an attractive collection of turbine wheels on a small scale, in tanks fitted with glass windows, through which their operations could be observed. This firm, it is said, have constructed within ten years more than 200 Girard turbines, representing a total of 9,000 horse-power. These are all made with what is called a "free discharge." The wheel is not allowed to work in tail-water, but in an atmosphere of air so compressed that the water is kept back at a lower level than the wheel itself. This air-chamber which incloses the wheel, and is opened at the bottom for the exit of the stream leaving the wheel, is kept full by an air-pump worked by the turbine itself—a somewhat costly addition to the machinery. This arrangement for relieving the wheel of the drag of tail-water has unquestionable advantages, and these engineers consider them more than sufficient to compensate the extra cost of their construction. Their assertion is well sustained by their success in introducing them.

186. COLLADON'S "FLOATING WHEEL."—The Swiss section contained a considerable number of exhibits of hydraulic machinery, one of which should be described, although a little out of place here. This was a design shown by M. Colladon, of Geneva, of a "floating hydraulic wheel" for rapid streams. One of these wheels was stated to have been at work on the Rhône, near Geneva, day and night for eight years. This wheel is a great barrel, of boiler-plate, carrying floats or paddles, by which it is turned as it floats upon the stream, revolving about an axle which may rise and fall with the tide. The wheel thus works equally well whatever the height of the water.

This wheel is rated at 12 horse-power, and is used to raise water to a height of 65 meters, (215 feet,) for the purpose of supplying the neighboring villages. It was said to have cost, with its attachments, but 10,000 francs, ($2,000.)

187. STRAUB'S VERTICAL WHEELS.—A fine exhibit of hydraulic machinery was made by Herr D. Straub, of Geislingen. One of his turbine wheels was constructed for a height of fall of 500 feet.

Digitized by Google

A more remarkable wheel was that of Millot, shown by the same exhibitor, in which, by a neat device, the inflow of water was directed into the wheel, passing from the interior into the bucket and thence outward at its discharge. The wheel was 18½ feet in diameter outside, 14 feet inside, 7 feet breadth of face, and intended to make five revolutions per minute. The exhibitor claimed for this wheel an efficiency of over 85 per cent., a result possibly, but in the opinion of many engineers not probably, attainable. Herr Straub also exhibited a breast-wheel, 16½ feet diameter, 6 feet in length, and for a fall of moderate height this is an effective wheel. The efficiency promised was 75 per cent.

188. NAGEL AND KAEMP, of Hamburg, exhibited a very interesting group of hydraulic apparatus, including four turbine water-wheels, of diameters ranging from 21½ inches to 83 inches. The ordinary method of regulation is practiced with the Fourneyron wheel as built by Nagel & Kaemp; the water enters from below, as is usual, instead of from above. The regulation is effected by altering simultaneously, by a very ingenious arrangement, the height of both guide-curves and wheel-buckets, thus altering the working depth of the wheel to suit the varying requirements of the case. The percentage of useful effect in the wheel is thus preserved nearly constant for all variations of power. The arrangement complies with theoretical requirements, and is, furthermore, practically successful. It is one of the best devices shown at Vienna. The entrance of the water below the wheel is of decided advantage, in permitting a partial balancing of the weight on the step and making the wheel far less liable to give trouble in consequence of defective lubrication at that point, the greatest difficulty usually experienced with the Fourneyron wheel. So freely does the wheel work, the exhibitors state, that they have actually in operation a wheel working under a head of but 6 inches. Another exceedingly neat device is that adopted for oiling the step. The lubricant floats on the water within a little bell surrounding the step as the air is retained within a diving-bell. Should the journal commence cutting, the particles fall down and are carried away by the water instead of choking the bearing, as usually occurs. The whole arrangement is neatly designed and well proportioned, and is an excellent piece of work.

189. Another "partial" turbine wheel, or wheel with "partial delivery," is shown, which belongs to a class already referred to. The gate swings about the axis of the wheel, closing off a greater or less number of openings through the wheel. This design is intended for great height of fall.

Another interesting device was the regulating-wheel used by this firm. An annular bucket-wheel, with floats capable of moving about axes at the inner ends, was fitted outside the turbine bucket-wheel. When the turbine was working properly, the water issued radially between these floats, leaving them in their normal positions. A dis-

Digitized by Google

turbance of the turbine producing a change in the direction of the outflowing water, it impinged against the floats of the regulating-wheel, changing their position on their axes, and, through a properly-arranged system of gearing, caused the necessary change of position in the gate. One of those turbines, built for a fall of 138 feet, (42 meters), weighs 800 kilograms, (1,760 pounds,) and is rated at 35 horse-power.

190. *Arrangement and efficiency.*—This firm received the "*Ehren Diplom*" for their extensive and, in some respects, very superior collection of hydraulic machinery. They have furnished the writer since the close of the Exhibition with data and calculations published in the Allgemeine Deutsche Polytechnische Zeitung, 1874, and in London Engineering of February 20, 1874.

A centrifugal pump, with eccentric casing, was driven from the shafting under the floor of the machinery-hall. This pump took water from a lower reservoir, raised it through a funnel-shaped tube 5 meters (16 feet $4\frac{7}{8}$ inches) high, whence it fell 1 meter (3 feet $3\frac{3}{8}$ inches) into an upper reservoir. A turbine, 930 millimeters (36.61 inches) outside diameter, drove a vertical centrifugal pump. This pump also took water from the lower reservoir, and forced it through another funnel-shaped tube into the upper reservoir, altogether through a height of 5 meters. The water supplied by the two centrifugal pumps was used for driving the turbine, the available head being 4 meters, (13 feet $1\frac{1}{2}$ inches.) The available cubic contents of the upper reservoir up to the level of the overflow amounted, after deducting the two tubes, to 801.44 cubic feet, and this reservoir was filled by means of one of the centrifugal pumps in exactly 101 seconds, whence the pump delivered, at its normal speed, and to a height of 5 meters, $\frac{801.44}{101} = 7.935$ cubic feet of water per second. This quantity was delivered by the vertical funnel-shaped tube, the effective diameter of which was D = 1.055 meters, or 41.54 inches, while the measured head of the discharge $h_1 = 0.089$ meter, or 3.5 inches.

191. The quantity of water Q_1 flowing per second over overflows of this kind is found by the known formula:

$$Q_1 = \frac{2}{3} \mu p h_1 \sqrt{2 g h_1},$$

in which μ represents the co-efficient of discharge; p the width, or, in this case, the circumference D of the overflow, this width being in the present instance—

$D\pi = 3.315$ meters, or 10.876 feet;
$h_1 = 3.5$ inches, or 0.2917 foot; and
$2g = 64.4$ feet for the acceleration due to gravity.

According to this formula, we get, in the present case—

$$7.935 = \frac{2}{3}\mu \times 10.876 \times 0.292 \sqrt{64.4 \times 0.292},$$

Digitized by Google

whence $\frac{2}{3}\mu=0.576$, which shows that, for such overflows of 1.055 meters diameter, the co-efficient of outflow is almost exactly the same as that found by Eytelwein for well-rounded-off weirs.

For further calculations we shall use the following symbols:

(1.) For the centrifugal pump with eccentric casing:

$Q_1=7.935$=the quantity of water per second in cubic feet;

$H_1=16.4$ feet (5 meters)=total height through which the water is lifted;

$b=D\pi=10.876$ feet circumference of overflow;

$h_1=0.292$ foot effective head;

n_1=percentage of effect;

N_1=effective working-power of the pump;

Therefore, taking the weight of water at 62.4 pounds per cubic foot,

$$N_1=\frac{1}{n}\times\frac{62.4\times 60\ Q_1\ H_1}{33000}\ \text{horse-power.}$$

(2.) For the centrifugal pump:

Q_2=quantity of water per second in cubic feet;

$H_2=16.4$ feet=total height through which the water is raised;

$b=D\pi=10.876$ feet width of the overflow;

$h_2=0.2362$ foot effective head;

n_2=percentage of effect;

N_2=effective working-power of the pump;

Therefore,

$$N_2=\frac{1}{n_2}\times\frac{62.4\times 60\ Q_2\ H_2}{33000}\ \text{horse-power.}$$

(3.) For the turbine:

$Q_3=Q_1+Q_2$=quantity of water per second in cubic feet;

$H_3=13.12$ feet (4 meters)=total available height of fall;

n_3=percentage of effect;

N_3=effective working-power;

Therefore,

$$N_3=n_3\times\frac{62.4\times 60\ Q_3\ H_3}{33000}\ \text{horse-power.}$$

The whole effective power developed by the turbine having been used in driving the centrifugal pump with vertical spindle; we find that $N_3=N_2$, or, by substitution, that—

$$n_3\frac{62.4\times 60\ Q_3\ H_3}{33000}=\frac{1}{n_2}\ \frac{62.4\times 60\ Q_2\ H_2}{33000};\ \text{but}$$

$Q_3=Q_1+Q_2$, and $H_3=13.12$ feet; $H_2=16.4$ feet; whence

$$n_3\frac{62.4\times 60\times 13.12\ (Q_1\times Q_2)}{33000}=\frac{1}{n_2}\ \frac{62.4\times 60\times 16.4\ Q_2}{33000}$$

$$\text{or, } n_3\ n_2=\frac{5}{4}\ \frac{Q_2}{Q_1+Q_2}$$

Digitized by Google

We also find, under the same conditions and for the case where the total amount of water (Q_1+Q_2) supplied by the two centrifugal pumps has been exclusively used for the working of the turbine, that the height h_2 of the effective head at the top of the funnel-shaped tube for the pump is—

$$h_2=0.2362 \text{ feet.}$$

Whence,

$$Q_2=\tfrac{2}{3}\mu\, bh_2\sqrt{2gh_2}$$
$$=0.576\times 10.876\times 0.2362\sqrt{64.4\times 0.2362}$$

Therefore, $Q_2=5.77$ cubic feet per second.

The same result is obtained in a shorter manner by division,

$$\frac{Q_1}{Q_2}=\frac{\frac{2}{3}\mu\, bh_1\sqrt{2gh_1}}{\frac{2}{3}\mu\, bh_2\sqrt{2gh_2}}=\frac{h_1\sqrt{h_1}}{h_2\sqrt{h_2}}$$

In this equation the relative values of Q_1 and Q_2 are expressed simply by the corresponding heights of fall h_1 and h_2, whence a very convenient calculation of the quantities of water by means of the easily-measured heights h_1 and h_2 is obtained. From the above equation we get—

$$Q_2 = Q_1\frac{h_2\sqrt{h_2}}{h_1\sqrt{h_1}}= 7.935\,\frac{0.2362\sqrt{2362}}{0.292\sqrt{292}}= 5.77$$

cubic feet per second. Substituting the value of Q_1 and Q_2 into the formula given above—

$$n_3\, n_2=\frac{5}{4}\;\frac{Q_2}{Q_1+Q_2}$$

we get

$$n_3\, n_2=\frac{5}{4}\cdot\frac{5.77}{7.935+5.77}$$

or

$$n_3\, n_2 = 0.52$$

That is to say, the real effect produced by the turbine and by the vertical centrifugal pump together is 52 per cent. of the theoretical power of the water which is available for the turbine, or the percentage of effect from the gross power of the turbine-water to the power represented by the effect of the pump is 52 per cent. This, it must be admitted, is a very favorable result, for, supposing that the percentage of effect of the turbine is *equal* to that of vertical centrifugal pump, we get

$$n_3=n_2=\sqrt{0.52}=0.72$$

That is to say, both turbine and centrifugal pump work with a useful effect of 72 per cent. It may be, however, safely admitted that the turbine produces a greater percentage of effect than the centrifugal

Digitized by Google

pump; and if we suppose, for example, and in accordance with the greater probability, that

$$n_3 = 0.75, \text{ we get } n_3 = \frac{52 \times 100}{75} = 69.3 \text{ per cent.}$$

That is to say, the turbine apparently gives 75 per cent. and the vertical centrifugal pump about 70 per cent. of useful effect. It should be borne in mind that this result is obtained with a turbine of small dimensions, which represents but a power of 15 horses, and the sluices of which for the admission of the water were but two-thirds open.

192. THIME'S FOURNEYRON-JONVAL TURBINE.—A Russian exhibitor, Professor Thime, of the Institute of St. Petersburg, has attempted to secure for the Fourneyron wheel the special advantage of the Jonval turbine—that of working at any point in the fall. The whole wheel is surrounded with a casing, out of which the issuing water is led by a pipe which is carried down to the bottom of the fall and its lower end submerged. He claimed thus to have secured the advantages of accessibility peculiar to the Jonval system, without sacrificing the more satisfactory method of regulation practicable with the outward-flow wheel. The exhibitor proposes to use wheels with either vertical or horizontal axes, as may be preferred. Regulation is obtained by the adjustment of the height of openings through the wheel by means of a damper carried on the axis and sliding in the axial direction, so as to close up a larger or smaller proportion of the opening, as may be required—a system claimed to have been introduced twenty years ago by M. Charles Huot. The general design of these wheels was not good. The water passed through channels of suddenly varying sections and with sharp turns, and the loss of energy must be quite objectionable.

193. PRINCIPLES OF CONSTRUCTION OF WATER-WHEELS.—The construction of an efficient turbine water-wheel involves simple principles, but their application affords a field for the display of great engineering skill and mechanical tact. These wheels are usually divided into three great classes: parallel-flow, outward-flow, and inward-flow turbines. In either case, the aim of the designer is to transform the energy of the falling water into useful mechanical effect without losing power by splashing of the liquid or the production of heat by its friction. The water is received on the wheel without shock, transmitted with uniformly decreasing velocity, and finally leaves the wheel at the minimum velocity, which enables it to just clear the succeeding buckets as it falls.

When the water enters upon the wheel without shock and leaves it without velocity, the speed of wheel being approximately one-half that due the height of fall, a maximum economy is attained.

To secure this result, the water should enter upon the wheel with the angular velocity of the latter, and should have its velocity reversed, leaving the wheel with a velocity opposite in direction and equal in magnitude to that of the wheel itself.

Digitized by Google

CHAPTER IX

PUMPS.

PUMPS; APPLICATIONS; CLASSIFICATIONS; STEAM-PUMPS; LATER FORMS; DECKER BROTHERS & CO.'S PUMPING-ENGINE; CAMERON'S, SELDEN'S, AND EARLE'S STEAM-PUMPS; PRUNIER'S PUMPING-MACHINERY; THE ERSTE-BRÜNNER-MASCHINEN-FABRIKS-GESELLSCHAFT; CENTRIFUGAL PUMPS; THEIR PROPER FORM; ADVANTAGES; GWYNNE'S EXHIBITS; THE PUMPS FOR FERRARA, ITALY; PUMPS OF J. BERNAY NEUT & DUMONT, COIGNARD, NAGEL & KAEMP; THE SCHIELE PUMP; BOULTON & IMRAY'S PUMP; ADAPTATIONS OF THE CENTRIFUGAL PUMP.

194. CLASSIFICATION OF PUMPS.—The elevation of water has always been one of the most important applications of mechanical power.

Before the time of Watt the power of steam had been applied almost solely to this purpose. The steam-engines of the Marquis of Worcester, of Savery, and of Newcomen had application exclusively in this direction. The first engines of Watt were pumping-engines, and that great engineer and his competitors were the first to apply steam as a prime mover to other machinery, only after the introduction of the improved pumping-engine had relieved the miners from imminent danger of being driven from their mines by the floods of water met with at the depths then already attained. While mechanical power since that time has found a wonderfully-extended and still rapidly-widening field of application, the elevation of water, although of far less relative, is of vastly greater absolute importance than at the time of Watt's death, nearly three-quarters of a century ago.

At that time the reciprocating-pumps only were known. They still remain in use for great pressures and high lifts, but have been quite superseded recently by the rotary and centrifugal pumps wherever the great volumes of water are to be raised through moderate heights.

The three important classes of apparatus for raising water are, therefore:

(1.) Reciprocating-pumps.
(2.) Rotary pumps.
(3.) Centrifugal pumps.

The first class are frequently called "piston-pumps," and consist ot a barrel in which water is intermittently displaced by a piston or a plunger with a set of valves, usually acting automatically, which compel the liquid to take the proper course when entering or leaving the pump-barrel.

The second class consists of pumps which usually have either two

Digitized by Google

sets of revolving vanes, geared with each other in such manner as to seize and drive forward a certain quantity of water at each revolution by a "positive" action, or of a revolving drum, fitted with sliding diaphragms which drive the liquid along the channel which extends around the periphery of the casing, advancing radially or retiring into the drum as that channel enlarges its section or contracts.

195. STEAM-PUMPS.—Of the latter two classes, none were exhibited at Vienna which called for extended consideration, although the number of exhibits was very great. The most important exhibits were the steam-pumps; and the most interesting of the steam-pumps were types well known as having been invented in the United States and very extensively used. The latest forms of these pumps have the valves of their steam-cylinders driven by small auxiliary pistons, driven in turn by steam which is distributed by a very small valve moved by tappets upon the main piston or its rod. In these pumps there is less liability to a cessation of action when working very slowly than in older styles of pump. In the latter, reverse-steam is necessarily given before the steam and water pistons have quite reached the end of their stroke. When running at ordinary speed, the momentum of the moving mass is such that the stroke is completed, and the valve thus necessarily thrown wide open before the reverse-steam can check the onward movement. When moving slowly, however, this cannot occur, and the pump is liable to stop before completing its stroke and reversing steam. With the auxiliary valves this is far less likely to occur, and becomes almost impossible to drive the pump at so slow a speed that it cannot make a full stroke; while at high speed, from beginning to end of stroke, the full steam-pressure is obtained and a greater amount of work is usually done than could be done with the older form of valve-movement.

196. The CAMERON "SPECIAL" PUMP was exhibited at Vienna, in the British section, by Messrs. Tangye Brothers, and is so well known in the United States as scarcely to require description. It is of the class last referred to, and large numbers are in use in the United States, where they are made by A. S. Cameron & Co.

The pump is well designed and well made. It is compact, handy, and durable. In the illustrations (Figs. 76 and 77) it is shown in side elevation and in section.

A is the steam-cylinder shown in section, Fig. 77; C, the steam-piston; D, the piston-rod; L, the steam-chest; F, the plunger; G, the slide-valve; H, a starting-bar, connected with a handle on the outside; I I are the reversing-valves, and K K, the bonnets over the reversing-valves; N is the body-piece connecting the steam and water cylinders; B is the water-cylinder with the valve-chest bonnet removed; M is a valve-seat shown in section; the valve over it is also shown in section; T is the discharge-air vessel.

Suppose the steam-piston C moving from right to left, when it reaches the reversing-valve I it opens it and exhausts the space on

Digitized by Google

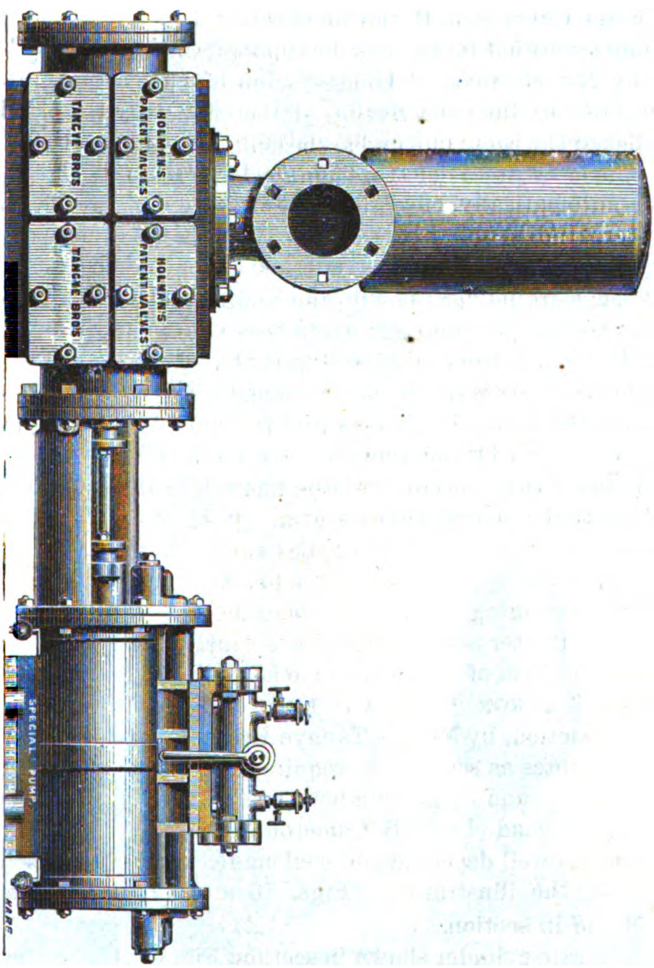


FIG. 76.—Tangye Brothers' "special" steam-pump.

the left-hand end of the plunger F by the passage E, which leads to the exhaust-pipe, the greater pressure inside of the steam-chest changes the position of the plunger F and slide-valve G, and the motion of the piston C is instantly reversed. The same operation repeated at each stroke makes the motion continuous. The reversing-valves I I are closed by a pressure of steam on their larger ends, conveyed by an unseen passage direct from the steam-chest.

A pump somewhat resembling in appearance the "special" pump was shown by Mr. McNicol, of Glasgow, the invention of Clarkson; and another pump by the same dealer, and invented by the same engineer, accomplished the same object by making the piston of the steam-cylinder of unusually great length and placing within it the valve which, working automatically, effected the distribution of steam. The pump-valves were India-rubber ball-valves. The valves of the special pump were of brass, with brass seats resting on India-rubber rings. Ten thousand of the latter pumps are said to have been made in Great Britain.

These varieties of pump are finding an enormous demand, and their manufacture constitutes an exceedingly important branch of manufacture. The English manufacturers seem to be more generally inclined to use the older form of "donkey-pump" than are our own people; but the fact that they are so generally adopting the class just described would indicate that practice in this respect in the United States is in advance of that in Great Britain.

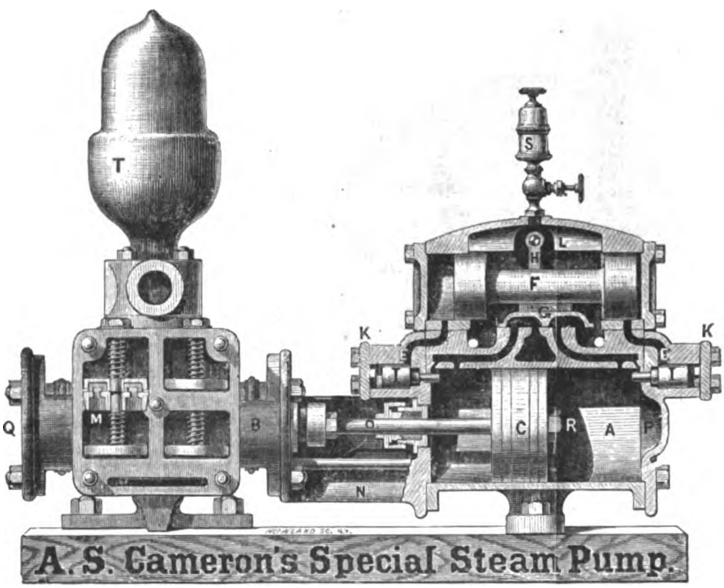


FIG. 77.

Several "donkey-pumps" were shown, one of which is a combination of what is known in America as Andrew's oscillating engine, with a

Digitized by Google

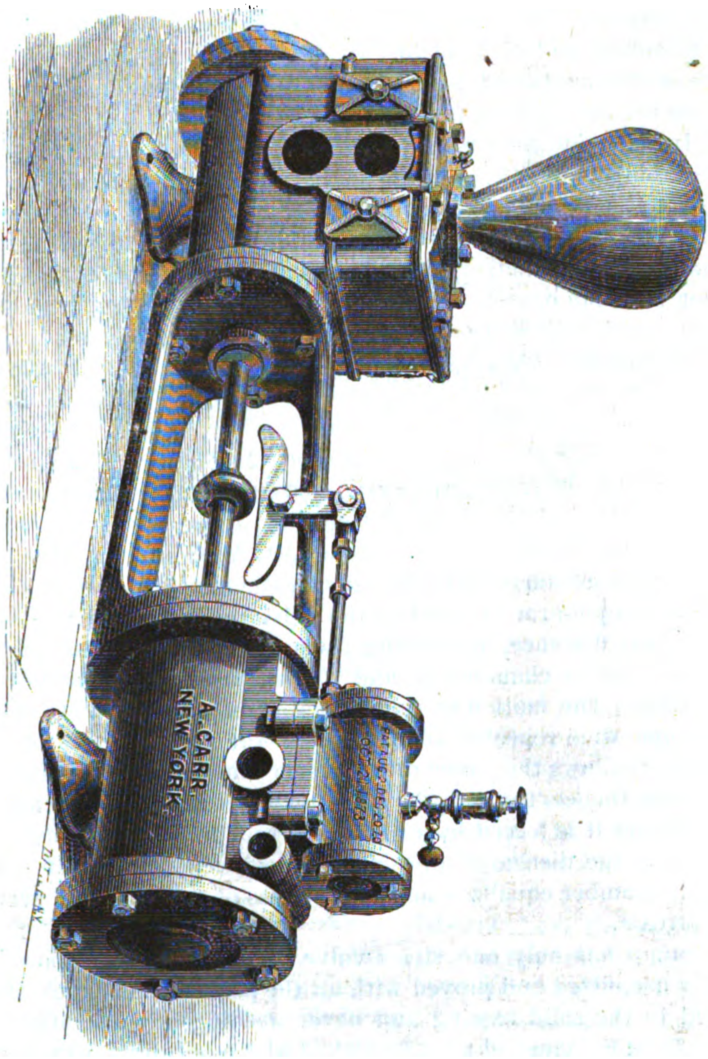


FIG. 78.—The Selden pump.

similarly arranged pump-cylinder, opposite each other and coupled to the same crank-shaft.

The best of the remaining pumps of this class are of the plainest design and most simple construction, and require no extended mention here.

197. There were three pumping-stations. At one of these DECKER BROTHERS & Co. had erected pumps of the style supplied by them for mining-purposes. They were 15¾ inches diameter, both in steam and water cylinders, and of 37 inches stroke. The pressure of steam was from 50 or 60 pounds and the water-pressure somewhat lower, and lower also than the pumps were designed to work against.

198. In THE SELDEN PUMP, another American design, as shown in Fig. 78, a button or disk, attached to the piston-rod at its middle point, strikes, as it reaches either end of its stroke, a bent lever connected with the valve-stem, as shown in the cut, and moves the starting-valve. It is simple in construction, positive in action, and is evidently intended more for use than ornament. The auxiliary valve, which is moved by the lever acted upon by the disk on the piston-rod, is recessed into the main valve so that they have a common seat. The pump-valves are accessible on removing one nut. They are flat, of bronze or composition, or they are sometimes faced with rubber or leather. They seat on bronze. The builder of this pump was Mr. A. Carr, of New York City.

199. In THE EARLE DIRECT-ACTING STEAM-PUMP, an American pump, exhibited by Decker Brothers, of Canstadt, steam passes into the center space of the steam-valve through a port, A; from thence the stream passes into the steam-cylinder B, causing the piston to make its stroke. When the tappet-arm D touches the valve-rod collar E, it moves the valve a short distance, uncovering the port F, when steam rushes up from below into a chamber, G, and its pressure causes the movement of the valve. The motion of the steam-piston is immediately reversed and the operation repeated at each end of the stroke. This operation of the valves allows the water to rush from the suction-pipes into a passage, J, from thence, through the suction-valves K, into the pump-cylinder H; thence it is forced by a piston up through the discharge-valves L and out at the discharge-pipe M. The elasticity of the air confined in the air-chamber equalizes any unevenness of pressure and secures a steady stream.

This pump has only one steam valve, a single piece, impossible to break by use, fitted and proved with all the ports and passages immovably fixed in the solid casting and never needing any alteration. The valve is fitted "steam-tight," is furnished with a peculiar steam-packing, and is balanced. It is impossible to place the valve in such a position that the pump will not start the instant steam is turned on.

At the moment of reversing, the movement of the valve is in unison with the main piston; and it is claimed to be impossible for the piston to strike the cylinder-head, however fast it is moving, since, from the method of construction and connection of the valve, it will be reversed

Digitized by Google

and admit steam ahead of the piston before the latter can strike the head. This point is highly important in a fire-pump, as it can then be driven at high speed without liability of breaking down. It is impossible for it to reverse its motion before it has completed the full stroke, and it uniformly delivers its maximum capacity, with an incidental advantage, the cylinders wearing equally throughout their whole length The valve is moved by steam which has completed its work in the cyl-

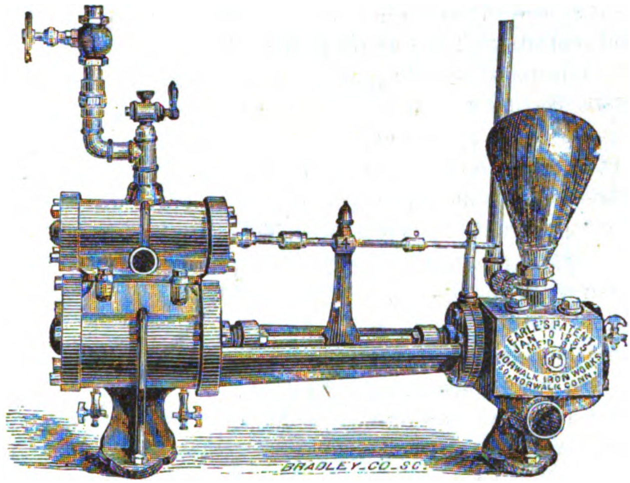


Fig. 79.—The Earle pump.

inder and is about to be exhausted. The water-passages of the pump are large and direct.

Fig. 79 is a perspective view of a boiler-feed pump.

Fig. 80 is a sectional view of the large fire-pump.

200. M. Prunier, of Lyons, France, erected a set of pumping-apparatus in a small building Northwest of the machinery hall. Here, two independent pumps raise water from two wells which are lined with an iron cylinder pierced with holes, very much in the same way as is customary with the tube-wells so extensively used in the United States. These tubes were one meter (3.28 feet) in diameter and 17 meters ($55\frac{3}{4}$ feet) long.

The engines were vertical, the steam-cylinders above the pumps, and the center line of both traversed the center line of the well. Each pump-barrel contained two pistons working in opposite directions. The rod which carries the lower piston was formed by continuing the steam-piston rod downward. The upper piston was carried on a hollow rod surrounding the first, and operated by a cross-head which was connected to pins on the balance-wheel at each side by connecting-rods of considerable length. These pistons were conical in general shape, and their valves were concentric India-rubber rings, having horizontal seats one above another, the smallest being uppermost. The plan here adopted was claimed to have the advantages of giving an equilibrium of weights

Digitized by Google

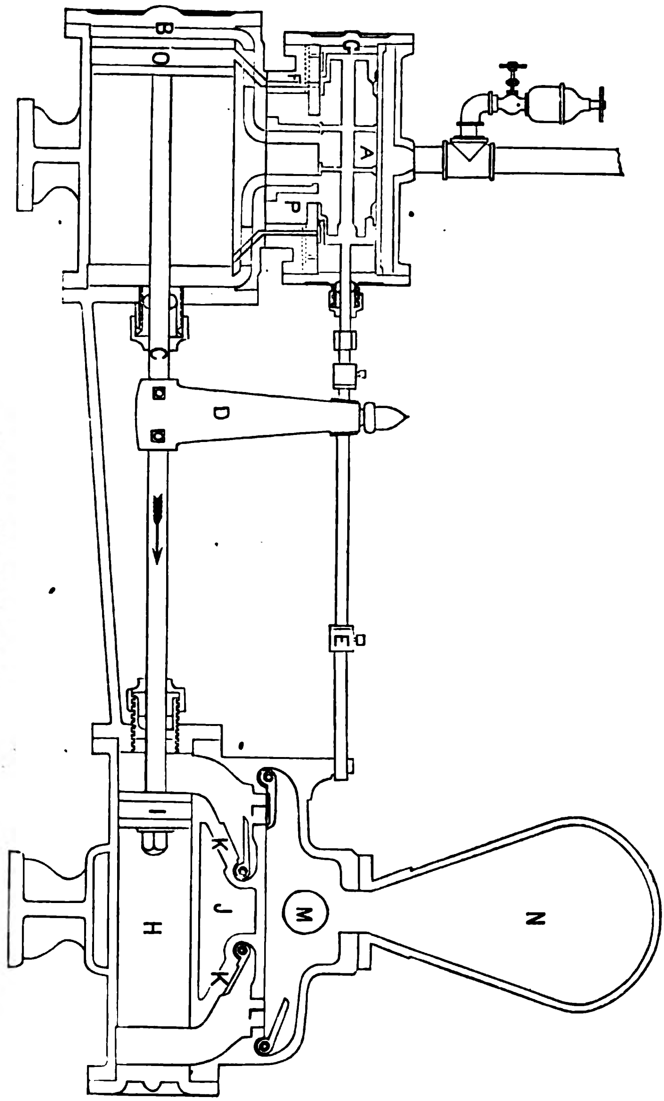


FIG. 80.—The Earle pump.

Digitized by Google

of pistons and other moving parts; a comparatively uniform flow of water, always in the same direction; adaptability to great depths, as a consequence of the fact that the rods are never submitted to a force of compression, and, further, absence of concussion, consequently permitting the adoption of high speed.

The point of cut-off of the engine is of course invariable, being originally determined by existing conditions which are quite invariable. In this case steam was expanded five times. The valves were "balanced" and actuated by steel cams. The condenser was placed directly beneath the steam-cylinder, and was annular in form. Two air-pumps were arranged, one on each side, working from the cross-head carrying the upper pump-piston.

The steam-cylinder was 24 inches diameter, (0.60 meter,) and had the same length of stroke of piston. The water-pistons had the same stroke as the steam-pistons, and were 10 inches (0.40 meter) in diameter. At 50 revolutions per minute, the pumps raise, together, 494½ cubic feet (14 cubic meters) per minute through a height of 24 meters (78.7 feet) with about 100 horse-power.

The whole apparatus is simple, compact, and effective, and did good work. The principal defect would seem to be the proximity of the condenser to the lower steam-cylinder head, and the consequent liability to absorb heat from it and to produce serious condensation of steam within the cylinder.

201. The ERSTE-BRÜNNER-MACHINEN-FABRIKS-GESELLSCHAFT established a set of pumping-machinery at the opposite extremity—the Western end—of the machinery hall, raising water, to supply the Exhibition, into a tank at the summit of a water-tower 150 feet high. The total lift was between 165 and 170 feet. The engines were Corliss engines, having cylinders 19¾ inches in diameter and 3½ feet stroke of piston. The pumps were double-acting, of the same length of stroke, and 12 inches in diameter. The same piston-rod carries steam and water cylinder pistons, the two cylinders being in line, the pump behind the steam-cylinder. These engines, when running at speed, made 22 revolutions per minute with a steam-pressure of 65 pounds. The engines are non-condensing. Speed is regulated by a hand-motion adjusting the cut-off apparatus. The exhaust passes through a feed-water heater. The whole of this work is creditable to designer and builders.

202. CENTRIFUGAL PUMPS.—The class of pumps misnamed centrifugal are now fully recognized as the most useful, and indeed the only kind which may be profitably used in elevating large volumes of water to moderate height.

Bucket or plunger pumps are not at all adapted to low lifts. The class here referred to excel them immensely in low first cost, in smallness of volume and of weight; even in efficiency the difference under the conditions here supposed is not great. Higher lifts and heavy pressure cannot be successfully met by centrifugal pumps, as the slip of the water

Digitized by Google

through the pump becomes very great, causing a corresponding loss of efficiency; but under low lifts this slip becomes insignificant, and the advantages are all on the side of the centrifugal pump. In these pumps a rapidly-revolving axle carries a set of blades or fans, which force a stream of water, entering in the line of the axis, outward between the walls of the casing, into an annular or helical channel, from which a pipe leads it off wherever desired.

PRINCIPLES OF CONSTRUCTION.—It was supposed by Appold, the introducer of this class of pumps, that the effect was due to centrifugal force; but careful investigation has shown that the action is precisely that seen reversed in the turbine water-wheel.

The best form of fan or vane has been found to be that of which the trace on the plane to which the axle is vertical is a spiral, having proportions determined in each case by the height of lift and velocity of revolution.

The problem involved in designed water-elevators of this class may be stated in few words. The direction of the current passing through the machine and the direction of movement of the impelling surface should be so related at each instant that the force due to a change of motion of every particle from that of the normal to the direction of impelling motion shall be greater than that due to the actual change of motion proposed, and this relation should, further, be such that the work done in producing the actual change shall be the least possible. When those conditions are all fulfilled, every particle of the fluid, always taking the path of least resistance, finds that path which produces the required ultimate change of position with least expenditure of energy.

The form of the impelling surface and the path of the fluid particles are evidently peculiar in every instance, and are determined by the conditions of the individual case.

The proper form of the blades of the pump resembles the Archimedean spiral in sections taken in the plane of its revolution, and is approximately trapezoidal in its development on a plane passing through the axis.

The generally admitted advantages of these pumps are, that they are of small volume and weight, and at the same time have vast capacity under small lifts; they are of the simplest possible construction; their motion is continuous, and hence they are not liable to injury or loss of effect by shock; they elevate water containing small solid or semi-fluid bodies without difficulty; they are fairly economical of power, and are of very low cost, as compared with reciprocating-pumps.

These machines have an importance which does not seem to have been fully appreciated, and it has hence occurred that very few have been constructed correctly.

The principles of design are closely related to those involved in the design of turbine wheels. To secure maximum efficiency, the pump must be so formed and proportioned that the water shall enter it with

Digitized by Google

Digitized by Google

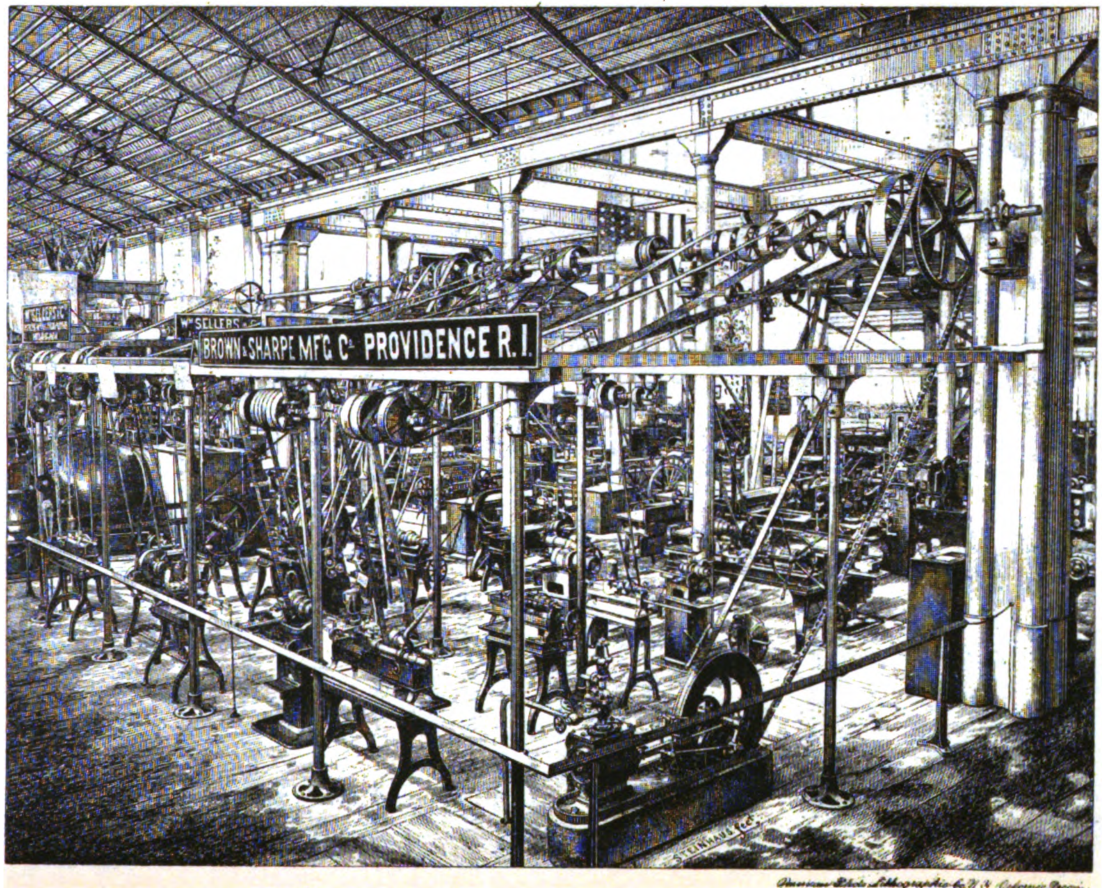


Fig. 82.

Digitized by Google

out shock; shall receive as nearly as possible a uniformly accelerated velocity; shall have the shortest possible path; shall make no sudden change of direction or velocity, and shall finally emerge into the delivery-pipe with a velocity somewhat exceeding that due the head of water incumbent upon it.

For a good form of pump, in which the interior radius is about 0.5 the exterior, the velocity of the circumference has been found to be satisfactory at 1.2 that due the height of elevation, and at the interior about 0.6.

As the velocity of the entering stream is obtained by suction, it cannot exceed that due the pressure of the atmosphere. It forms a part of head-resistance, therefore, equal in all cases to

$$H_1 = \frac{V_1^2}{2g_1}$$

and this must be added to the head H, under which the pump works. The maximum velocity is, therefore, that due to about 34-feet head, and is obtained when the pump is set at water-level. For any other case, the maximum velocity is reduced by the height of suction.

For excessive heights, the lift should be divided, and two or more pumps, set one above another, to re-enforce each other at regular intervals.

In laying out the form of the vanes, it is simply to be remembered that the path of the water is a resultant of the direction of motion of the water and of the pump itself, and that it must be made as smooth and direct as possible.

In construction, smoothness of surfaces, uniform variations in section of water-passages, accurate reproduction of the forms laid out by the designer, and ample bearing-surface in journals are the main requirements.

In operation, the pump should be driven smoothly and with perfect regularity at the speed best adapted to the lift. The pump should always be placed as low as possible, to reduce height of suction and to secure maximum delivery.

203. THE GWYNNE CENTRIFUGAL PUMP.—The most interesting collections of centrifugal pumps at Vienna were those of Messrs. J. & H. Gwynne, and Gwynne & Co., of London.

These pumps (Fig. 81) are built in large numbers by these firms. Both firms exhibit in their designs great strength, solidity, and neatness of proportions. They are claimed to be efficient under heads ranging up to 100 feet, and, in at least one instance, they have been actually used in the water-supply of a large town in two lifts under a head of 65 feet each.

J. & H. Gwynne cast their foundation-plate in one piece with the connecting-pipe and standard, thus securing greater rigidity and steadiness in working, and permitting the pump-case to be removed without disturbing the suction-pipes. This seems a comparatively cheap method of constructing also. The spindles are of steel running in bearings in

Digitized by Google

which careful provision has been made for effective lubrication. The foundation-plate is moderately heavy. The motion of the pump is continuous, and, when well balanced, free from jar. It is, however, difficult to make the balance so perfect that, at the great speeds at which they are driven, they shall be entirely without shake, and a good foundation is desirable. For small sizes, two heavy beams are generally used to carry the pump. For larger sizes, brick or stone foundations should always, where possible, be provided. In soft ground, piles make a cheap and very good support.

These pumps have as few and as gradual changes of section in their pipe as can well be given. A change of transverse section always causes some loss. A sudden change in the area of cross-section is liable to produce a marked decrease of efficiency. The action of the pumps here referred to must be unusually perfect if, as claimed by their makers, the larger size will give satisfaction when set with a suction of 28 feet vertically. A very important requisite, ample width of driving-pulley, seemed to have been provided.

Several styles and sizes are made, in which the driving-engine and pump are on the same bed-plate. Such a combination finds many applications in ordinary engineering operations, and it is generally coming into use as a "circulating-pump" for steam-engines with surface-condensers. In this arrangement the engine is coupled directly to the pump-shaft without belting or other intermediate mechanism of transmission, and are given a somewhat greater diameter than would be considered best were it convenient to give the speed of rotation attainable where driving by belts. Some of these pumps are mounted on wheels for convenience of transportation. In one example, the axis of the pump coincides with that of the supporting wheels, and it can rotate about that axis, taking any position which may best suit the directions of suction and discharge pipes.

204. PUMPS AT FERRARA, ITALY.—The exhibitors first named have built a set of immense centrifugal pumps for the purpose of draining the Ferrara marshes of Italy, which cover an area of two hundred square miles, and from which they are expected to be capable of lifting 2,000 tons of water per minute to a height of 12 feet as a maximum. The mean lift will be 7¼ feet. Eight pumps are to do this immense work. They are arranged in pairs, each pair driven by a compound engine. The diameter of the disks of the pumps is 5 feet, that of the pipes 4½ feet. The casing is 15 feet in diameter. The driving-engines have cylinders 27¾ and 46⅝ inches diameter, with a stroke of piston of 2¼ feet. The cylinders are steam-jacketed. The cranks are so placed as to make an angle of 130° with each other. Surface-condensers are used of 750 square feet of cooling-surface each. Steam is supplied by ten boilers, each having 30 square feet of grate and 730 square feet of heating-surface. These are probably the largest centrifugal pumps and the most powerful set of pumping-apparatus ever constructed.

Digitized by Google

The senior of these two firms, Gwynne & Co., make not only the centrifugal pump, of which they are the original patentees, but very good gas-exhausters. Their merit was fully appreciated; they were given a high award by the jury.

205. Mr. J. BERNAY, of London, exhibited a centrifugal pump, built from his designs by Messrs. Owens & Co., in which a passage is cut from the delivery to the suction leading through the shaft-bearings, and thus keeping the latter cool by the circulation of water through them.

The arms or vanes are carried between two disks which have a bearing against the sides of the casing along two rings, concentric with the axis, the intention of this arrangement being to prevent the usual loss of power from the friction of the liquid between side disks and casing by reducing the pressure there. The suction-pipe divides when it meets the pump, and the water enters at each side through orifices concentric with the axis, an arrangement now frequently adopted by other builders. This arrangement for keeping the bearings cool will probably be found very useful at such great speeds as are necessary with small pumps running under great heads. Under more favorable conditions as to speed, it will probably be found that the greater economy of power when the bearings are of good length, and well lubricated in the usual way, will be an important consideration, while, with proper proportions and good management, liability to heat need not be apprehended.

The arrangement for reducing friction between the surfaces of the disks and casing and the intervening layer of water by simply taking off all pressure will probably be found of less value than was anticipated, unless the experiments of General Morin, which indicated fluid-friction to be independent of the pressure, are less reliable than is generally supposed. The liability to severe grinding between the two metallic surfaces where contact is made, and at the great relative speed at which they run, is a somewhat unpromising feature. The slightest amount of gritty material passing through the pump would entirely destroy the smoothness of all rubbing-surfaces, and with bearings cutting and the disk grinding against the casing, the pump would be likely to be quickly injured beyond repair.

206. In the French section, the centrifugal pumps of MM. NEUT ET DUMONT formed the most interesting collection. In these pumps, the vanes are in form more nearly in accordance with correct principles than were those of some of the other pumps exhibited. They were regularly curved from heel to tip, and were usually comparatively short. Four of them, however, extended to the axis, forming arms by which the whole set were carried. The water entered on each side, thus balancing horizontal pressures on this axis.

The arrangement for preventing the entrance of air through the stuffing-boxes of the shaft was quite neat, resembling somewhat the "lantern brass" of the steam-engines of a few years ago. A space is formed

Digitized by Google

within the journal which stands full of water. Out of this space rises a small pipe which leads to the main pipe. Any air entering through the stuffing-box bubbles up through this small pipe instead of passing through into the pump. One of the most noticeable arrangements in this collection is that for great lifts, in which two pumps are used, the one re-enforcing the other. The water enters one pump and is driven by it into the second, which in turn forces it into the main under maximum pressure.

Dr. F. A. P. Barnard, in his valuable report on the machinery of the Paris Exposition of 1867, describes this arrangement as exhibited there by Coignard & Co., and calls attention to the fact that its successful application is a proof of the entire incorrectness of the idea, until lately entertained, that this class of pumps is dependent upon the action of centrifugal force for lifting-power.

The details of these pumps are unusually well considered. The driving-pulleys are covered with India rubber to prevent slip, as proposed in the United States by Mr. Sutton, of New York. The journals have large bearing-surfaces and are lined with anti-friction metal. The shafts are of steel, as are those of the best makers of other countries. The entrance of solid substances between the revolving disk and the casing is prevented, by properly-placed rabbets. The pumps seemed well proportioned and well made, and their builders have evidently succeeded in doing a large amount of business.

The experiments of M. Tresca show a useful effect of from 60 to 70 per cent., the former being the more usual results for moderate sizes, and the latter being sometimes reached with large pumps steadily working, as in supplying cities with water.

207. In THE COIGNARD PUMP the water enters a cavity which separates the two disks which the pump contains, and the current, dividing, enters at the middle or either side. The arrangement resembles somewhat a pair of the older sort, in which both disks are set on the same arbor. This double disk neutralizes the lateral pressure of the entering current, and this design also takes away all difficulties arising from the existence of shaft stuffing-boxes, where they may permit the entrance of air to the suction-side of the pump. The form of vanes is spiral, only two in number, and of considerable length. The water is not thrown out in the plane of rotation, but passes off laterally at the periphery of the disk into the main pipe. The current is thus divided from the moment of entrance to that of exit, and the designer claims to have succeeded in avoiding a considerable loss of energy which takes place in the other forms of pump in consequence of the collision of the double stream entering the pump and meeting at the center. The pump has given good results.

208. Messrs. NAGEL & KAEMP, of Hamburg, exhibited centrifugal pumps, with the turbines already described. The pumps raised water into reservoirs, from which the wheels were supplied. This pump was

Digitized by Google

the only one exhibited in which guide-buckets were used, the general plan closely resembling that of the turbine. The exhibitors claim a considerably improved performance as the result of this arrangement, but do not give reliable data relating to their performance. Messrs. Nagel & Kaemp do not use check-valves on the suction-pipes of their pumps, but fill them at starting by means of a jet-pump resembling somewhat the Giffard injector, an arrangement which is probably better than a leaky valve, but vastly more inconvenient and also more expensive than a simple float-valve, where the latter can be kept in good order.

209. THE SCHIELE PUMP.—In another design, the Schiele pump, also exhibited in the German section, the vanes or pallets are not fixed between two disks, but revolving unsupported except by the shaft, and the current of water is confined laterally by the casing of the pump. This plan would seem likely to cause unlimited trouble when pumping water laden with sand or other gritty material, which, entering between the vanes and the casing and cutting away both, would rapidly reduce the efficiency of the pump.

210. The most radical and perhaps most interesting departure from the usual form of the centrifugal pump was that of Messrs. BOULTON & IMRAY, exhibited in the British section. The shaft carries a cylindrical barrel, on the exterior of which is a set of straight vanes, quite closely pitched. This is set in a casing which, as the name indicates, is helical in form. The current enters the casing in a tangent line and follows a helical path, sweeping around its circumference and along the casing in an axial direction, crossing the orbit of the revolving blades which give it its motion, and finally emerges through a second opening, also tangent to the cylindrical casing. The action of the vanes or buckets is similar to that of the floats of the common steam-vessel's paddle-wheel. The general design bears some resemblance to that of the pump of Andrews & Brother, so well known in the United States. One of the important differences, however, is that in the latter the helix is also spiral, while in the former the line traversed by the current is at all times equidistant from the axis and is a true helix; the current enters and is discharged at the same distance from the axis. In this case the action is evidently a direct one, and the fact that centrifugal pumps are misnamed is well indicated by this simple illustration of the real action—that of pressure.

At Vienna this pump was driven by a three-cylinder steam-engine. It worked smoothly and well, but no statistics of performance were obtainable.

211. SPECIAL ADAPTATIONS OF THE CENTRIFUGAL PUMP.—The centrifugal pump, so called, is not capable of giving very high duty on even moderate lifts, and cannot compete in duty with those of positive action under such conditions. Its proper place is where low lifts and large masses of water are found. Here it does excellent duty, and in cases of

Digitized by Google

unexceptionally low lifts and great volume it even exceeds other forms of pumps in efficiency. Its low cost, its cheapness of "installation," its lightness and portability all combine to make it the only type of pump fitted for such work. Manufacturers of these pumps, however, are naturally exceedingly anxious to compete with builders of pumping-engines of other kinds, and vie with each other in the endeavor to secure contracts, even where the pump is quite unfitted for the work. As the duty given is too low to permit a reference to it in such cases, they usually avoid even its measurement, relying upon the real and undeniable advantages of the pump to secure its selection in spite of its lower efficiency. In very many cases, even where the lift is considerable, cheapness of first cost, portability, and compactness are more important than extreme economy of power and fuel. The centrifugal pump has, therefore, a wide field, and builders find a ready market for all of the best designs, and they are now constructed in immense numbers.

There is evidently still room for improvement, but American builders are not behind foreign makers. Were the principles of the machine more generally understood, we might expect more rapid changes and much better results.

Digitized by Google

Digitized by Google

Digitized by Google

CHAPTER X.

METAL AND WOOD WORKING MACHINERY.

Metal-working machinery at Vienna; European copies of machinery from the United States; Comparison of British and American practice in tool-making; British authorities on American metal-working tools; Tools of Sellers & Co., of Philadelphia, their lathes, methods of work, and principles of practice; Lathe-construction; The spindle; The cone-pulley; Weight and strength of shafting; Description of the Sellers gear-cutter and slotting-machine; The Pratt & Whitney Company's (Hartford, Conn.) shaper, profiling-machine, milling-machines, gang-drill, revolving-head-screw machine, engine-lathe, cutter-grinder, die-sinking machine, chucking-machine, planer, and special tools; The Browne & Sharpe Manufacturing Company's screw-machines and milling-machines; The Stiles & Parker drop-presses and power-punches; British opinion of American machine-tools; Comparison of British and American methods; Webb's wheel-finishing machine; Other British exhibits; Opinion of an Artisan reporter; French metal-working tools; Swiss tools; Other European exhibits; Wood-working tools; General character of exhibits; American wood-working tools; B. D. Whitney's pail-making machinery, gauge-lathe, scraper, band-saw; Richards, London & Kelley's band-saw; History of the band-saw; Hall's dovetailing-machine, "sudden-grip" vise; J. H. Fay & Co.'s tools; British wood-working tools; Tools of Ransome & Co., Robinson & Co., Worssam & Co.. Powis, James & Co.; French wood-working tools; Perin & Co.'s band-saw; Arbey & Co.'s planing-machine; Austrian wood-working machinery.

212. **Metal-working machinery at Vienna** occupied a large part of the space appropriated to the United States as well as that of European countries, and it is in this department of industry that we observed the closest competition and the finest display of inventive talent and of mechanical skill.

The principal attraction to the professional visitor was found in the exhibits of the firms of Sellers & Co., Browne & Sharpe Manufacturing Company, Pratt & Whitney Company, and a few others from the United States; of Messrs. Sharpe, Stewart & Co., Ransome & Co., and one or two other British firms, and of Messrs. Duconun & Co., of France, all of whom exhibited machinery distinguished for strength, neatness of design, and excellence of material and of workmanship. These firms have also largely discarded the "high polish and deep scratches," which were once the characteristics of much of the work turned out by even the best houses, and have adopted the less flashy but far better tool-finish, which can now be so readily given by the standard machine-tools of the best builders.

There was a considerable number of exhibitors who displayed fine

Digitized by Google

looking machine-tools, but they rarely gave evidence of originality in design, and a practiced eye and the hand of an experienced mechanic, who had been brought up in the recent school of American practice, detected readily the half-concealed file-marks and the inaccuracy of lines and surfaces, which proved them to have been built under a system which is out of date on our side of the Atlantic, and which would not be found had they been made by good machinery in skillful hands and finished with the tools which are now standard in form with us.

213. EUROPEAN COPIES OF AMERICAN TOOLS were seen in every section of the Exhibition. The more striking innovations made by our leading mechanics, where they had been previously exhibited at Paris in 1867, were almost invariably found to have been reproduced by European makers, and were exhibited at Vienna sometimes with, but oftener without, acknowledgment. Sellers's planer, with its peculiar cinematic combination of worm and rack, was one of these tools. The driving and the reversing mechanism were both seen on foreign copies, and the machines were sometimes placarded "*Système Sellers*" as an evident recommendation. Browne & Sharpe's tools were also copied, and all of the systems of sewing-machine combination were found, in *fac-simile* of American machines, among the exhibits of European nations.

It seemed the usual practice of continental firms to copy, with as great exactness as possible, the standard designs of British and American builders. In a few cases the copy was modified to suit the ideas of the copyist or to suit his market. Such cases, however, rarely exhibited success in the attempt to improve, and every departure from the standard design was, in most cases, an evident error on the part of the maker.

There were very few tools by continental makers which were nearly equal to those of the firms first above mentioned, and the advances made by the latter since 1867 were quite lost to the former. The tools now exhibited by our manufacturers are used as models in their turn, and form the starting-point for a new departure. A considerable number of American tools were sold to continental makers, and are probably to be copied at once for the European markets. The character of the work done by the firms named was fully appreciated by the members of the International Jury, one of whom, a distinguished authority in Europe, pronounced them "the leading constructors of the world." The tools most frequently copied were the Sellers planer, the Browne & Sharpe universal milling-machine, and the screw-cutting machine of the Pratt & Whitney Company.

214. BRITISH AND AMERICAN PRACTICE IN TOOL-MAKING differs somewhat, but each nation excels in some respects. The British builders put more metal and less ingenuity into their tools; while the American makers of tools are often distinguished for a combination of strength with lightness, and for a degree of ingenuity in adapting the machine to its work, which appears to the unfamiliar observer very remarkable.

Digitized by Google

The tendency, however, of practice on both sides the Atlantic is toward making heavy, strong frames, free from useless irregularities, and entirely without ornament of any kind; the finish is more generally given by the smooth cut of a well-formed and properly-adjusted machine-tool, and all parts are made to exact size and precisely alike, in duplicating for other machines, by the use of very accurate gauges.

The British practice of building their machinery so very substantially is one which every one admires, and, at first thought, approves, and yet it may well be questioned whether it is, all things considered, good policy in general work. In every branch of manufactures changes are continually occurring, and improvements are being made unceasingly. A time invariably comes when the owner of the almost imperishable machine cannot afford to keep it working, but must purchase a more modern machine, which will do the same work so much more cheaply that it will save its own cost in a very short time. The length of working-life remaining in the older machine, when it is thrown away to give place to the improved form of tool, is then representative of a certain amount of capital which is wasted. This loss is a very frequently-occurring one, but it is a more serious matter in new countries than among older and wealthier nations.

Where both capital and labor are plentiful and comparatively cheap and where ingenuity is not producing very rapid changes, machinery may and should be built more substantially and with a view to longer life than where labor and capital are held at a higher price, and where improvements are rapidly succeeding each other.

Within a few years manufacturers in the United States have learned that the only way to produce cheaply and to make their wares as excellent in quality as is demanded by the consumer, and yet to secure a fair profit, is to manufacture in considerable numbers machines that are precise fac-similes of each other in design and dimension. They have found it necessary to displace manual labor by machinery and to make every part to a standard gauge. Of this kind of work the sewing-machine and gun-making trades afford the best illustrations. The sewing-machine, which now costs the manufacturer $12 or $15, could probably not be made under the now obsolete system for less than $30, or perhaps even $40. The military rifle which is now placed in the hands of the soldier is made with equal economy. The benefit of this change inures to both producer and consumer. The former is able to manufacture and to sell in such large quantities and with so little incidental trouble and expense that his profits are larger in the aggregate than the amount of his capital could have produced for him under the old system. The consumer receives the product at a vastly lower price, and many people who could not purchase at all at the higher price cannot afford to decline purchasing at the lower cost.

In Great Britain there is less seen of this method of manufacturing, but the practice is gradually becoming established, and is now adopted

Digitized by Google

by the more enterprising firms. They are not as well prepared, however, to profit by the advantages which it offers as their American competitors. They have less of that ingenuity and that originality which have become so well known as characteristic of our people, and which, encouraged by our excellent system of patent-laws, has enabled the latter to make such remarkable progress, and consequently their standard machinery usually lacked that remarkable elegance, symmetry, compactness, and fineness of tool-finish which is seen in the best work produced in the United States.

The standard tools of continental builders are such as were accepted standards among our own tool-makers a few years ago, and it seems to have been the fact, from the first, that, while closely following British and American practice, they are always somewhat behind them. Our method, of establishing standard designs and building in quantity, makes it a more serious matter to make a change than under the old system, which enabled the change to be made without incurring much additional expense, and this fact makes it more difficult for the continental builder to make such change.

When the European patent-code shall have been intelligently remodeled and brought into the form which experience in the United States has shown to be so efficient, and when European workmen shall have obtained such a social position and have received such a training that their ingenuity and their ambition and interest in their work shall have brought up the character of workmanship, as well as that of the workman, European makers may be expected to stand fairly beside their Anglo-Saxon competitors. It is of the same material that we make a large proportion of our workmen; the material is good, and only requires proper stimulus and training.

215. British opinion of American tools.—The merit of the tools exhibited in the United States section was fully appreciated and cordially affirmed by all foreign critics. London Engineering remarks:

"Machine-tools of all kinds form a very important section of the exhibits collected in the machinery-hall at Vienna, and there is probably no class in which the examples shown are so numerous. The number of instances in which real originality of design is shown is, however, far from being great, and where it does exist, it far more generally shows itself in the improvement of constructive details rather than in the introduction of machines of entirely new types. For the number of machines it includes, there is in fact no collection of tools in the Machinery-Hall which can compete for real originality of construction with that to be found in the American section. Setting aside the wood-working machinery, which we intend to treat in separate articles, we have in this section three chief exhibitors, namely, Messrs. W. Sellers & Co., of Philadelphia, Messrs. Pratt & Whitney, of Hartford, and the Browne & Sharpe Manufacturing Company, of Providence, all of whose exhibits will well repay careful examination.

Digitized by Google

"Messrs. W. SELLERS & Co., of Philadelphia, are well known as the Whitworths of America, and their exhibits at Vienna well sustain their reputation, both by their designs and the excellence of their workmanship."

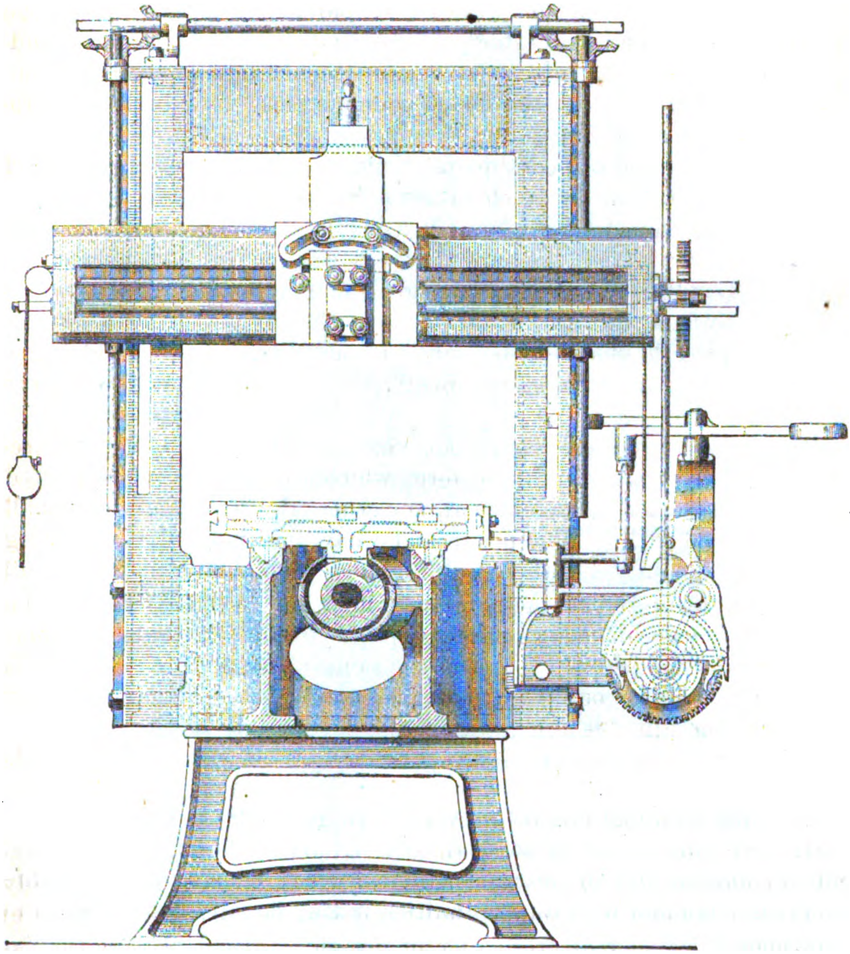


FIG. 83.—The Sellers planer—section of bed and driving-screw; elevation of cross-head and feeds.

216. The most striking and most important of the exhibits of Messrs. Sellers & Co. were their standard planer and their lathes, the new revolving puddling-furnace, a set of rolls, and one of their steam-hammers. They were all well placed and well exhibited, and were inspected carefully by every visitor at all interested in such subjects. Their neatness of design, simplicity of combinations, excellence of proportions in detail, and beautiful material and finish were unexcelled by anything found in Machinery-Hall. Comparing these machines with the copies found in

Digitized by Google

other sections, and which were intended to be fac-similes, the difference already alluded to between the practice of the two classes of machine-makers was seen in a very marked degree. It should, in justice to the atter, be said, however, that a few of the copies were very creditable pieces of work.

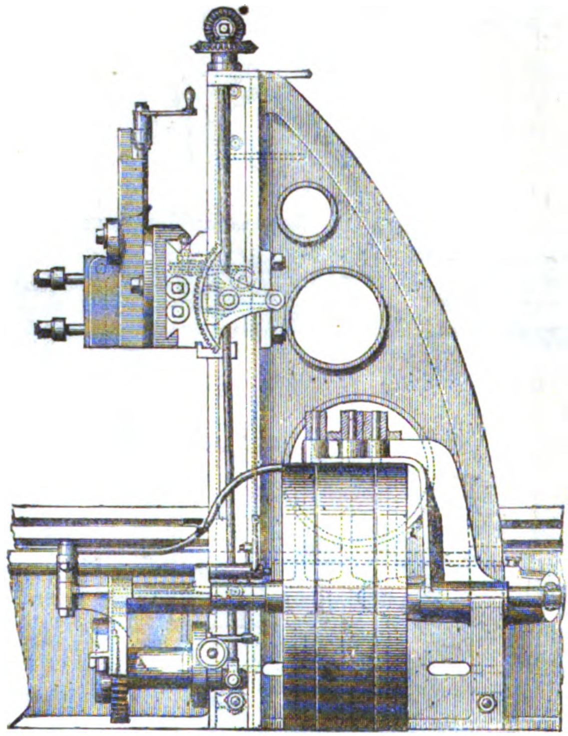


FIG. 84.—The Sellers planer—side elevation.

217. THE SELLERS PLANING-MACHINE (Figs. 83–88) is so well known that, were this report to be read only by tool-builders, it would be entirely unnecessary to describe it, but, for the benefit of the reader who is less familiar with its peculiarities, it may be advisable to describe it in some detail.

The frame, as shown in the figures, (83 and 84,) is of the usual general shape, but it is exceptionally neat and light, yet strong and rigid; the bed is solid and stiff, and the table is well arranged for the securing of the work upon it. The table is driven by a worm, Fig. 85, of which the axis extends diagonally across the machine, and which gears into a rack secured in the usual position beneath the table. The teeth of this rack are not set at right angles to its length, as is usual, and the inclination of its axis is such that the thread of the worm lies fairly between the rack-teeth. An examination of the cinematic action of this combination will show that it gives approximately a rolling contact, and that the friction and wear are consequently reduced to a minimum. This is

Digitized by Google

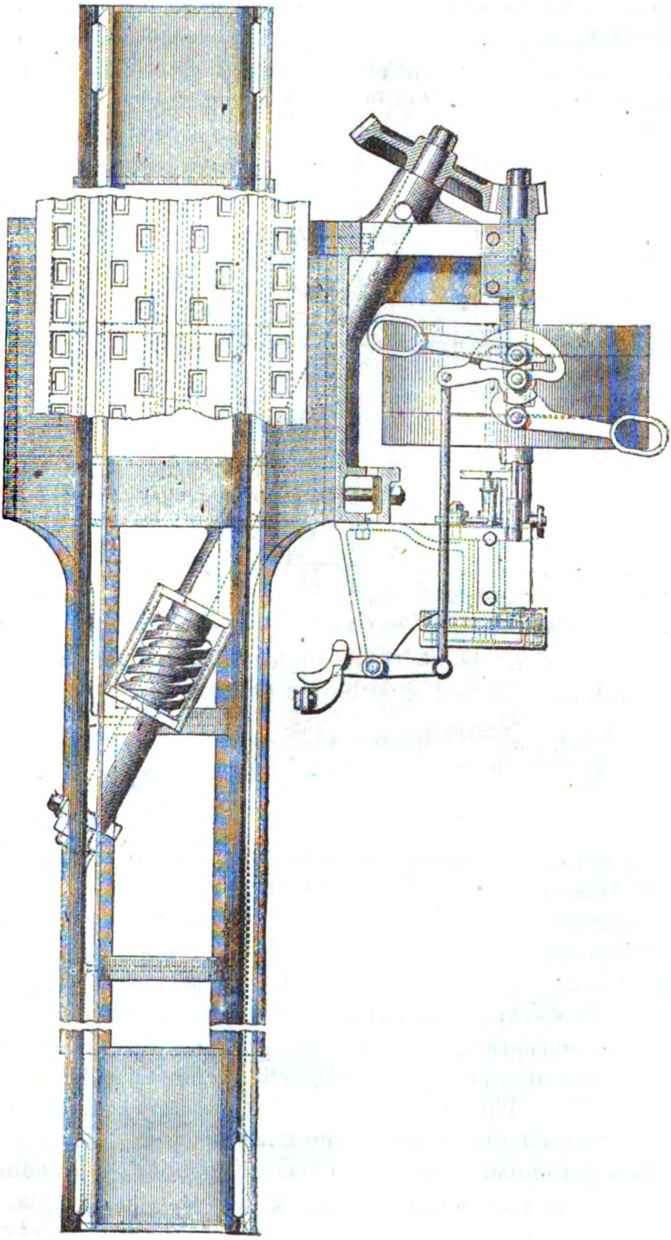


FIG. 85.—The Sellers planer—plan, table removed, showing the spiral gear.

well illustrated by a model shown the writer by the makers a considerable time before their appearance as exhibitors. It is this happy application of this geometrical combination that enables the makers to dispense with the trouble and annoyance incident to the lubrication of the driving-mechanism of the usual form of planer. The transmission of the motion of driving-pulleys to the worm-shaft is effected by bevel gearing so set that the shaft of the former lies in a line parallel with the side of the planer-bed. In the case of the planer driven by rack and pinion, the

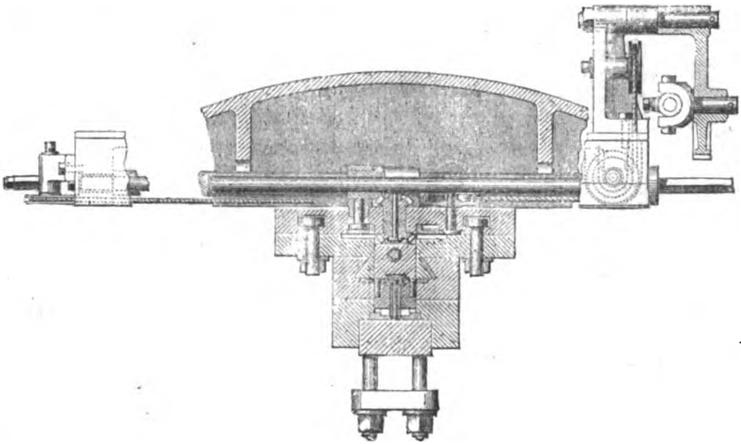


FIG. 86.—Section oi cross-head and tool-holder.

direction of this shaft is at right angles with the fore-and-aft line of the machine, and the tool must be set at right angles to the line of

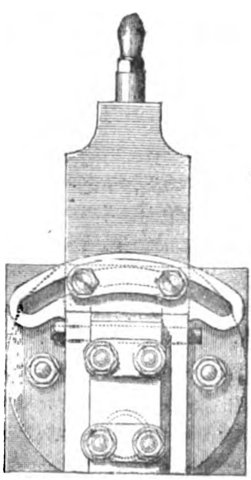


FIG. 87.—Tool-holder—elevation.

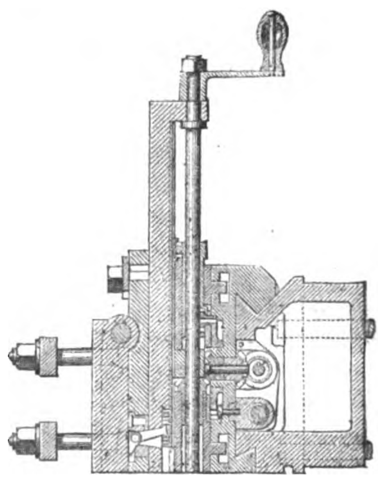


FIG. 88.—Tool-holder—section.

direction of the other kinds of tools in the machine-shop. The Sellers planer stands parallel with the lathes and is belted, and its counter-shaft is arranged as in the case of the lathe.

Digitized by Google

The belt-shifter acts upon the two belts alternately, throwing the driving-belt upon the loose pulley before the other belt is thrown into action. This is done in a neat and positive manner by the use of a sliding cam-bar. The arrangement saves a great deal of power, of wear and tear and loosening of belting, and the annoyance incident to the occasional catching of the table and halting at reversal.

The feed-motion, the methods of raising the tool on the return-stroke, and all other details are equally ingenious and effective. The tool only requires the addition of some such device as the Whitworth tool-holder, to enable it to do work on the return of the table, to make it in all respects better than the finest tool of its class known to the writer.

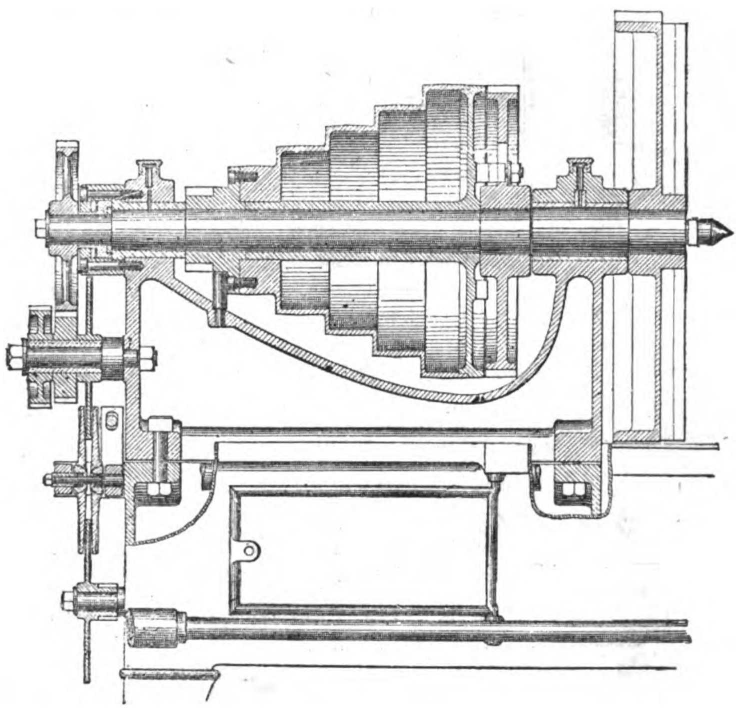


FIG. 89.—Sellers lathe-head—section.

The table of this tool affords the best illustration of the kind of machine-tool finish which has already been referred to. The final touch is given by a broad round-nosed planing-tool, with a coarse feed, and it is left smooth, neat, and absolutely plane.

218. THE SELLERS LATHE (Figs. 89–93) is another excellent example of the work of the firm. It is made strong and stiff by the character of the design, rather than by weight of metal. It has the same simplicity of form and neatness, without extravagance of finish, which characterizes the planer, and embodies some valuable peculiarities. The spindles are identical in form and size, and are ground to finished size in a machine built for the purpose, and in considerable

Digitized by Google

numbers at a time. They are, of course, interchangeable. The feed-motion is adjustable to any speed within certain limits, and with an accuracy which is only limited by the skill of the workman. The adjusting-mechanism consists of a set of mutually-acting friction-disks, and the adjustment is effected by altering, as is found advisable, the relative diameters of the circles of contact by means of a small handle provided for the purpose. The back-stock is fitted with a clamp, which draws it precisely to the center-line, even though a considerable amount of side-wear on the shears has taken place before it is secured down. The spindle is secured, when adjusted in contact with the work, by a clamp which takes on both sides, and thus does not tend to throw the dead-center out of line.

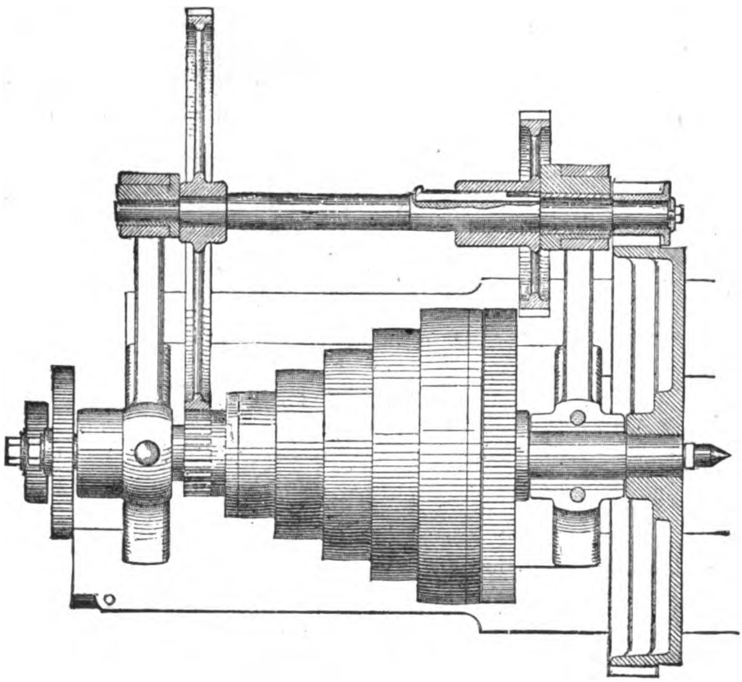


FIG. 90.—Sellers lathe-head—plan.

219. The 30-inch engine-lathe exhibited by Messrs. Sellers & Co. is illustrated in the accompanying engravings. It has, as is seen, the flat-topped bed, instead of the "shear" with V-shaped guides, a form which permits much less wear than the latter. Fig. 89 is a sectional view of the back-head, cone-pulley, and feed-apparatus. Fig. 90 exhibits the same part of the lathe in plan, and shows the back-gear in section. Fig. 91 exhibits the construction of the movable head-stock, with the device for clamping the spindle; and Fig. 92 shows the same parts in transverse section. The sides of the bed are connected by cross-girths at intervals of each 2 feet of length; these have an I-section, and extend from the base of the bed to as near the top as they can be carried

Digitized by Google

without coming in the way of the rest and back-head. Fig. 93 shows the construction of the compound slide-rest and its accessories, including longitudinal and cross-feed motions.

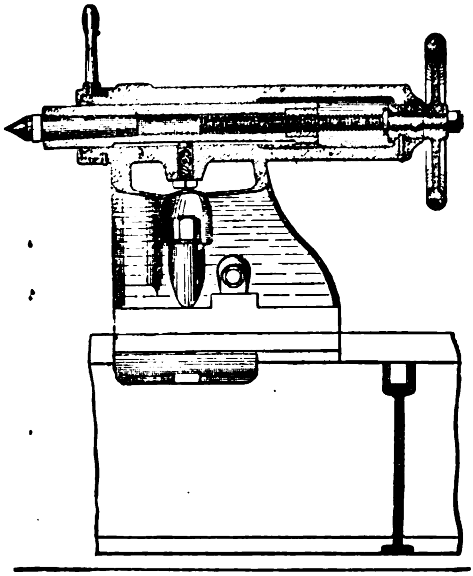


FIG. 91.—Sellers lathe—poppet-head.

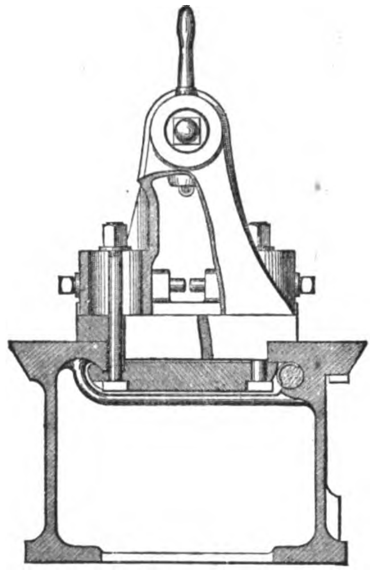


FIG. 92.—Sellers lathe—section.

220. THE PRINCIPLES AND METHODS OF WORK of the Messrs. Sellers & Co. are representative of those of our best tool-builders. They and

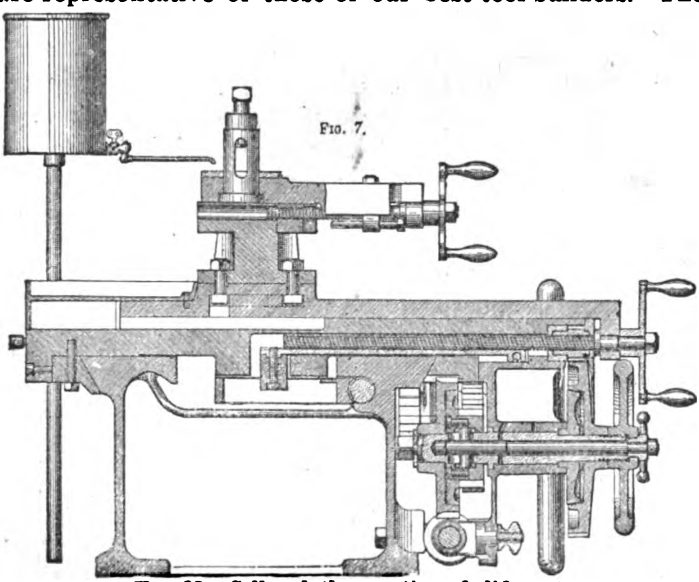


FIG. 93.—Sellers lathe—section of slide-rest.

others have effected very important improvements, within the last ten or fifteen years, by careful experiment and intelligent study of the

Digitized by Google

problems involved in their constructions, and of the methods adopted in accomplishing their work.

To be able to produce a good lathe, it is necessary to know precisely what is demanded of this tool. It must be made as rigid as possible, to secure smoothness of cut and regularity of outline; it must be able to cut a perfect cylinder from irregularly-shaped masses, and it must be capable of producing a perfectly plane surface in the direction transverse to the line of the axes; it must do its work well, without liability to excessive wear, and must even do it well when old and worn. As these builders of our best tools themselves say, it is now necessary to furnish tools with which even inexperienced and untrained workmen, such as are too generally found in our shops, may do good work after very little training. This has a good result in two ways: it permits good work to be done where only unskilled labor is available, and it enables work to be done cheaply where skilled labor is only attainable at high prices, and thus permits the employment of untrained labor on routine work, and sets free skilled labor to attack work of exceptionally exacting character.

221. *The flat-topped bed* is always adopted by the Messrs. Sellers for the reason above given, and in this they have followed British rather than American practice. They say, in reference to their practice in this point, and in the distribution of the cross-girths, that they obtain very much greater nicety of adjustment and fit, greater wear, and very much more stiffness than can be secured in the older form of lathe shear built in this country, without introducing into the latter a great increase of weight of iron. The flat-topped bed gives much greater wearing-surface, and that surface is situated at right angles to the directions of pressure, and is, therefore, better prepared to resist wear; it is more easily finished and brought to size than the V-shaped bed; it gives less span between the points of bearing at the edges of the opening in the bed for the saddle of the slide-rest, permitting the latter to be made lighter or stronger than if fitted up in the other way; it gives a greater "swing," on lathes of equal size, over the slide-rest; this lightness makes the rest easier to move.

The method of clamping adopted with this bed permits a loose fit to be made where the back-head slides between the shears, and this insures less wear and less serious consequences from that wear. A V-shaped guide on the under side of the shear insures accuracy of movement for the clamp and precision in bringing the head into position. This they claim, with good reason, to be one of their most important improvements. The shear as made by these builders is very stiff transversely and in resistance of stresses tending to wrench or twist it, which stresses are the most serious influences tending to destroy the perfection of the work when the lathe is driven at high speeds, and when making heavy cuts. Such strains spring the bed downward and laterally, twist the spindles and the head-stocks, and strain the tool and the tool-post to an

Digitized by Google

extent that is sometimes very serious. A lathe-bed of the form of a hollow cylinder, could it by any possibility be practically used, would best resist such strains. The common lathe cannot be thus mounted, and the form of the bed is largely determined by the arrangements of the several parts of the tool. The skill exhibited by our tool-builders in securing this required stiffness by the modification and arrangement of the bed and cross-girths is remarkably great. The broad flat-topped bed is incidentally useful, also, as a cover and to furnish support in carrying the lead screw along within it, giving it stiffness and exactness of line, and protecting very perfectly from the falling chips and from the dust which settles on all exposed surfaces.

222. *The lathe-spindle.*—As has been stated above, the spindles of these lathes are ground into proper shape, and are all made precisely to gauge. The importance of this method of manufacture will be understood when it is seen that the slightest looseness or irregularity of this little detail may destroy the value of all the labor and all the precaution taken in the making of the other parts of the lathe. If the spindle is irregular in shape, or ground "off center," it will produce a fatal loss of symmetry in the work.

In the Sellers lathes, and in the lathes of the Worcester School of Industrial Science and of some other tool-builders, the spindle is of steel, hardened and then ground into shape, and fitted into boxes of the same material, similarly brought to perfect size and form. With such spindles wear occurs very slowly with fair usage, and the lathe may run a very long time without the necessity arising for taking up play. A provision is, however, made for such adjustment. The bearing at the back end is made slightly conical, and loss by wear is taken up by simply moving it endwise in its bearings by means of the nuts provided for the purpose. The Messrs. Sellers take the end-thrust of the work on hardened and ground steel collars running between hardened and ground steel plates carried on the head-stock. They thus dispense with a "tail-screw," and are enabled to carry the spindle back and make it carry the change-wheels driving the screw-cutting feed.

The cone-pulley is turned, in Sellers' lathes, both inside and out, and is thus very nicely balanced; it is given a very long bearing on the spindle to insure freedom from wear. The changes are made by regular gradation. The arbor on which the pulley is carried is usually, except in very large lathes, of steel hardened and ground to size like the centers. The hole in the end to receive the latter is made with equal care and precision. The face-plate is not only carefully threaded to fit the thread on the arbor, but it is also nicely fitted with a plane bearing surface in the rear of the screw-thread, which insures perfect steadiness as well as absolute concentricity with the axial line of the spindles, even though the thread may become somewhat worn. A "former-attachment" is provided for turning tapers, &c.

223. *The weight of these lathes* does not seem to be as great

Digitized by Google

for similar character of work and in similar sizes as in some other makes, especially of English lathes, but it is evidently ample for their work. With their rigidity and strength, their few adjustments, and their excellence of workmanship, they permit an extraordinary amount of work to be done upon them in a given space of time.

The pulleys used on the counter-shafts are, like those on their main shafting, very light; but they are carefully proportioned and quite strong enough. They are made of selected iron, molded and cast under careful supervision, and are very symmetrical and are well balanced.

224. THE SHAFTING OF MESSRS. SELLERS & CO. was a less generally observed but yet very interesting illustration of their peculiar practice. It was very light, carried light pulleys between bearings arranged in short spans, and the journals were of great length. It was driven at a speed greatly exceeding that of the heavier shafting used in other sections, or supplied by the authorities of the exhibition. Their couplings and their hangers were also in some respects peculiar, and contrasted singularly with the older and heavier styles seen everywhere else in the machinery hall. This method of driving machinery by means of light shafting running at high speed is essentially an American practice. It is seldom seen in Europe. In fact, the European methods of transmission of power have undergone very little change for many years. In mills, heavy gearing, running at slow speeds and carried on very heavy shafting, has been the rule. he expense of its manufacture is comparatively high ; it is ill adapted to the high velocity-ratio required to connect it to the machinery of high speed, now more and more generally used ; it is noisy, and it has many minor disadvantages. In the United States—instead of heavy lines of shafting and clumsy gearing, shafting 3 and 4 inches in diameter and wheels weighing from 100 to 500 or even 1,000 pounds—shafting 1¼ to 2 inches in diameter and pulleys of a few pounds' weight are found amply sufficient, and are in general use. Instead of speeds of 100 and 120 revolutions per minute, 250 is frequently seen, and in at least one instance the writer has seen shafting running at 450 revolutions per minute. With us the belted pulley has almost entirely driven out the older gearing. Even engines of 600 or 800 horse-power drive their loads by a pulley fly-wheel carrying three or four separate wide double belts. Power is a product of resistance into velocity ; the first factor is expensive, the latter inexpensive. Increasing the former and reducing the latter means greater weight, increased first cost, and greater expense of maintenance of the machinery of transmission. The converse practice brings in light machinery and reduced expense. The "telo-dynamic" method of transmission of power, which has been introduced on both continents, is simply an illustration of the same principle carried still further for special purposes.

In the manufacture of shafting, the higher speeds and the light pulleys and belting now used have greatly reduced the first cost where the

Digitized by Google

power transmitted is the same. The system of manufacture now standardized in the United States and practiced by the Messrs. Sellers is the same as that which distinguishes the sewing-machine business. All sizes are determined by gauge, and the shafting and pulleys are made in quantities for the general market, instead of to special order, and of various sizes. This also lessens the price in a very important degree.

The sizes were determined after an elaborate series of experiments, and were made standard, and the shafting was then sold by a schedule in which the weight was not given but sizes and power were stated, and a guarantee was given of their fulfilling the requirements of the purl chaser.

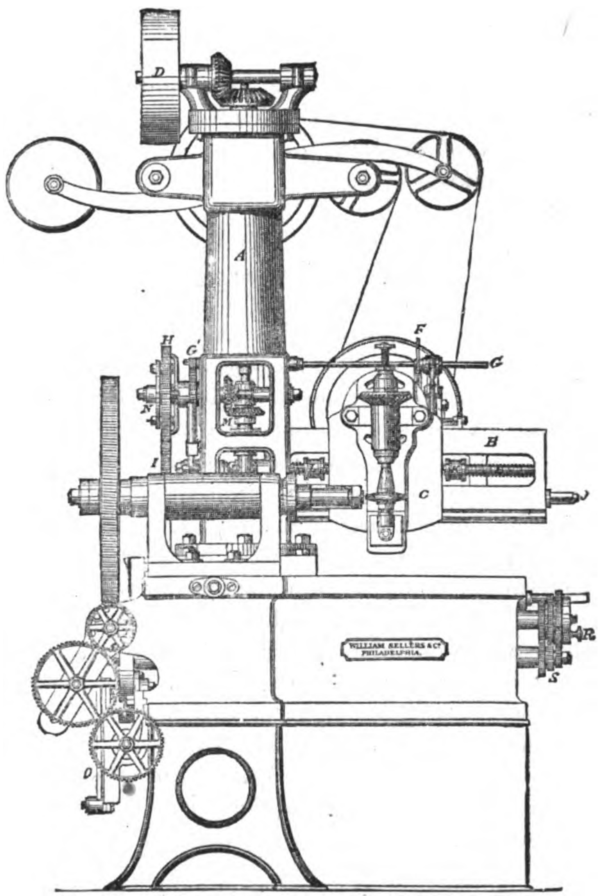


FIG. 94.—The Sellers gear-cutter—front elevation.

The Bancroft hanger, as improved by the makers, is used with the shafting. Its journal is so mounted that it may swivel in all directions and accommodate itself perfectly to the line of the shafting, however great the departure from its proper location. Some slight variation from the correct line is usually unavoidable, and it introduces frequently a very serious addition to the power required to drive the shafting.

Digitized by Google

225. THE SELLERS GEAR-CUTTER.—A very beautiful and ingenious gear-cutting and wheel-dividing machine was exhibited by Messrs. Sellers & Co. This machine is arranged for cutting both spur and bevel wheels, has a capacity up to 54 inches diameter of wheel, 9 inches face, and will cut a number of small spur-wheels of same size at one time. It is entirely automatic, performing all its work after adjustment, without attention of workmen, to the completion of the wheel being cut or divided. The division is obtained by a tangent-wheel and worm carefully constructed. The turning of the handle and all other motions are done by the machine itself. Thus, a blank wheel being put in place and the proper cutter adjusted to depth of teeth, length of stroke of cutter-head, &c., the cutter will pass across the face of the wheel, cutting the space between two teeth. It will then return quickly to the starting-point. The blank will then be turned to present a second space to be cut, and the cutter will automatically start again. One machine is said to do one and a half times the work done by a skilful workman on a gear-cutter operated by hand. In practice, one man can attend to four of these machines.

Fig. 94 is a front elevation and Fig. 95 a side elevation of the machine. An important feature in this machine is that the various movements required to do the work follow each other automatically in regular sequence, each one being dependent on the completion of the motion which preceded it.

In the figures the machine is shown as arranged when cutting spur-gearing. The post, with its projecting arm carrying the cutter-head c, is made to swivel between its base-plate and the cap which carries the driving-pulley, so as to set the arm either parallel to the axis of the wheel to be cut for spur-gearing or at an angle for bevel gearing. It is adjustable to any required position on the bed. Motion is conveyed to the cutter-head spindle from the pulley by means of bevel-wheels to the cone-pulley at the top of the post, and thence by belt over guide-pulleys (one of which acts as a tightener) to the cone-pulley back of the cutter-head, thence by bevel-wheels to the spindle. The cutter-head slides back and forth on the arm, driven by a nut on a screw. This screw is stationary, the nut only revolving, and the train of gearing which moves the nut or causes it to revolve starts from the lower cone-pulley by bevel-wheels, through a set of variable friction-disks, to a shaft, and by a pinion through a sun-and-planet system of wheels to a gear-wheel on the end of a shaft, which passes through the arm below and parallel to the screw, which shaft terminates in the square end. Spur-wheels convey motion from this shaft to the revolving nut. Upon the screw are two nuts which are adjustable on the screw, and are readily clamped at any required position. These two nuts determine the length of stroke of the cutter-head. By means of a crank on the end of the screw within the post, the turning of the screw one way or the other through a small portion of a revolution operates clutches within the post, which

Digitized by Google

determine the requisite motions of proper sequence. Thus, the screw being stationary during the travel of the cutter through the wheel, the revolution of the nut on the screw causes the advancement of the cutter-head toward the nut. When the revolving nut comes in contact with this stationary nut, a tooth in the revolving-nut engages with a tooth on the stationary nut, and turns it and the screw, and as both nut and screw revolve in the same direction at the same time, the forward mo-

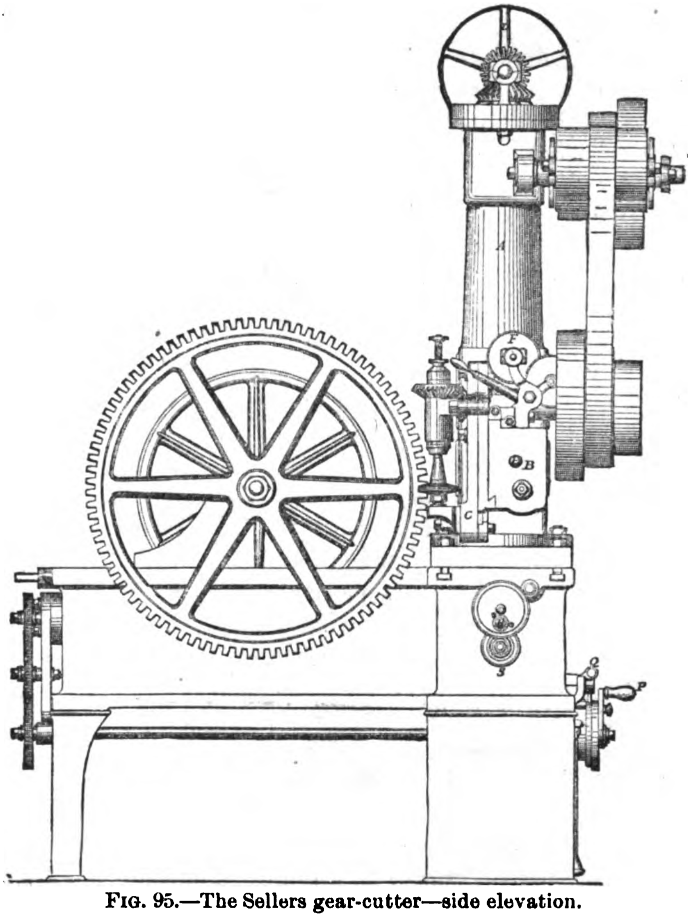


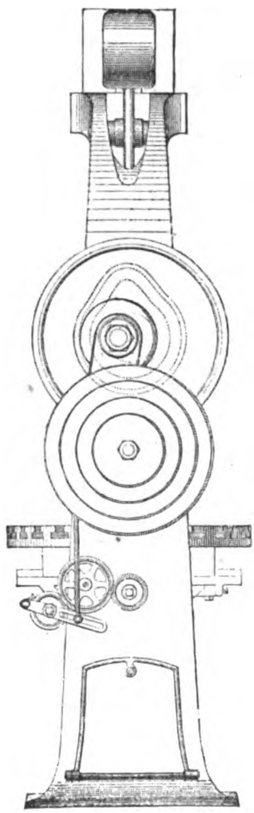
FIG. 95.—The Sellers gear-cutter—side elevation.

tion of the cutter-head ceases and the rotation of the screw operates the device that is to start the next motion, *i. e.*, the running back of the cutter-head to its starting-point. Here it again comes in contact with the nut, ceases its lateral motion again, and imparts a rotary motion backward to the screw, stopping the driving-machinery last in motion and putting in motion the machinery that turns the blank. The completion of this last operation starts the cutter into the work again. Through the center of the column is a vertical shaft, which revolves continually in one direction. The bevel-wheels are held from turning,

Digitized by Google

allowed to run loose, or are driven by the vertical shaft, as may be required. The planet-wheels are attached to a face-plate, this face-plate to one of the bevel-wheels. When the bevel-wheels are held stationary the sun-wheel in the center drives the outer wheel and the feed. If the bevel-wheels run loose, the feed stops.

THE SELLERS SLOTTER.



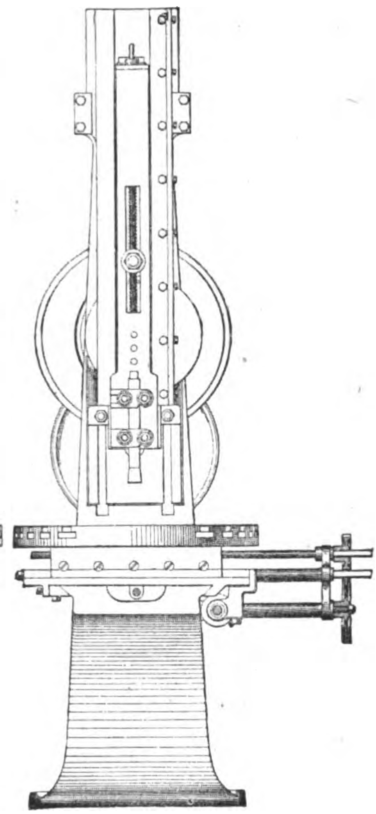


FIG. 96.—Rear elevation. FIG. 97.—Front elevation.

If a rapid rotation be given to the bevel-wheels, they will drive the planet-wheels around the center one, and thus impart a rapid motion to the nut on the screw to carry the cutter back to its starting-point; but when it has reached this point, the wheels are cut loose from this driver, machinery is put in motion within the bed, that, by means of a crank, rack, and pinion, turns the crank-handle, lifting the latch at each revolution. The number of turns of this handle are determined by a pin being placed in one or the other holes shown in the face-plate that controls a nest of gearing. A cam on a shaft within the bed, upon the completion of the proper number of turns of the handle, moves the clutch to clamp the bevel-wheels, and thus starts the feed once more.

This completes the series of operations. Any one of its individual

Digitized by Google

motions may be lengthened or shortened, and yet not affect the others. The failure of any one to act merely prevents the next one from starting, so that no harm can be done the work.

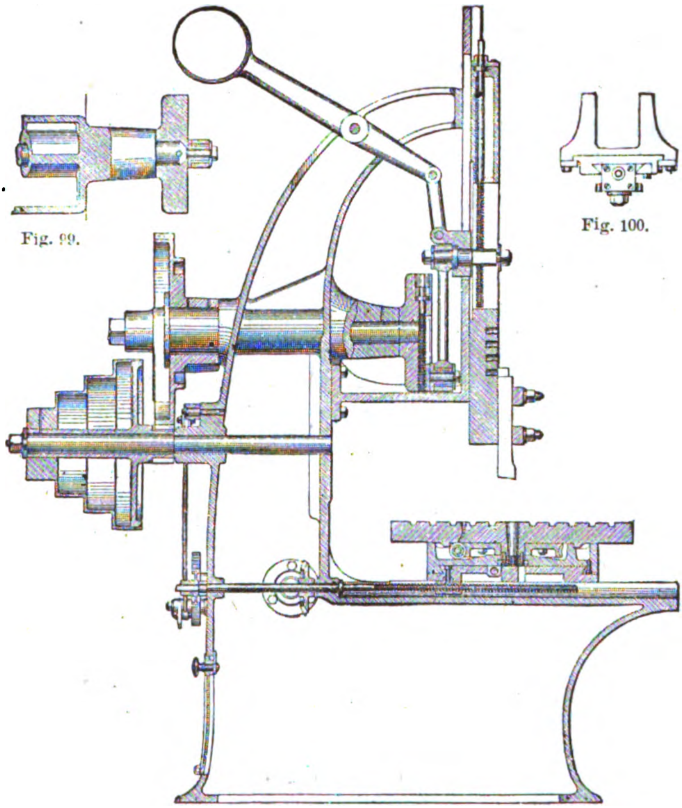


Fig. 99.

Fig. 100.

Fig. 98.—Section.

226. The Sellers slotting-machine.—The Messrs. Sellers & Co. exhibited a 48-inch slotting-machine, (Figs. 96–100.) The slotting-tool is operated by means of a crank driven by the "Whitworth motion," giving a slow movement when cutting and a quick return. The crank is adjustable in length of stroke, the maximum being 12 inches. This adjustment is effected by a screw in the crank-plate. The adjustment of the connection of the connecting-rod with the slotting-bar is obtained by means of a screw, regulating the position of the slotting-bar in height from the table upon which the work rests.

The connecting-rod is attached to the slotting-bar by means of a wrought-iron block connected with a counter-balance-lever. The counter-balance is heavier than the slotting-bar and cutting-tool, so as to take up all lost motion and to steady the operation of the machine under cut. The bearing or slide carrying the bar is adjustable for different heights of work. When the nature of the work will permit, the supporting bearing can be carried quite close to the table, thus giving a

Digitized by Google

firm backing to the tool during its whole stroke and insuring steadiness of motion. The compound table upon which the work is bolted consists of the usual slide-rests with a rotating-table on top of the upper rest, all provided with automatic feeds. An important feature of the machine is the arrangement of its feed-motion, which insures the feed always occurring at the top of the stroke, and never during the cut. The great advantage of this is manifest when it is remembered that should the feed occur at lower end of stroke, the rigid tool will drag back with a pressure due the amount of feed. The working-handles to operate the feed by hand are, on all these machines, within easy reach of the workman, and in such a position as to enable him to readily see the point of the slotting tool as he adjusts the feed, an advantage readily appreciated when the machine is used to slot to scribed lines.

227. The PRATT & WHITNEY COMPANY, of Hartford, Conn., had an exhibit which, although somewhat less extensive than that of Messrs. Sellers & Co., was very interesting, and was reported upon by the International Jury in terms of exceptional commendation. Their tools were a light class of machines, intended for gun-makers and for similar light work. They were remarkable for their excellence of design; each was beautifully adapted to the special work which it was intended to do; the material and workmanship were of the highest class, and the finish was neat and appearance pleasing.

Their screw-machines had already attracted the attention of continental dealers, who had had opportunities of seeing them in several governmental and private European establishments. This firm have for some time supplied their tools to foreign markets. In the screw-machines the rod of which the screws are to be made is clamped in the hollow spindle of the machine, and the dies are mounted on a "turret." The several cuts are rapidly made, the workman setting the bar in position, clamping it by a single movement of the handle operating the chuck, throwing up the turret into position by another motion, and then, setting his machine in operation, a cut is made. The reversal of this succession of movements releases the screw after the cut is made, and a second cut is then taken, the turret being turned so as to bring the next die into action. A cutting-off tool is mounted on the slide-rest, with which the screw is separated from the bar when completed.

The chuck-lathe made by this firm is a very neat, simple, and effective tool for use in turning pieces to peculiar form or for boring them out. Their drills are also of designs original with them, and very excellent tools, and their milling-machine, although not having the wide range of adaptation of the Browne & Sharpe machine, is an exceedingly well-designed and well-made tool, and is even better adapted to general use on plain work.

228. *Descriptions with Illustrations.*—The Pratt & Whitney Company's machines are illustrated in the accompanying engravings.

Digitized by Google

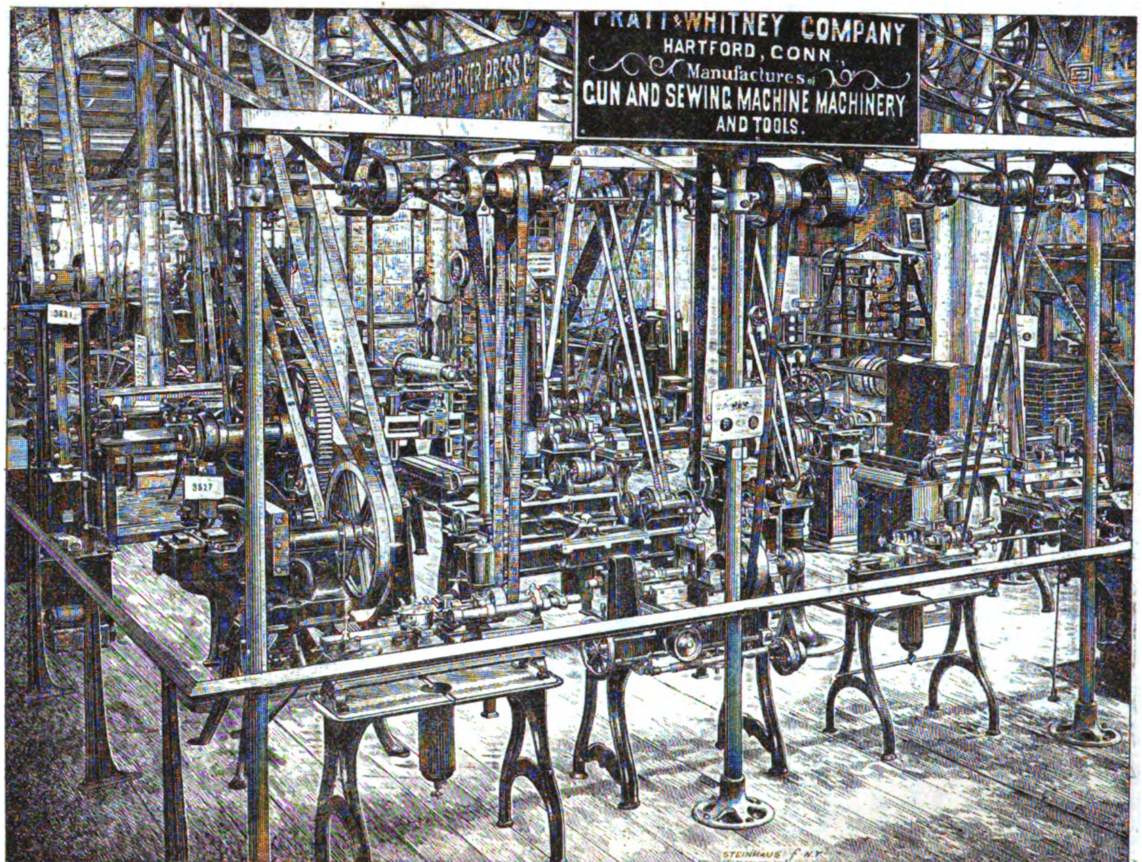


Fig. 101.

Digitized by Google

The ten-inch pillar-shaper (Fig. 102) is also known as the "compound Planer," and, in a large proportion of cases, it is a substitute for the ordinary and expensive shaping-machine. It is particularly well adapted to die-work. The stroke may be graduated to any point within the extreme limit; the tool-bar has a quick return, and the cross-feed is automatic and adjustable. The designation indicates the extreme length of stroke, which is, in this machine, ten inches. All the slides and bearings are fitted carefully by scraping, and the nuts, screws, and wrenches are hardened. The Newell patent vise is exhibited with the machine. It is

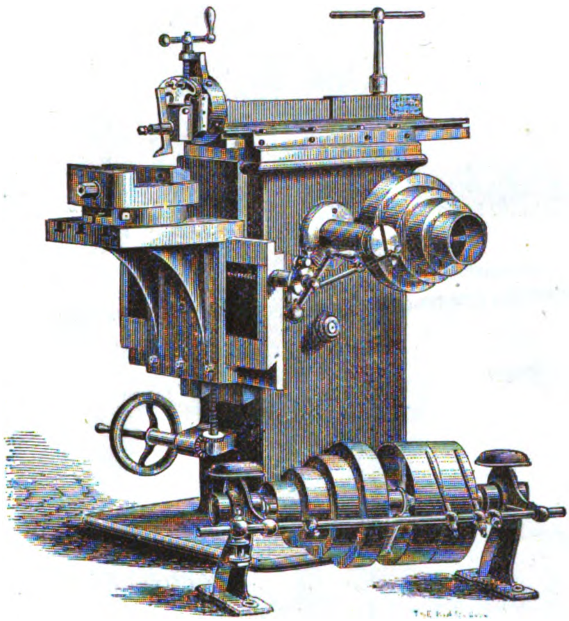


FIG. 102.—Ten-inch pillar-shaper.

intended for holding the work, and has a circular graduated base, and hardened-steel-faced jaws, ground true, one of which "swivels," to present either a straight or a V-shaped slide, the latter for holding circular work. The machine stands on a hollow column, the base of which measures thirty-six by twenty-seven inches, as shown in the figure.

229. The profiling-machine is a well-known and highly-valued tool for cutting irregular forms. The one shown in the engraving (Fig. 103) is a two-spindle machine, and has Parkhurst's patent device for cutting forms without reversing the fixtures. With this improvement, to produce the forming-pattern, the model-piece is secured in the place and position afterward occupied by the work to be "machined," and the piece to be cut for the forming-pattern is placed in the position it will permanently retain. The guide-pin is put in the spindle which usually carries the cutter, while the cutter in the spindle which afterward holds

Digitized by Google

the guide-pin cuts the pattern in the exact position it will retain in use. After disconnecting the gearing upon the spindles, reversing the relative positions of guide-pin and cutter, and smoothing the edge of the forming-pattern, (if this be necessary,) the machine is ready for work.

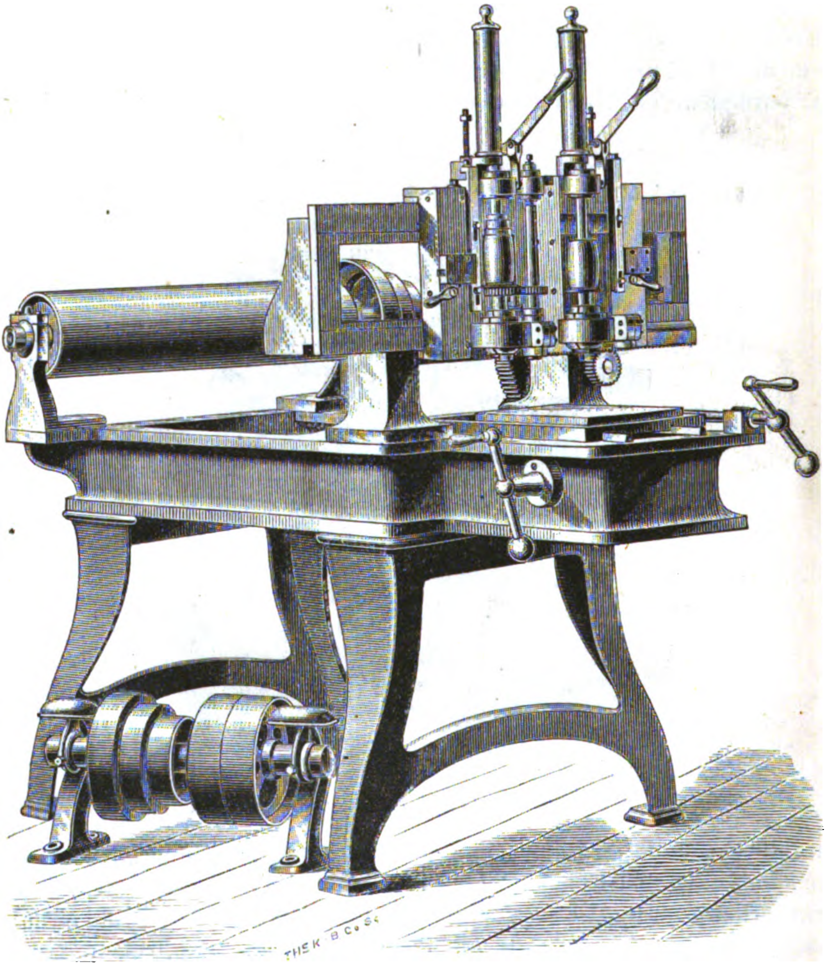


FIG. 103.—Two-spindle profiling-machine.

The gearing for moving the table and cross-slides is adjustable by means of double gears set, to prevent "back-lash," by two independent adjusting-screws, and also by a double rack adjusted in the same manner. This arrangement is indispensable to secure perfect accuracy in cutting irregular forms, especially in turning corners.

Two sizes are made. The engraving represents a No. 2, having an area of table of 15 by 12 inches.

Distance between top of table and under side of cross-head 4½ inches,

Digitized by Google

and between centers of guide-pin and cutter 4⅛ inches. The cutter will profile or surface work to the extreme limit of the table-area.

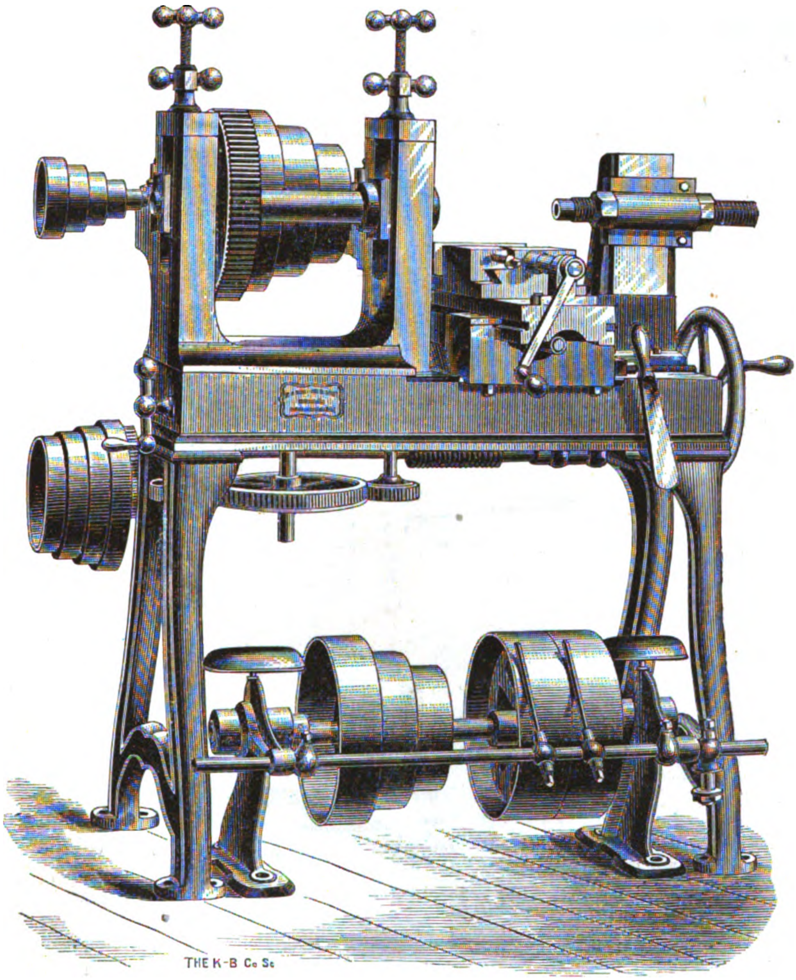


FIG. 104.—No. 2 milling-machine.

230. The No. 2 milling-machine (Fig. 104) is said to be in extensive use in armories and sewing-machine manufactories in this country and Europe and at the United States Armory, Springfield, Mass. It is also excellently well adapted to general work. It has self-acting screw-feed, with four changes of feed; self-acting stop-motion, adjustable at any point; a foot-stock for steadying the ends of long arbors in heavy cuts; a vise for holding work furnished with a permanent crank screw-wrench, and the spindle has a cone for three changes of speed, which may be varied by means of back-gears.

231. The four-spindle gang-drill (Fig. 105) is adapted to a variety of work where many pieces of uniform character are to be furnished, the

Digitized by Google

four spindles having each a separate tool for beginning and finishing holes. The table with the piece to be operated upon is raised either by hand or foot lever, by means of a rack and pinion, and a convenient gauge determines the depth of the hole to be drilled. The spindles are of steel, having two speeds, and the driving-cone has three grades.

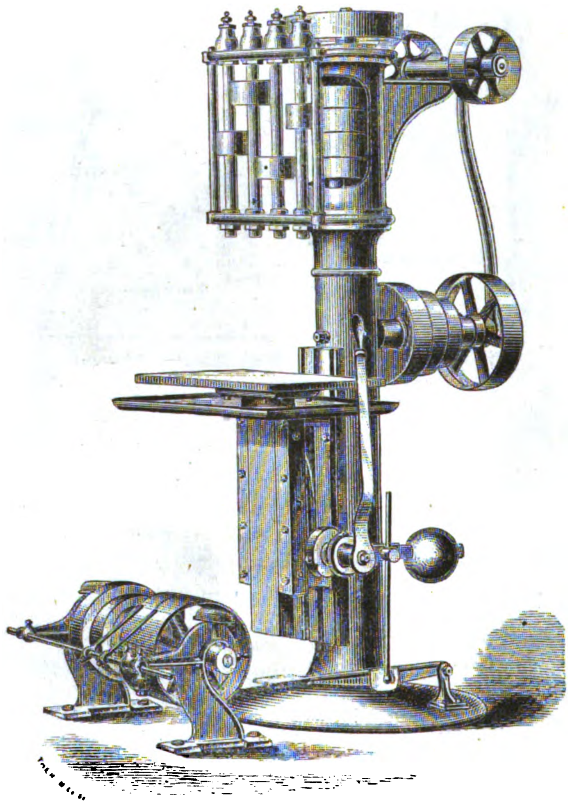


FIG. 105.—No. 2 four-spindle drill.

232. The No. 2 hand-milling machine (Fig. 106) is a convenient tool for general use. It is adapted to a variety of small work. The pieces to be operated upon are moved against the cutter by means of a lever, rack, and pinion. Cutters of ¼ to 2½ inches diameter may be used. The head-spindle is of steel, and runs in boxes lined with "Babbitt metal." The table has a vertical adjustment of 15 inches, and the upper side a movement of 2½ inches vertically, horizontal adjustment of 5 inches to or from the column, and a transverse movement of 5¼ inches. The machine is mounted on a column, the interior of which is a tool-closet.

233. The revolving head-screw machine, with wire-feed, (Fig. 107, is intended to form and finish screws of different sizes and lengths direct from the rod or wire without removing the material or interrupt-

Digitized by Google

ing the process. The revolving head is made to receive six distinct tools, including a gauging-stop to determine the length of the screw. Every operation of making a screw from the rod or wire is successively performed without removal of the work, change of tools, or stoppage of the machine. The Parkhurst wire-feed is operated while the machine is running by a simple movement of a lever, and has any range of length that may be desired. It is adapted to rods up to ⅞-inch diameter. The

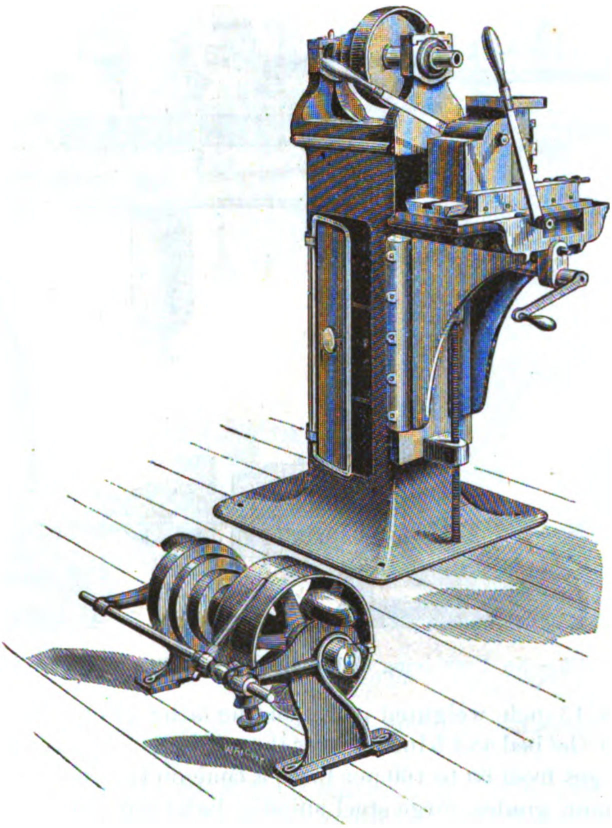


FIG. 106.—No. 2 hand-milling machine.

different sizes of the machine are arranged for forming the thread by dies or cutting them with a screw-cutting tool. A cross-rest for carrying cutting-off tools may be attached.

The engraving (Fig. 107) shows the No. 1 screw-machine, with the Parkhurst patent wire-feed attachment. The device does not seem likely to get out of order, and is a great assistance in facilitating work. It feeds and holds the wire in position without stopping the machine or delaying the work, as the operation of setting forward the wire and firmly clamping it is performed by a single movement of a lever. The turret is of steel, (as is that of the No. 0 machine,) is self-rotating and self-fasten-

Digitized by Google

ing, and the tools are held securely by convenient clamps. The cone has three grades, carrying a 1½-inch belt. The counter-shaft is fitted with Pratt's patent friction-clutch pulleys. Case-hardened wrenches and an oil-tank were with the machine.

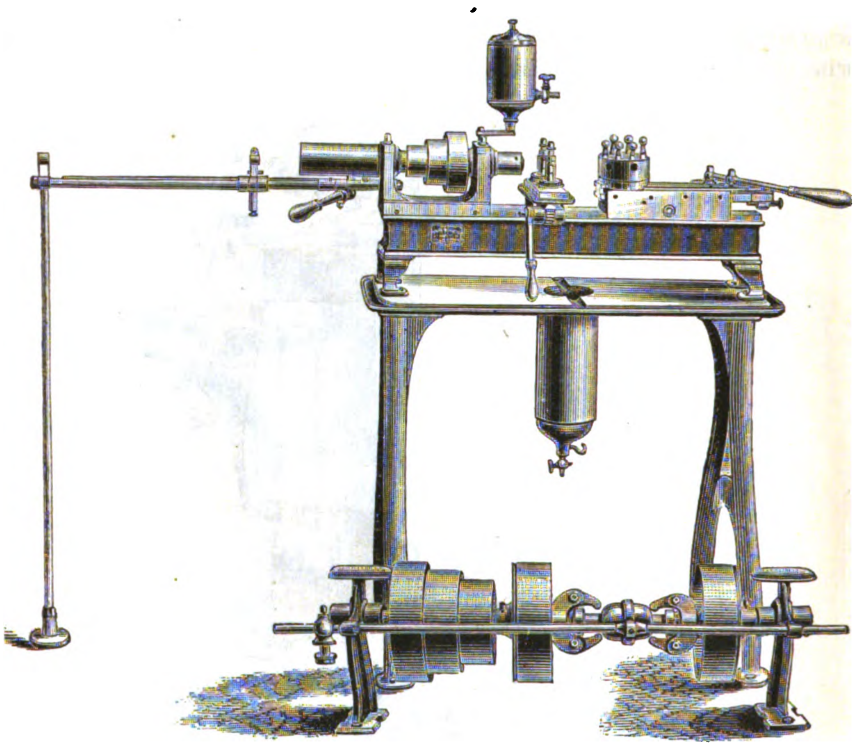


FIG. 107.—No. 1 revolving tool-head screwmachine, with wire-feed.

234. The 13-inch weighted plain engine-lathe (Fig. 108) swings 13 inches over the bed and 6 inches over the carriage. It has a pulley-feed, three changes from 60 to 160 per inch, a cone on the spindle for a 2-inch belt with four grades, large steel spindle, balanced cone turned inside and outside, and the boxes are lined with Babbitt metal, which is compressed after being run into the shell. All the parts are well fitted, insuring accuracy in turning, squaring-up, and boring. The foot-stock is secured in place by a cam-lever, the screws, nuts, and wrenches are case-hardened, and the counter-shaft is furnished with self-oiling boxes. There is a hole through the live spindle to receive rods up to $\frac{9}{16}$-inch diameter for convenience of cutting into lengths for studs, &c.

235. The cutter-grinder (Fig. 109) is a very convenient tool for shops and manufactories in which rotary cutters of any style are used for gear-cutting, milling, or slotting. A columnar support, with a broad base, sustains the spindle-head and the cutter-holder and guide. The

Digitized by Google

platen to which the holder and guide are attached may be adjusted in height to suit the diameter of the cutter to be operated upon. The guide rests against the tooth that is being ground, thus gauging the work perfectly, even though there may be irregularity in the size of the teeth. The machine is adapted to cutters of all sizes and styles of teeth, whether straight, beveled, or spiral. Either small grindstones or emery-wheels may be attached to the spindles.

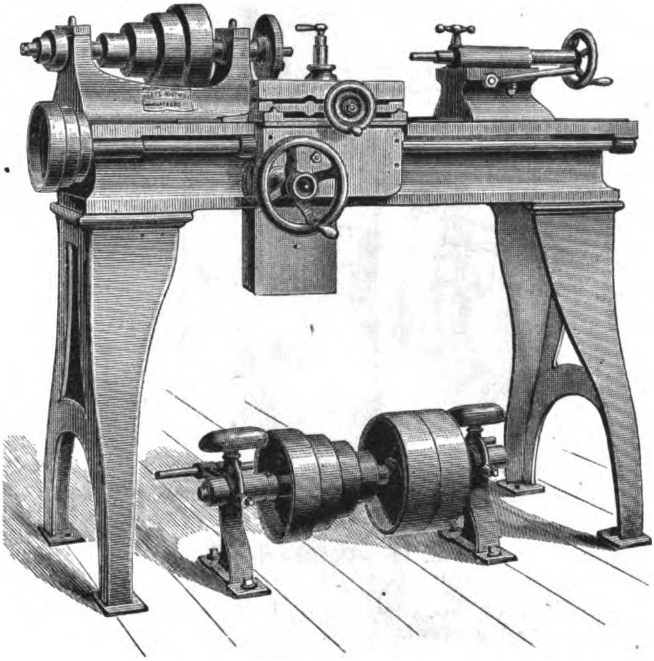


FIG. 108.—Thirteen-inch weighted-plain engine-lathe.

The weight, with counter-shaft, is 425 pounds; stated speed of counter-shaft, 480 revolutions per minute.

236. In operation the die-sinking machine (Fig. 110) is similar to the profiling-machine, the spindle being stationary, and the work to be operated upon being held in a vise, which may be moved in all directions horizontally by compound slides on the table of the machine, and may be elevated or depressed by the vertical movement of the platen or table. The cutter, which may be of any suitable size or form, revolves with the spindle, which is driven by a belt, giving much smoother action than is possible with gears. The work may be guided either by a pattern or forming-piece, or controlled wholly by the operator. This machine is very strongly built, insuring smooth work, freedom from chatter-marks, and is adapted to a great variety of work, being particularly efficient in forming and finishing recesses of either a circular, annular, or irregular shape, and for recessing dies for the drop-press. The differ-

Digitized by Google

ent movements of the vise and platen are independent each of the other, and are perfectly under the control of the operator.

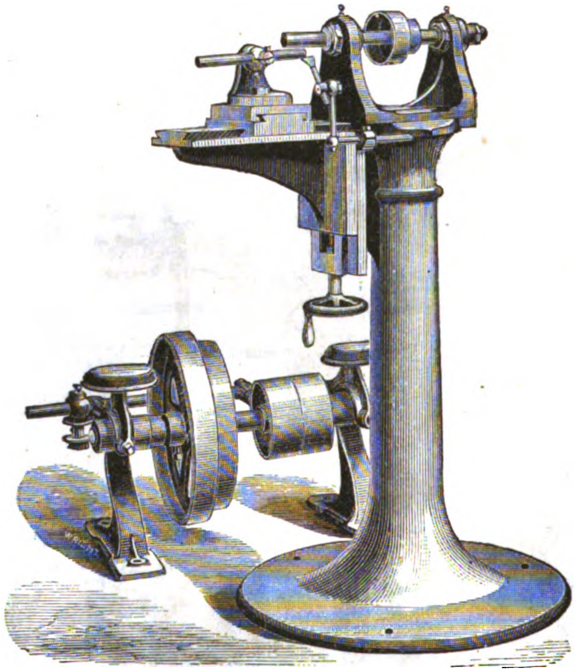


FIG. 109.—Cutter-grinder.

The greatest distance between the end of the spindle and top of the table is 24 inches. The platen has a vertical adjustment of 16 inches, and the horizontal movement of the vise is 10 inches. The counter-shaft has two sets of pulleys, giving two speeds, which may be varied on the spindle by a cone with three grades.

237. The tool represented in Fig. 111 is designed for a variety of work where the piece is to be finished by drilling, facing, and tapping holes without being removed from the chuck or face-plate. The revolving head carries from six to eight spindles for the reception of tools, and each one is brought to the work successively, by a single movement of a lever or handle, and is fed forward by a rack and pinion, operated by a convenient hand-wheel. The machine is rapid in its operation, and very accurate in its results. The number of spindles in the head may be varied to suit the work to be done, and the length of the bed may be increased or diminished, as ordered.

238. The size-designations of the planers indicate the width and height the machine will plane; thus, the 16-inch planer planes 16 inches in width and height, and in length 3 feet 2 inches. The length of the bed, as compared with the length of the table, is greater than is usual

Digitized by Google

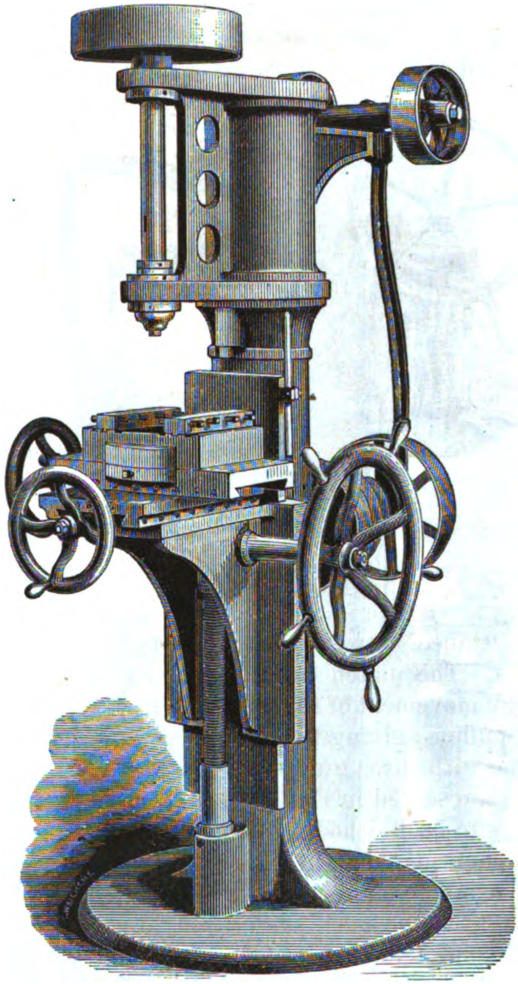


FIG. 110.—Die-sinking machine.

Digitized by Google

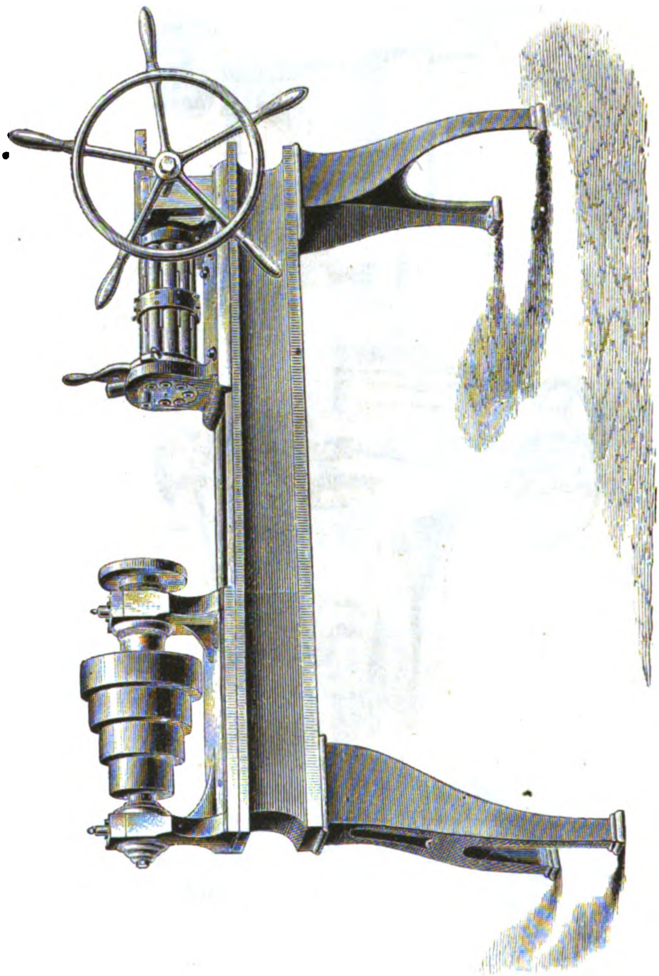


FIG. 111.—The horizontal revolving-head drilling or chucking machine, with eight spindles.

with this class of machines, preventing the tipping of the table from the bed when the rack is run out of gear with the pinion. The shafts are large, gears and racks accurately cut, sliding-surfaces perfectly fitted by scraping, and the nuts, screws, and wrenches case-hardened. This planer (Fig. 112) has automatic cross-feed, patent shipping movement, and movable dog, allowing the work, when desired, to be run either way from under the cutting-tool without changing the stops. Length of bed, 5 feet; length of table, 3 feet 6 inches; length that may be planed, 3 feet 2 inches; weight, with counter-shaft, 1,650 pounds; speed of counter-shaft per minute, 270 revolutions.

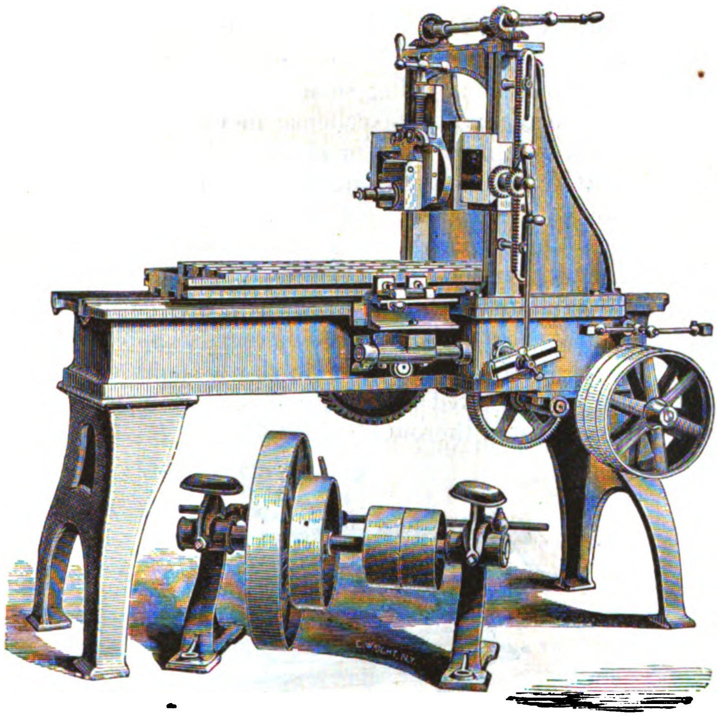


FIG. 112.—Sixteen-inch planer.

239. This firm seem to make a specialty of tools for such peculiar work as that demanded in sewing-machine and gun-making establishments. As has been seen, their tools are most creditable illustrations of this class—a class in which our manufacturers excel all others; and we were fortunate in being thus well represented.

The tools are illustrated with somewhat exceptional completeness, as excellent examples of these peculiar kinds of tools for rapid work on many pieces of usually the same, or nearly the same, form and size.

The modern system of *manufacturing*, as the term is used in contra-distinction to simply *making* on single orders, has given occasion for the designing of an immense variety of these machines of special applica-

Digitized by Google

tion. So great is this demand that many firms, like the Pratt & Whitney Company, are making their supply an important branch of business.

240. THE BROWNE & SHARPE MANUFACTURING COMPANY, of Providence, R. I., was another firm whose exhibits attracted great attention, and won for them unusual distinction. The milling-machines made by this firm were of the very highest order of merit. Their universal milling-machine obtained for them the highest honors at Paris in 1867, and has always been considered as among the finest tools made in the United States or in the world. This machine is, as the name indicates, intended to do an immense variety of work. It is capable of cutting at any angle, either horizontal or vertical, and is fitted up so as to make an excellent gear-cutter. The feeds are automatic, and capable of a wide range of variation in speed. There is probably no tool made which is so universally applicable in doing small work. The screw-machines of this firm are also of marked excellence in every respect, and do a wide range of work with invariable precision and in the most excellent manner. The cutters used on the milling-machines have a very excellent and valuable feature, which is peculiar also to them, that they may be ground, when dulled by use, without loss of form.

241. DESCRIPTION WITH ILLUSTRATION.—The following illustrated description of the exhibited tools of the Browne & Sharpe Manufacturing Company will indicate how well the preceding remarks apply to the design and proportions of these tools. Their finish was most excellent, and every part of every tool worked smoothly and accurately, with a uniform resistance which indicated thoroughly good fitting.

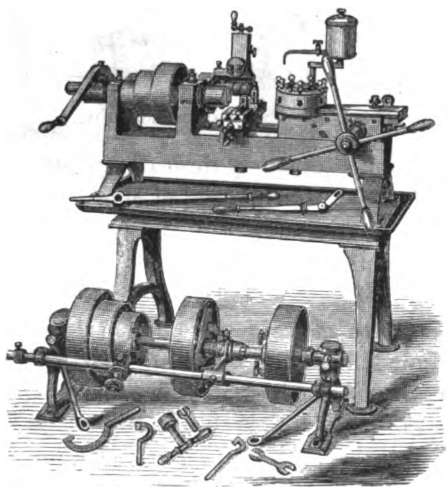


FIG. 113.—No. 1 screw-machine.

The No. 1 screw-machine, here shown in Fig. 113, is a small, compact, handy tool, and is suitable for making from bar-iron all kinds of screws and studs ordinarily used in a machine-shop. One man, with this machine, will, it is said, produce as many screws as from three to

Digitized by Google

five men can make on as many engine-lathes, and they will be more uniform in size. Nuts can be drilled, tapped, and one side faced up, and many parts of sewing-machines, cotton-machinery, gas and steam fittings made on this machine, with a great saving of time and labor. The size of hole through the spindle is 1¼ inches. The size of holes in revolving head is $1\frac{1}{16}$ inches. The length that can be milled is 6 inches. The friction-pulleys on the counter-shaft, are 14 inches diameter and 3½ inches wide. Counter-shafts which run 170 turns per minute are furnished. The weight of the machine is about 1,450 pounds.

242. Their No. 4 screw-machine (Fig. 114) is of a somewhat different pattern, but it is also a very excellent tool. It is of the same general

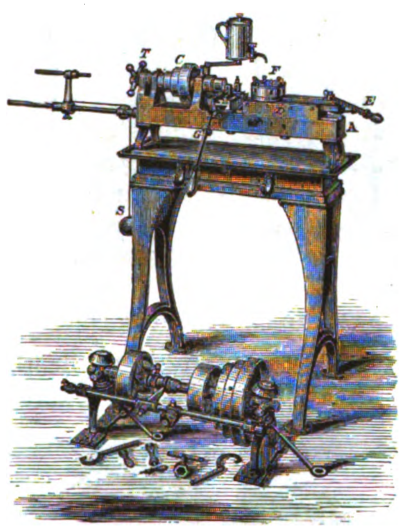


FIG. 114.—No. 4 screw-machine.

construction as the one previously described, but much lighter, and especially intended for making the smaller screws that are used by sewing-machine manufacturers, gunsmiths, and clock-makers. The spindle has a hole bored through it seven-sixteenths of an inch in diameter, and is provided with a patented device for opening and closing the jaws in the chuck which holds the wire from which the screws are made.

This operation of opening and closing the jaws of the chuck is performed in an instant without stopping the machine, and effects a great saving of time in making small screws. The revolving head is made entirely of steel.

The size of the hole through the spindle is $\frac{7}{16}$ inch; the size of the holes in the revolving head is $\frac{9}{16}$ inch; the length that can be milled is 2½ inches. Friction-pulleys on counter-shaft were supplied, of a neat and apparently effective pattern; they are 7½ inches diameter and 2½ inches wide on the face; the counter-shafts run 260 turns per minute.

Weight of machine prepared for shipment, about 450 pounds.

Digitized by Google

243. The "plain milling-machine" of the Browne & Sharpe Manufacturing Company, is exhibited in Fig. 115. It is a very strong, stiff,

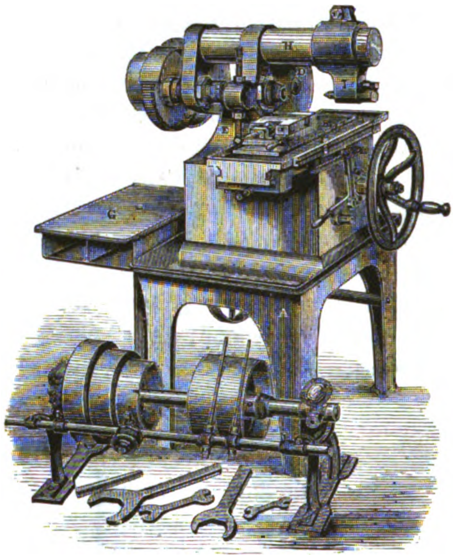


FIG. 115.—Plain milling-machine.

and evidently serviceable tool, and is excellently well fitted for a standard tool in the machine-shop to do plain work.

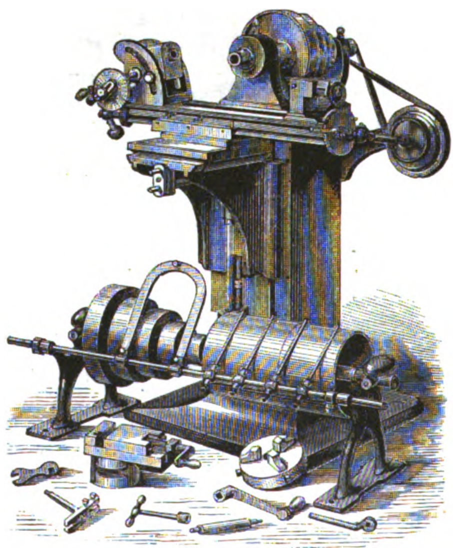


FIG. 116.—Universal milling-machine.

It is stated to be designed for ordinary milling-operations. The spindle is raised and lowered by set-nuts upon the screw C, and moved horizontally by nuts on the front box. The table is fed automatically, the feed being disconnected by the adjustable stop E. The spindle of the machine is provided with anti-friction bearings and arrangements to close up as wear takes place. Attached to the stand is a table, G, for holding work, tools, &c.

The whole length of the table is 28 inches, and whole width of table is 9½ inches; the distance of feed of table is 18 inches, and the height of center above table, at the lowest point, is 2⅝ inches; the height of center above table, at the highest point, is 6 inches; the vise-jaws are 5 inches long and 1 inch deep.

244. The most beautiful machine in this collection, however, was the "universal-milling-machine," the same tool which attracted so much attention and secured so high an award at Paris in 1867. (Fig. 116.)

The machine has all the movements of a plain milling-machine, and the following in addition: The carriage moves and is fed automatically, not only at right angles to the spindle, but at any angle, and can be stopped at any required point. On the carriage, centers are arranged in which reamers, drills, and mills can be cut either straight or spiral. Spur and beveled gears can also be conveniently cut. The head which holds

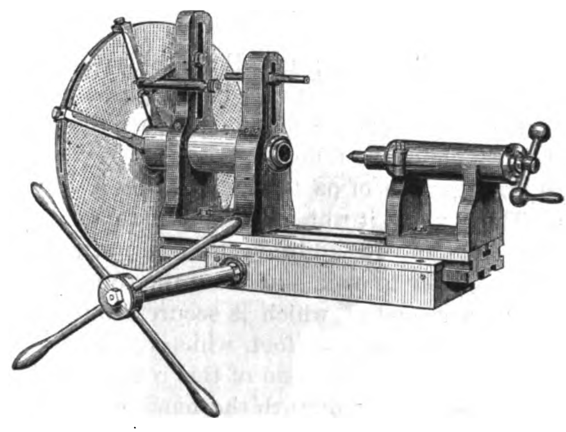


FIG. 117.—Gear-cutting attachment to the universal milling-machine.

one center can be raised to any angle, and conical blanks placed on an arbor in it cut straight or spirally. Either right or left hand spirals can be cut. The pulleys on counter-shaft are 14 inches in diameter, and the whole width of the three 15 inches. The counter-shaft runs 110 turns per minute. The weight of the machine, with overhead work, prepared for shipment, is about 1,500 pounds.

The machine, with the attachments just exhibited and enumerated, is capable of doing an immense variety of work which cannot be done conveniently or well by the ordinary standard machines. Its extremely

Digitized by Google

accurate workmanship and its convenience of adjustment and operation make it a most valuable addition to the usual machine-shop plant.

The writer has had ample opportunity to study this machine, as fitted up in the workshop of the Mechanical Laboratory of the Department of Engineering of the Stevens Institute of Technology, and has been unusually pleased with its beautiful workmanship; its remarkable range of application and the excellence of work done by it.

The machine is also furnished with a gear-cutting attachment, (Fig. 117.) This is designed to accelerate the operation of cutting gear-wheels and for cutting larger and heavier wheels than can be cut with the ordinary apparatus belonging to the universal-milling-machine. It swings 13 inches, and is furnished with a 20-inch index containing 4,294 holes. It will divide all numbers to 75 and all even numbers to 150. Arbors fitted to the universal-milling-machine can be used in this attachment. The screw with set-nuts over the spindle is designed as a support for the wheel while being cut.

The collections of the three firms above described were unrivalled in the whole Exhibition, and were commended, by all who saw them, as equally admirable in design, material, and workmanship.

245. Messrs. STILES & PARKER, of Middletown, Conn., exhibited a collection of tools for various uses. The most interesting were their presses.

The Hotchkiss and Stiles drop-press (Fig. 118) is of that class in which the hammer is raised by a stiff belt or a board passing up between two friction-rolls. The improvements of this drop are those of Mr. Bennett Hotchkiss; the firm claim the following:

1st. Such an arrangement of parts that it makes a very excellent jobbing-hammer. They expect it to take the place, to a great extent, of all other kinds for forging. In addition to the upright rod, which is operated by the hammer to open and close the rolls, they have placed another rod, the lower end of which is secured to the end of a lever, which is operated by the hand or foot, which operation also opens and closes the rolls at will. The lower end of this rod has a slot, so that the action of the hammer will not disturb the hand-lever, thereby preventing the hand being injured, as otherwise would be the case.

2d. No dog is used on the upright to hold up the hammer. The belt or board passes up between two clamps, situated under the rolls, so arranged that as the hammer ascends they will freely open themselves, but on descending they will close and hold up the hammer. To let the hammer fall, the clamps are opened by pressing upon the foot-treadle.

3d. The board or belt is secured to the hammer by an elastic connection, which prevents the sudden jar, and its consequent destruction. The back is made adjustable to different thickness of board or belt, as also are the clamps. An adjustable collar on the upright rod allows the operator to obtain any height of blow desired automatically. If one blow

Digitized by Google

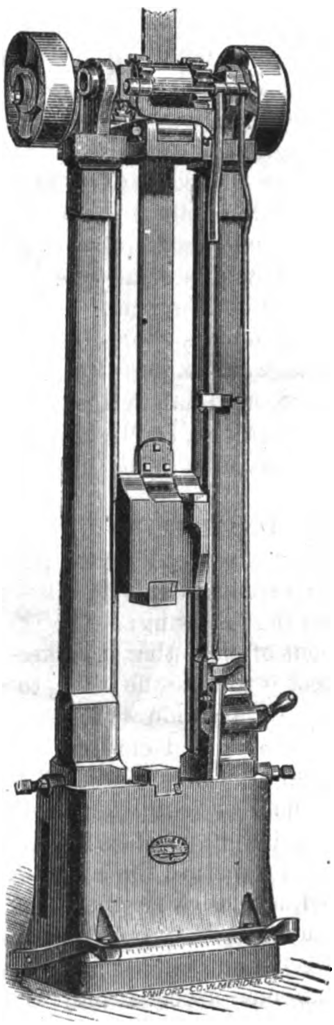


Fig. 118.—The Hotchkiss or friction-roller drop, with Stiles' improvements.

Digitized by Google

is wanted, he first presses upon the treadle, then removes the pressure as soon as the blow is given. Keeping the foot upon the treadle, the blows are repeated until the foot is removed. If a blow of less height than the collar is set for is required, the hand-lever is used, giving any

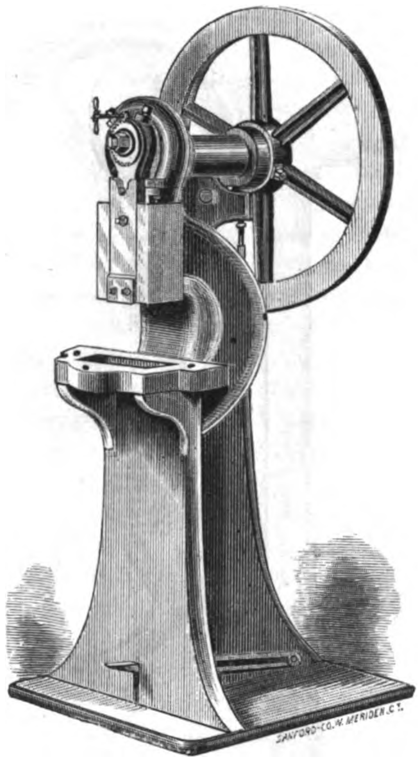


FIG. 119.—The Stiles power-punching press.

height of blow desired. The hammer can be held up at any point below the collar by bringing the hand-lever into action when the hammer is at the desired height, so that the next blow can be given from a state of rest of less height than the collar is set for. This is a feature, it is said, which no other drop has; thus the first blow struck can be of less height than the second or third, and obtained from a state of rest. A gentle pressure of the foot upon the treadle will allow the hammer to go down slowly, but it will stop and remain suspended at any point as soon as the pressure is removed.

The clamps holding up the hammer keep the board from touching either roll, and this prevents them from being worn unevenly.

246. Fig. 119 represents the Stiles power-punching press, as exhibited by the same firm, and Fig. 120 illustrates the construction of a much more powerful tool of the same kind. These tools are neat and

Digitized by Google

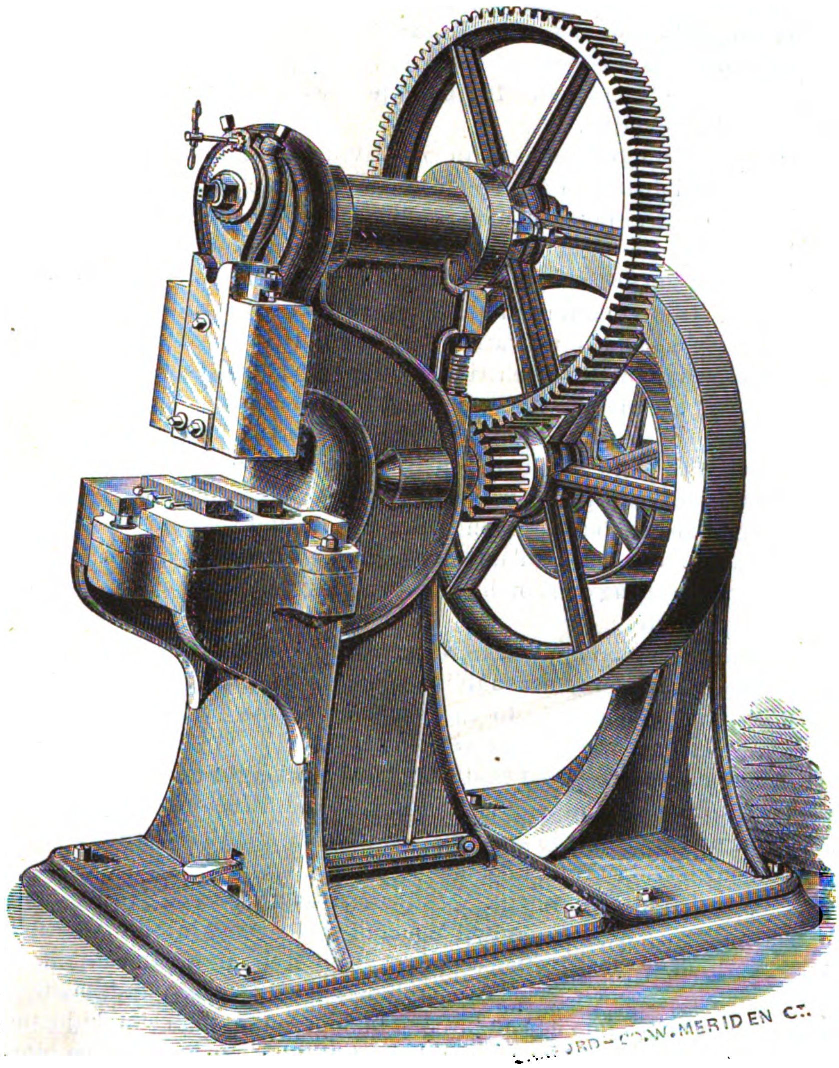


FIG. 120.—The Stiles power-punching press.

Digitized by Google

substantial in design, well built, and possess some decided advantages over older forms of press.

It is important that the press should be so arranged that it may be stopped after a single revolution and at the top of its stroke, in order that the work may not be spoiled by the return of the die before the workman brings it into the right position for the succeeding action of the punch, and in order that there may be the greatest possible amount of room for the adjustment of the piece. Many ways of accomplishing this result have been tried. In these presses the device is very simple and perfectly effective.

The upper end of the pitman or driving-rod carrying the slide is bored out sufficiently to receive an eccentric which fits the crank-shaft snugly, but which may still slide freely. This eccentric is turned by a small pinion on the head of the pitman, which pinion is turned by a handle projecting at the side. Turning the eccentric, the punch is raised or lowered, still remaining in rigid connection with the driving-shaft. The length of stroke is not varied, but the limits of throw are altered by the full range of the eccentric. When it is turned down the punch rises clear of the metal to be punched, then descends through it and into the die. When turned up, the punch still rises and falls, but never descends so far as to strike the plate or the piece of metal which the workman is adjusting upon the die. These parts are of steel, with bronze (gun-metal) bushings on the crank-pin and shaft, which may be replaced whenever worn. This gives great accuracy of action without throwing the bearings out of line or bringing any extraordinary strain upon the machine.

The automatic stop applied to these machines is an excellent improvement. The punch may not only be stopped at the highest point, but also with the punch close to the sheet when the workman wishes to secure unusual accuracy of adjustment.

The manufacturers stated that they have built eight thousand of these presses on orders in the United States, and had filled orders for government and private shops in nearly all European countries, the Prussian government having taken fifty machines.

247. BRITISH CRITICISMS OF AMERICAN DESIGNS.—The distinguished British authority already quoted concludes a survey of the American tools, of which the description has just been given in greater detail, by remarks which are of the most complimentary character, and, made as they are by a writer who has no interest in doing more than simple justice to our countrymen, and who would naturally be expected to be influenced, if in either direction, by a natural prejudice in favor of British tools and tool-builders, are likely to prove most gratifying to every citizen of the United States.

The friendly criticism, at the same time made, is well founded, and will be received in the same fair spirit in which it is given.

London Engineering remarks that the American metal-working tools

Digitized by Google

"are of special interest, and that they are decidedly characterized by great originality of design. In this respect they are, in fact, distinguished beyond any other collection of machine-tools at Vienna, each tool shown in the American section being a specialty of its makers, and embodying a greater or less number of ingenious devices, which distinguish it from the production of other firms. The workmanship, too, of the various machines shown is excellent, and every care appears to have been taken to insure accuracy. The only fault, in fact, which we have to find with the American machine-tools is that some of the frames are not what they should be. With a few exceptions—and notably Messrs. Sellers, whose frames are excellent—our American friends are apt to run a little wild in the matter of frames, and we miss in their designs the solidity and simplicity which distinguish the productions of our leading English firms. Hollow or cored frames are not so largely used in the United States as they are now with us, and the ribbed frames which are adopted, although probably amply strong enough for their work, are apt to be distinguished by many unnecessary curves and twists, which certainly do not add to their rigidity, and which we cannot regard as lines of beauty. This is especially noticeable with the legs for supporting the smaller machines. In the design of machine-framing there is, however, we believe, a steady improvement taking place among American makers, and we expect that in a few years the productions of all the leading firms will be as good in this respect as they undoubtedly now are in other and perhaps more important details."

The same periodical, in commenting upon the exhibit of machinery in the United States section of the Paris Exhibition of 1867, remarks of the machines of Sellers & Co.: "In the designs it would be difficult to point out any precise English original; there is nothing but the mode of distributing the material, and the manner in which most of the details are constructed, which shows Mr. Sellers's really intimate acquaintance with English practice. In every other respect there is a decided originality about these machines, placing them upon a totally different level from mere imitations, and giving in many instances to Mr. Sellers the credit of having originated some of the most useful specialties of tools now to be found in English workshops."

248. What is here said of Sellers & Co. is also true of nearly all American manufacturers who sent their goods to Vienna. American ingenuity and the American system of manufacturing in large numbers and with exchangeable parts, and the use of special tools, are well recognized throughout Europe, and are noted by all engineering papers. Builders of machinery from all countries, and professional engineers of every class, stated that the United States section was to them, small as was the collection, a mine of wealth in its combined originality and excellence of both design and construction. The only real competition is between American and British builders, and here it is extremely close, as it should be expected to be between what are really divisions of the

Digitized by Google

same nation. Could we combine more thoroughly British solidity and thoroughness of work with the distinctive excellencies of the work of our people, we should never find dangerous rivals. The Germans are not unlikely, however, to develop ultimately such a combination of characteristics, and we may well congratulate ourselves as a nation that so large a proportion of our foreign population is coming from Northern Euope.

The criticism of American machine-tools given above was taken from a British journal as, in the main, very just, and as coming from an unprejudiced foreign authority of well-recognized standing. The following are remarks made by the same authority upon the British exhibits:

"Leaving the American collection, and passing on to the British section we cannot but be struck by the difference in the character of the exhibits. In the American department almost every tool possesses some novel feature, and each is distinguished by an individuality which shows it to be the special design of its maker; while in the British section the great majority of the tools are reproductions of old and well-known patterns, possessing scarcely any interest whatever as exhibits. Messrs. Sharpe, Stewart & Co., of Manchester, show, it is true, a collection of tools which, as far as good design and workmanship are concerned, are all that could be wished for; but we could have wished that the exhibits of this firm had been accompanied by others from our other leading makers."

249. THE BRITISH METAL-WORKING TOOLS were usually well designed and splendidly constructed, of the best material.

The firm of SHARPE, STEWART & Co. were not as fully represented as a subsequent visit to their establishment indicated that they should have been. In their exhibit was a Sellers planing-machine, of which the Messrs. Sellers themselves need not have been ashamed, but with some slight modifications of design, which were, perhaps, of doubtful value. Their slotting-machines were fine tools, but demand no detailed description. Their shaping-machines and their drilling-machines were of the best proportion and the finest workmanship.

The WEBB WHEEL-FINISHING MACHINE, for trimming out the insides of the rims of railway-wheels, was one of the best tools here. The forged wheel is a somewhat awkward piece to finish up.

The machine was designed by Mr. Webb, of the London and Northwestern Railway Company, and is of some value as assisting in an important degree by trimming out the inside of the wheel rim between the spokes. It is shown in the accompanying sketch, Fig. 121. It consists of a strong bed, like a lathe-bed, on which is mounted a horizontal face-plate which may be rotated by means of a worm acting upon a screw cut upon its periphery. On this face-plate the wheel is carefully set so that its center may coincide with that of the plate, and it is then clamped firmly in place. At the extreme end of the bed-piece is mounted a train of gearing driving a disk which carries a pin. This pin engages the arm of a lever, giving it a slow rise and quick return-stroke. On the

Digitized by Google

opposite side of the fulcrum is an arm carrying the tool-holder, which is thus made to vibrate in an arc of proper radius to shape the interior of the wheel-rim, giving the desired convexity. The position of the face-plate is determined by the size of wheel to be planed up, and is adjusted by a screw traversing the bed, like the feed-screw of a lathe, and moved by a handle at the end.

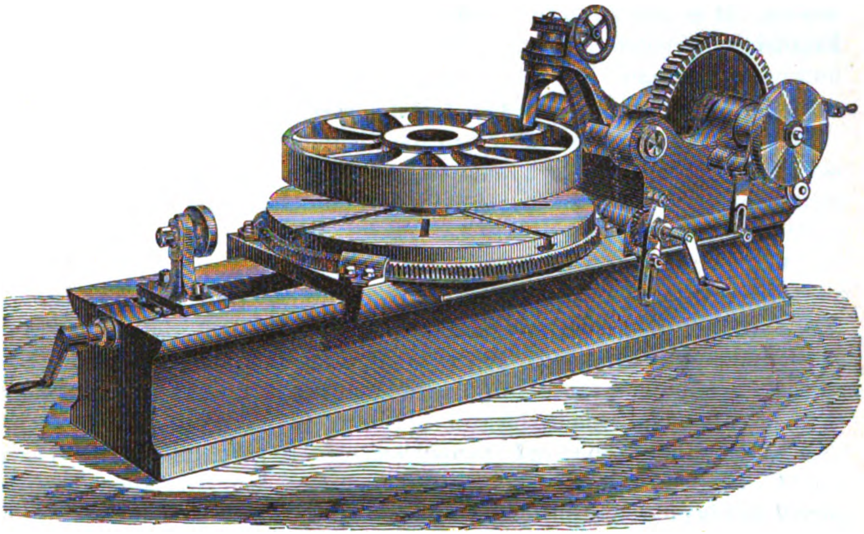


FIG. 121.—Webb's wheel-finishing machine.

250. Messrs. C. DE BERGUE & CO. displayed one of the finest collections of machine-tools in the machinery-hall. They were best represented by their boiler-makers' tools, of which they seem to make a specialty.

Their punching-machines were heavy tools, and drove their punches through the heavy iron plates without the slightest springing and without the slightest check in their movement. The shears were equally strong and well made. The most interesting tool was the rivet-making machine. It was, however, less perfect than those which our own mechanics are familiar with, and deserves mention principally because of its substantial design and its excellence of material and workmanship.

Messrs. HIND & CO. exhibited some plain, strong, well-built tools, which were evidently intended for hard service, and, although well made, were by no means extravagantly finished. They exhibited no noticeable novelties in design, and there seemed to be no points in their practice which might serve as models to our own builders.

Messrs. NEW & CO. exhibited a good collection of tools of common forms and of plain finish. The work on them was fairly done, and the tools were such as would find a good market among dealers in low-priced machinery. Their railroad-axle and wheel-turning lathes were excellent tools.

Digitized by Google

The British exhibit of machine-tools was not what it had been hoped and expected that it might be. The reason given for the non-appearance of many well-known firms and for the small collection of tools exhibited by those who did present themselves was the fact that tool-builders had been extremely busy for many months preceding the opening of the Exhibition, and had been unable, frequently, to fill regular orders. It is greatly to be regretted that so few of the most celebrated English and Scotch makers were represented, and that out of a vast number of new and important improvements which have lately been made by them, but a very small fraction should have been exhibited.

251. The "Artisan" reporter to the British "Society for the Promotion of Scientific Industry" remarks, in his report to that society on machine-tools: "I may say that I was very much disappointed with the exhibits from our own country."

* * * * * * *

"Comparing the whole of the English exhibits with those of Germany and Austria, we are entirely put in the shade. I am glad to say that this country was very badly represented, and must not be judged by her exhibits at Vienna, or else, in place of standing A 1, she will sink below Germany, Austria, and America."

A careful inspection and comparison of all exhibits in this class would, however, indicate that the last-quoted writer was somewhat too severe in his judgment of his own people.

252. FRENCH, BELGIAN, AND SWISS METAL-WORKING TOOLS.—In other sections there was comparatively little which requires description.

The French tools possessed neither the substantial character of the British nor the peculiarly ingenious adaptation to their work noticed in American tools, but many of them were of good design and elegant form, and were very well finished. In the French section, there was an extraordinarily large display of machinery for the manufacture of chocolate, and of soda-water, and of soaps, some of which were remarkably ingenious and very efficient.

Messrs. DANDOY-MAILLARD & CIE, makers of light machine-tools, exhibited some very good machinery, and some of the tools very ingeniously adapted to special purposes.

L. DENY exhibited a collection of presses and mint-machinery of excellent design and construction. The finish was the best seen in this section. Their coining-press was driven by friction-wheels arranged to reverse promptly, and they worked admirably. The products of these presses were coins and various kinds of peculiarly-shaped pieces, such as are more frequently made in the United States by means of the drop-press, and also what are sometimes designated as "Birmingham wares." In many cases, they were beautifully executed. Each member of the jury was presented with samples of this work and of medals struck off in their presence.

MM. LAMBERT & CIE exhibited nail-making machinery, which was

Digitized by Google

well made and did good work. As the best work of this kind is probably done in the United States, it is unnecessary to describe this exhibit.

MM. BARIQUAND & FILS exhibited the finest collection of "*fraises*"—rotary cutters for milling-machines—that the writer has ever seen. They were equally remarkable for their variety of form, excellence of workmanship, and cheapness. The exhibitors state that they represented, in material, workmanship, and finish, their standard marketable products, and that equally excellent cutters were invariably furnished at the prices given in the catalogues furnished to the jury.

Belgian tools were, in character, intermediate between those of France and of Great Britain. They were usually of excellent character.

The principal exhibitor was the firm of BEDE & Co., of Verviers, who also exhibited a large collection of textile machinery. There were, however, no new designs.

An Alsacian firm, the proprietors of the Ateliers Ducommun, exhibited some of the best tools in the Exhibition. Some of them were of original design, and all were of excellent material and fine workmanship. Among their tools was a copy of an American screw-cutting machine, which was an acknowledged fac-simile; but as it was a fac-simile in excellence of construction as well as in design, its presence was a compliment to the original manufacturers with which they may justly feel pleased.

253. RIETER & Co., of Winterthur, Switzerland, exhibited most creditable work, and of designs which were in some cases novel; in other instances, they were very nearly fac-similes of tools well known in the United States. This Swiss work was generally excellent. The most noticeable machine was a large and heavy drilling-machine, in which the drill-spindle was mounted on a traversing-head, somewhat resembling that of a planer, which head was made capable of sliding laterally, with a reciprocating movement, for the purpose of working out slots. This traversing motion was given by a revolving disk, recessed into the main cross-head, or girder, which disk carried a pin connected by a rod to the drill-holder. The motion of the disk was obtained by a very neatly-arranged train of mechanism, which attracted much attention from the jury.

254. OTHER EUROPEAN TOOLS.—The firm of Pfaff, Fernau & Co., of Vienna, exhibited a considerable collection of tools of good design, and of unusually excellent workmanship.

Zimmermann, of Chemnitz, Saxony, and his rivals, Schmalz and Hartmann, presented collections of tools, of which the designs were evidently British and American. They were of good material, and usually of most creditable finish.

Bede & Co., of Verviers, Belgium, exhibited the best work from that country. Belgian work stands only second to the British and American.

The Swedish section contained some very good tools, of designs which were in several instances of American origin. They deserved more con-

Digitized by Google

sideration than they received. They were usually of designs familiar to American mechanics, and chosen with an intelligence that indicated an appreciation of their best points. The material was apparently excellent, as might be expected of the country which has the reputation of producing the finest iron in the world. The workmanship was good, and the finish was appropriate, sensible, and satisfactory.

Digitized by Google

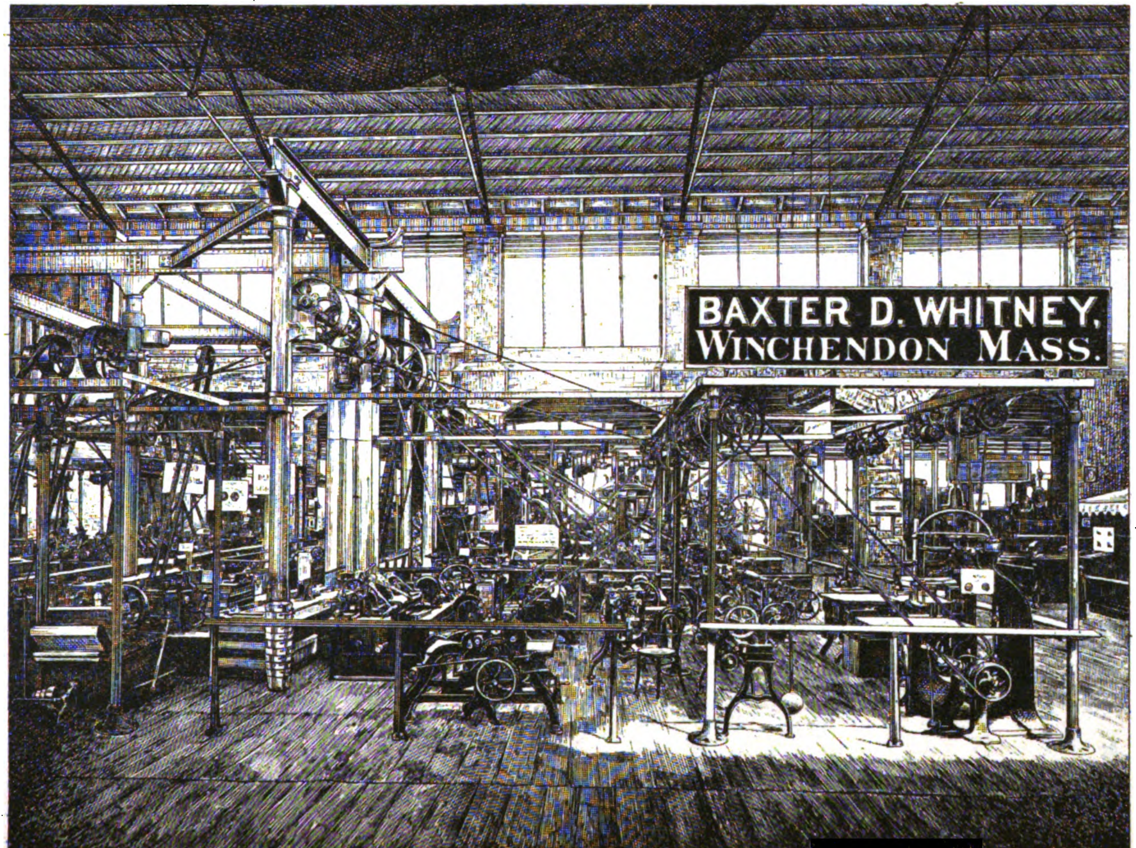


Fig. 122.

WOOD-WORKING MACHINERY.

255. The same characteristics which are observed in the study of the metal-working tools of the several nations are also seen in even a more marked degree in the wood-working machinery.

Here, also, the sharpest competition was between the builders of the United States and those of Great Britain. The several principal types of wood-working machinery are probably of British origin. American mechanics have, however, originated a vast number of machines for special purposes, and have so improved many machines which have been long known that they are almost to be regarded as new tools.

British and other European builders have copied extensively from our own makers of tools, and have frequently modified the designs. In such cases, British makers have sometimes improved the machines by strengthening and stiffening them, enabling them to do more and heavier work, while adding somewhat to their cost. Continental builders have rarely improved these tools while copying them; and having copied them in some cases with modifications, they have exhibited an unhappy facility of detracting from their efficiency where it was intended to improve them.

256. GENERAL CHARACTERISTICS.—The first notable distinction, this difference in the weight and solidity of British and American tools, strikes the eye of the mechanic at once. The former are also invariably painted with plain colors, while the latter are sometimes most elaborately adorned with a variety of colors, which offend the eye by their intensity, their inappropriateness, and their inharmonious arrangement. The forms of the tools from the United States, and their general design, indicated, by their variety and their special characteristics, the wonderful variety of wood-working to which they must be adapted to meet the demands of purchasers in this country. European tools were in less variety and were more generally intended for a few standard applications.

The British "Universal Joiner" is a form of tool much less frequently seen in the United States. It consists of a combination of several tools mounted on a common frame. For example, a circular saw, a planing-machine, a molding-machine, a mortising and a tenoning machine, are frequently all made to form parts of a single complex tool. The combination makes a very compact machine, and its cost is less than would

Digitized by Google

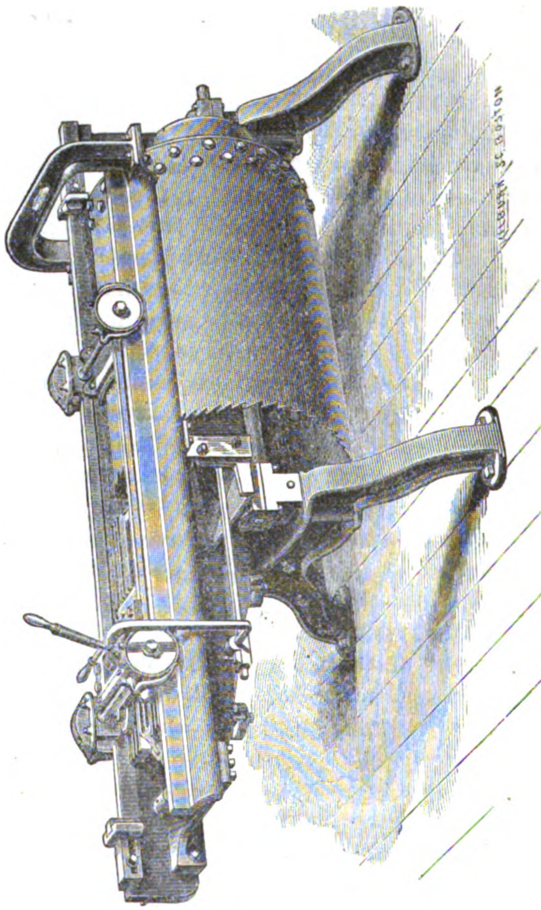


FIG. 123.—B. D. Whitney's cylindrical saw.

Digitized by Google

be that of the several machines if built separately. It would not suit the purposes of large establishments, but probably answers well for small shops. This was the most noticeable wood-working tool in the British section.

257. AMERICAN TOOLS—B. D. WHITNEY'S PAIL-MACHINERY.—Taking up this class of machinery in greater detail, space should be given for an extended description of the pail-making machinery of Mr. B. D. Whitney, which attracted more attention from visitors than probably any other collection of machinery in the exhibition, and which was remarkable alike for its ingenuity in general design, its richness in original details, and for the perfect adaptation of each machine to its special work.

There were two of these machines, one of which resembles, however, the universal joiner above described. The other machine was a cylindrical saw, (Fig. 123, page 248.) A steel cylinder, of the thickness proper for a saw-blade, and having teeth cut at the outer end, was carried at the extremity of a well-supported horizontal spindle. The length of the cylinder was somewhat greater than that of the pail for which it was to cut the staves, and its diameter such that it gave them the proper concavity or convexity of surface. Staves were first taken "in the rough" to the cylindrical saw, where, mounted upon a rest having a motion parallel to the axis of the saw-spindle, they were cut into shape. They were given the proper bevel by a saw mounted on the larger machine, the rest being mounted on a horizontal spindle, of which the center line held the same position relatively to the stave that the center line through the pail would have when the stave was finally fitted in its place.

The length of the stave was next made right by passing it between a pair of circular saws mounted on the same arbor; and finally the grooves for securing the bottom were cut by a revolving cutter in a lathe in which the pail was first put together in a hollow chuck, finished inside, the top edge properly beveled, and the upper hoop forced on. The bottom was turned and put in place, and the other hoops being driven on, the pail is taken out ready to receive the handle and then to go into the market. Somewhat similar methods are adopted in the barrel-making machinery made by the same ingenious mechanic.

258. In Mr. WHITNEY'S "GAUGE-LATHE," (Fig. 124,) for turning exceptional shapes, three cutting-tools are used: one for turning the stick to a rough cylindrical form; a second to rough out the irregular outlines wanted; and a third to smooth-finish it. The second cutter is caused to approach or recede from the line of centers by a templet, against which the tool-holder rests and along which it slides. The roughing-tools are of the usual V-shape. The finishing-tool is a long blade, set at an angle with the center line of the lathe in order to take a smooth shaving. Its edge is given such a shape that it finishes the work accurately.

The piece to be turned is supported between centers by a ring, and

Digitized by Google

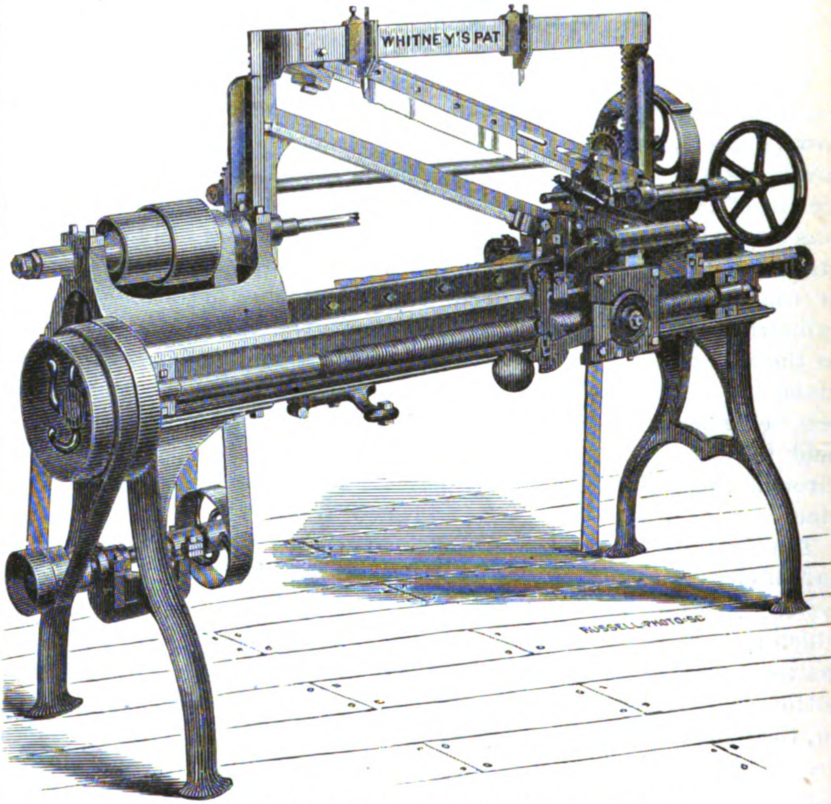


FIG. 124.—B. D. Whitney's automatic turning-lathe.

Digitized by Google

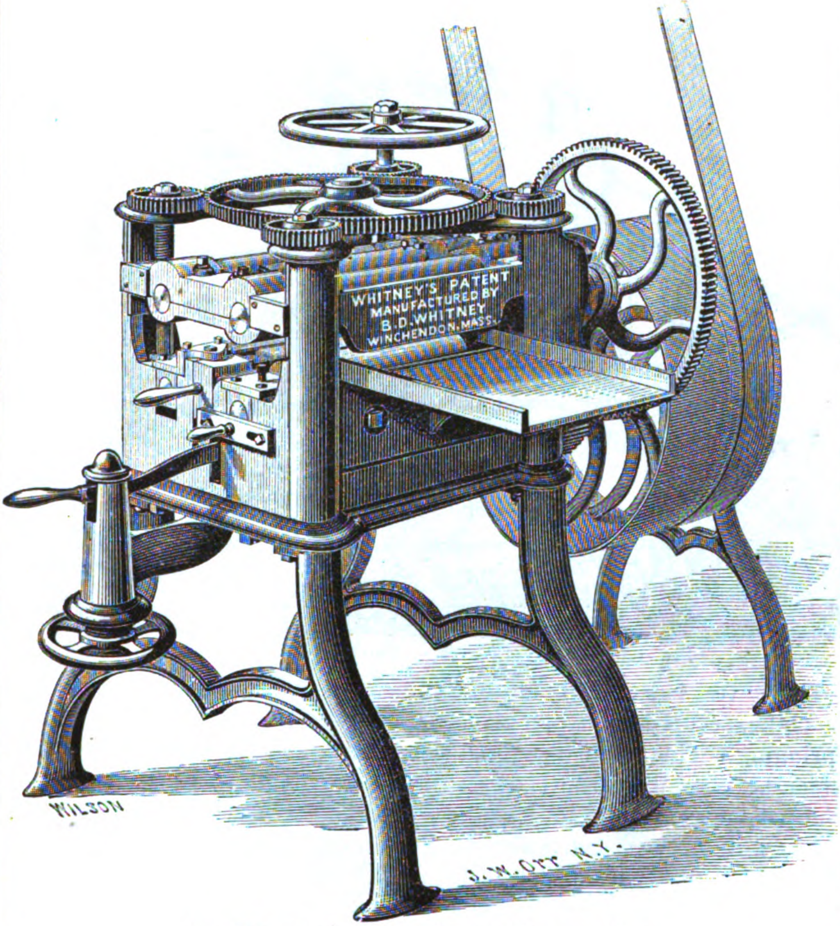


FIG. 125.—B. D. Whitney's smoothing-machine.

Digitized by Google

the workman is thus enabled to turn a comparatively long and slender stick. The movement of the slide-rest which actuates the cutters is checked at the end of its throw by a self-acting stop.

259. WHITNEY'S SCRAPER.—Another original design by the same exhibitor is his "scraper," a machine for giving a fine surface to hard woods, particularly where the grain is irregular. This is a planing-machine, in which the wood is carried by rolls suitably placed against a stationary cutter.

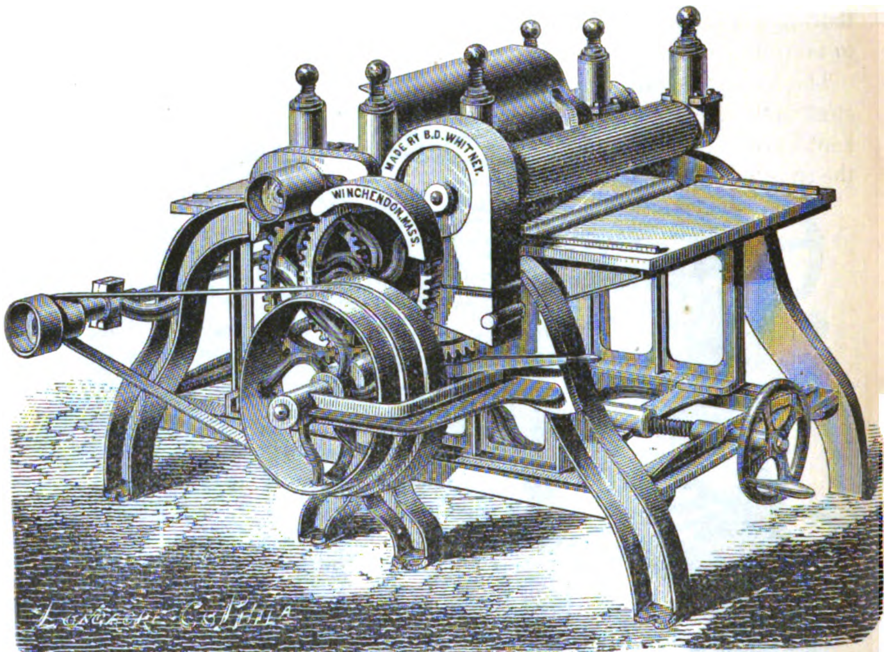


FIG. 126.—B. D. Whitney's cylinder planing-machine.

This cutter is a steel blade of sufficient length to extend across the machine, secured in a block of such strength as to be safe against springing. This blade is exceedingly sharp, and has the feather-edge which is generally considered essential in a scraping-tool for wood. The blade is very carefully set to take the thinnest possible shaving from the surface of the wood, which is given an ordinary good finish on the planing-machine before it is sent to the scraper. A little machine accompanies the scraper specially designed to sharpen the blade. It consists of a pair of emery-wheels, so set that one can bevel the edge of the cutter while the other squares up the face. The blade is clamped, during the operation, between a pair of jaws, which hold it firmly and precisely in position. As the sharpened blade passes from under these wheels, a stationary steel bar touches the edge, and, sliding along it, turns it, producing the feather-edge. Mr. Whitney states that this tool, if of good steel and well managed, will scrape several thousand square feet of hard wood without regrinding or resetting.

Digitized by Google

260. Several other tools—a neat little fret-saw, beautifully balanced; a tenon-drill, with table adjustable in all directions; a circular-saw bench carrying two saws, one a cross-cut, the other a rip saw, either of which can be brought into use as needed; and a planing-machine, with adjustable table—were in this collection, and were greatly admired by all who were capable of criticising them.

261. WHITNEY'S BAND-SAW.—The band-saw exhibited by Mr. Whitney has already been mentioned. It was thought by many the most thoroughly well-considered design in this department of mechanism to be found in the whole *Ausstellung*.

The saw was supported against the backward push of the work by a steel disk, set with its center at one side of the line of the blade, and kept slowly revolving by a little worm and gear receiving motion from the axle of the upper band-wheel.

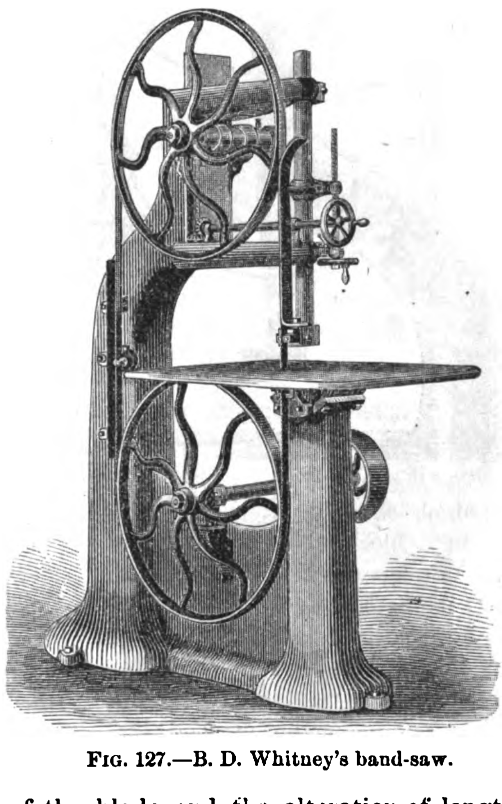


FIG. 127.—B. D. Whitney's band-saw.

The spring of the blade and the alteration of length due to change of temperature was provided against by hanging the upper wheel in a journal carried on a pivoted arm, the opposite extremity of which was sustained by a rubber spring. The arrangement was shown, by careful and repeated experiments, to be very perfect in action, and the uniform tension thus secured must have considerable effect in diminishing the risk of breakage of the saw-blade. The wheels carrying the band are

Digitized by Google

usually overhung in such a manner as to create a side-strain, tending to cramp the shafts in their journals, and to cause heating, as well as to make it difficult to insure the blade against excessive and varying strains. In this example, the wheel was "dished" in such a manner (see Fig. 127) as to bring the line of pull on the blade into a plane passing through the center of the length of journal.

262. THE BAND-SAW OF MESSRS. RICHARDS, LONDON & KELLEY, of Philadelphia, was the only tool shown, built by that justly-distinguished firm. In neatness of design it excelled all others of its class. The frame was simple, strong, and stiff; the parts were well put together; the table had a convenient method of adjustment; the wheels were light, but stiff and strong; the expansion and contraction of the blades were provided

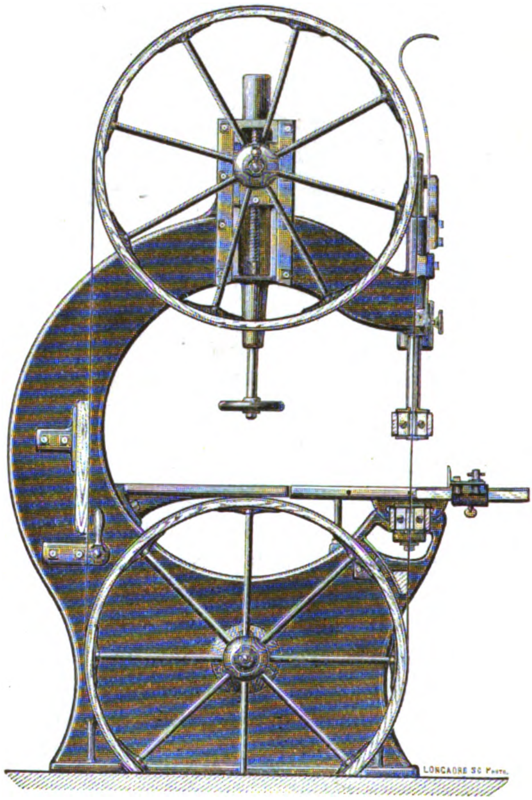


FIG. 128.—Richards, London & Kelley's band-saw—side view.

against by a neat and handy adjusting-device. This design has evidently found favor abroad, for one of the best known English firms has copied it, and a fac-simile was shown in the British section, as already stated.*

* A MAMMOTH BAND-SAW.—A band-saw, fifty-five feet long, sawing planks from a pine log three feet thick, at the rate of sixty superficial feet per minute—probably the most extensive experiment in log-cutting ever undertaken and successfully carried out—is the subject of the illustration herewith presented. No more forcible instance of the

Digitized by Google

263. **The introduction of the band-saw** is one of the latest and most important advances in the history of machine-tools. Mr. Richards states that within the past ten years this introduction has occurred to such an extent that already thousands of machines have been made and sold by the comparatively small number of firms building them.

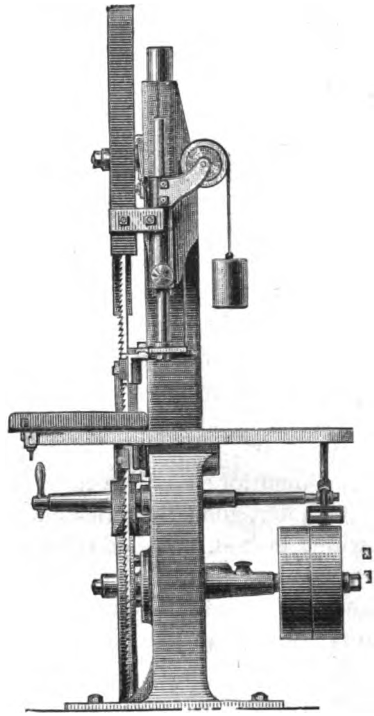


FIG. 129.—Richards, London & Kelley's band-saw—front view.

They were first invented in 1808, by a London mechanic, William Newbury, who is said to have made a very excellent machine, and one embodying the greater proportion of the devices which have made the modern machine so valuable. They were first introduced into the market and made commercially important by M. Perin, of Paris, who

great capability of the continuous saw-blade can, we think, be adduced, nor its superior efficiency, as compared with the gate and circular saw, for the purposes indicated be better demonstrated, than by the details below given, obtained directly from Mr. J. J. Van Pelt, in whose mills (at the foot of Tenth street, East River, in this city) the immense machine has, for some time past, been employed.

The saw, which is 55 feet long, 4½ to 6 inches wide, and of 16 gauge, was made by the celebrated firm of Perin & Co., of Paris, France, at a cost of one hundred dollars. The machinery was constructed from the drawings and specifications of Mr. Van Pelt, by Richards, London & Kelley, of Philadelphia, Pa. The pulleys are of 75 inches in diameter, including hubs of wrought iron, and are mounted centrally on the main column so as to equalize the strain of the saw and prevent its springing, and to economize its weight. They are covered with a lagging of pine, over which is glued an envelope of heavy harness-leather. The bearings for the wheel-shafts are 4 inches in diameter and 12 inches long, and are made of an alloy of six parts copper and one of

Digitized by Google

commenced experimenting with them about the year 1850, and who finally succeeded in conquering the only seriously formidable obstacle to their complete success and general introduction—the difficulty of securing a perfectly reliable weld in the endless steel band which formed the saw. His success was first publicly acknowledged in 1867, when he received at the Paris Exposition the Grand Cross of the Legion of Honor.

264. M. Perin still holds the leading place, in the business of making these tools, in France; but the Messrs. Dougoujon are apparently rivaling him in the making of blades. Nearly all band-saw blades have been, until lately, made in Paris. They must be made of a special quality of steel, which has sufficient wearing-power to do good work, but which, at the same time, must be capable of welding firmly, and of sustaining subsequently the severe trial to which it is subjected, as it is alternately bent and straightened while doing its work. This is a combination of qualities very difficult to secure, and one which demands special grades of metal as well as a peculiar treatment, which can only be given by a skilled and experienced workman. Sheffield manufacturers are now taking up this business, and it will probably not be long before they will have secured a fair share of the trade.

265. The other firms mentioned above as exhibiting wood-working machinery presented, usually, good illustrations of the class of wood-working machinery which best suits the market of the United States, or of any country where wood is plentiful, capital expensive, and the demand for cheap and effective machinery very great.

The bad taste shown in painting some of these machines probably

tin. The tension is from one to four tons, and necessarily calls for the greatest rigidity in the framing to prevent the guides from being thrown out of position by the varying tension of the blades.

The timber lies perfectly still upon the carriage and hardly requires dogging at the ends. The first cut is directed by adjusting the log as the saw progresses, after which the slab face is carried past permanent gauges, very much on the principle of common hand-slitting. The operation brings into play several ingenious devices for supporting, setting, and guiding the log, inventions of Mr. Van Pelt, to which, however, no special reference is here necessary.

The kerf of the band-saw is ⅛ of an inch, or less than one-half that of a circular saw. Its speed is 4,500 feet per minute. We are informed that it cuts pine timber at the rate of sixty feet, and oak and yellow pine at thirty feet a minute, the logs being from one inch to five feet in thickness.

By far the most important advantage remains yet to be noticed. It is that the saw will follow the curvature of long timber, such as is used in ship-building and is cut with the grain. This not only causes no inconsiderable saving of material, but enhances the value of the work accomplished to such an extent that it is stated that deck-planks thus sawn are worth fully ten per cent. more than when cut by a circular blade. Another and more striking idea of its capability may be gathered from the fact that a board ⅛ of an inch thick has been taken, without the slightest variation, from the whole length of a log 50 feet long and 20 inches through. In the establishment above referred to, we learn that from eight to ten blades are yearly expended, and that the cost of running is about the same as that of the ordinary forms of saws in common use.—*Scientific American*.

Digitized by Google

had some influence in awakening prejudice and creating adverse criticism; but it is more probable that the principal cause of the unfavorable verdict which many visitors undoubtedly rendered against some of them, after comparison with the more substantial and more expensively gotten up machines in the British section, was the impossibility of appreciating the circumstances under which they were intended to be used. For the market for which they were built, they are far better than the heavier, more highly-finished, and much more expensive foreign machinery.

266. HALL'S DOVETAILING-MACHINE belongs to the same class with the collection shown by Mr. Whitney—a special application embodying the evidences of "Yankee ingenuity."

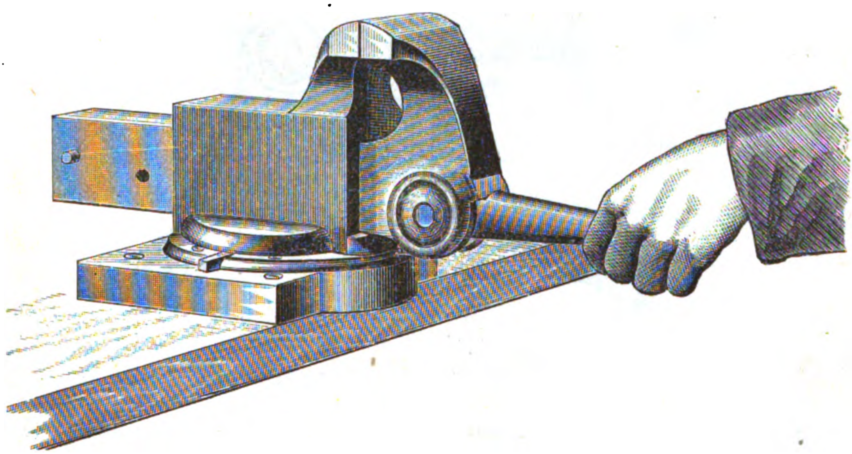


FIG. 130.—Hall's vise.

A set of revolving drills and cutters, with a single movement of the rest carrying the piece to be "dovetailed," do the whole work, and the dovetailed pieces fit into each other with an accuracy only attained in such work by automatic machinery.

A BENCH-VISE for metal-workers was also exhibited by Mr. Hall, which, by a peculiar and ingenious arrangement of simple mechanism, was made to grasp or loosen the work with a single movement of the hand. Fig. 130 shows the appearance of this vise as mounted on the bench and about to be used by the workman; Fig. 131 represents the vise with a piece of metal clamped between its jaws; and Fig. 132 represents a longitudinal section, and exhibits its interior mechanism.

P P is the plate by which the whole is secured to the bench; A and B are the jaws, the first movable by sliding inward and outward, and the second secured by the collar B B N. With the handle in position as shown, the jaws may be approximated or separated without obstruction, and to any desired extent. When the piece is placed between the

Digitized by Google

jaws, as in Fig. 131, the jaws are brought snugly together to hold the piece, and the handle is then depressed, and the one motion causes the jaws to grasp the piece more firmly and to take positions from which no force or blow can dislodge them. The clamping-mechanism is the knee-joint R E G, which receives a support by the depression of the

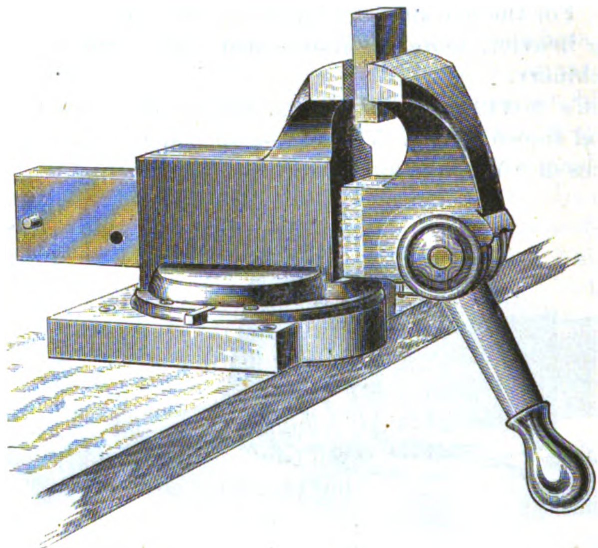


FIG. 131.—Hall's vise.

serrated piece G into contact with the serrations in H on the base. On dropping the handle, the lever J is elevated at K, permitting G to fall into action, and the same motion draws the bar D D outward, forcing E downward by the action of the wedge at that end. The spring L acts

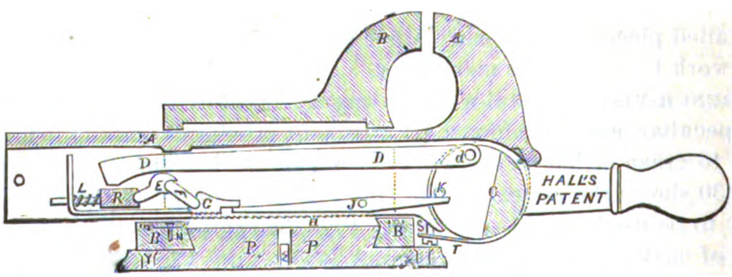


FIG. 132.—Hall's vise—longitudinal section.

with the parts already described in restoring the parts to their positions, as seen in Fig. 132, when the handle is raised to loosen the vise. The vise turns freely to any angle on the bench when the handle is up, but when anything is griped, the vise cannot turn on the swivel.

In Hall's vise the farther the handle is depressed the greater the power. By drawing the wedge D more and more directly across the center C, and at the same time the gradual straightening of the toggle E F, the power to grip is increased much faster than the friction. The handle can be adjusted to operate as easily or hold as firmly as desired by screws S. The swivel can be tightened more or less by wedge W to suit any work. It can readily be placed on any bench without putting a bolt through, and can be used over drawers. Chips, filings, or dirt cannot get into it. Wear does not cause lost motion or injure the vise.

It is built of the best material, by machinery which produces numbers to gauge alike.

267. Messrs. J. A. FAY & Co., of Cincinnati, Ohio, exhibited some plain, serviceable, and comparatively inexpensive tools, such as are well adapted to the western market. The illustrations exhibit the form of these tools. Their band-saw attracted the attention of many visitors, particularly from the wooded districts of the Austro-Hungarian Empire, where the conditions of the market more closely resemble those of our Western States than probably in any other portion of Europe.

BAND-SAW.—This machine (Fig. 133) represented the medium-sized band-saw of J. A. Fay & Co., Cincinnati, Ohio, and is constructed for the more general purpose of scroll-band-sawing, being equally applicable to light or heavy sawing. The several novelties applied to the working parts of this machine are worthy of a description. The column is constructed of cast iron of a cored box-section, flanged, with the supports for the lower wheel and table webbed and flanged, all cast in one piece.

The lower wheel is 33 inches in diameter, of cast iron, and fastened to its shaft by a nut. This shaft has with its bearings both lateral and vertical adjustments, and upon it the tight and loose pulleys are placed.

The upper wheel is a combination of cast iron and steel, made very light, to reduce inertia and relieve the saw from the sudden strain in starting and stopping. The shaft of the upper wheel revolves in bearings which are adjustable for the guidance of the saw to its correct line on the faces of the wheels. The bearings of the upper wheel have also a vertical adjustment for different lengths of saws, and their support is flexible in its gibbed sides for variations in the expansion or strain upon the saw. This flexibility is maintained by the weighted lever acting upon the screw which raises and lowers the bearings of the upper wheel. The guides for the saws, one above and one below the table, are arranged to accommodate different thicknesses and widths of saws, and have behind the saw a steel wheel which relieves the back of the saw from all sliding friction. There is a combined shipper and brake, which act simultaneously, the brake being applied when the power is thrown off. The vertical bar which carries the upper guide is governed and re-

Digitized by Google

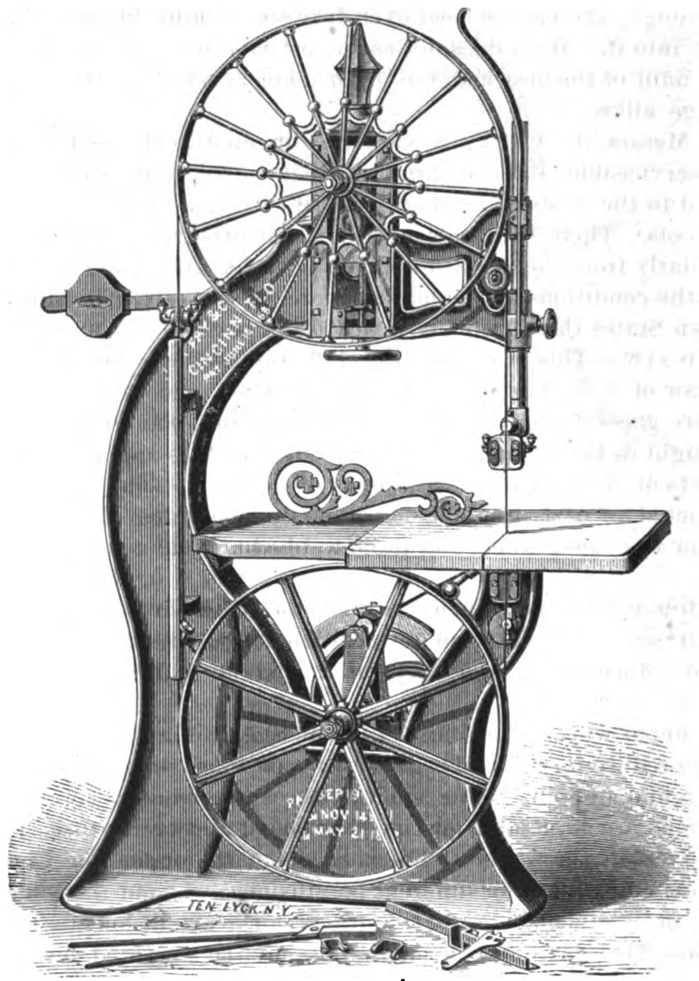


FIG. 133.—Band-saw, by J. A. Fay & Co.

Digitized by Google

tained in its position by a retracting spring, by which it is counterbalanced. The table is adjusted to an angle of thirty degrees, and is adjusted to return to a right angle with the saw.

No. 2. COMPOUND BED-MORTISING MACHINE.—This machine (Fig. 134) is adapted for work ranging from the lightest to a medium heavy class of mortising, and in its arrangement is equally applicable to all. The column has a heavy-plate front, with deep sides, well braced, and open at the back for convenient access to the reversing-gearing.

The driving-shaft is at the top of the column, and has upon it the pulleys and crank-wheel from which the chisel-stock receives its vertical reciprocating motion.

The bed is moved laterally under the chisel by a rack and pinion, with a hand-wheel for different lengths of mortises, and it can be set to mortise at any angle. The support of the compound bed is gibbed to the column, and can be raised and lowered by a screw actuated by a crank and bevel-gearing.

The treadle can be graduated to give greater or less lift to the bed by means of a segmental ratchet, into which a spring-pawl operates, giving the treadle a greater or less arc to move in, as the pawl may be adjusted, and this also changes the depth of the mortises.

An economic feature of this machine is the positive automatic reverser for the chisel. This is operated by a pawl, which is attached to a bar connected with the bed-support and treadle. The weight of the bed as it drops from its highest point is utilized in the last part of its fall by the pawl falling into a step, which revolves a series of segmental gearing, and in the alternate raising and dropping of the bed the chisel presents a reversed position toward either end of the bed. The chisel is held rigidly in its position, when reversed, by a detent which comes in contact with the connecting-bar as the bed is raised to the chisel.

BUILDERS' AND SASH AND DOOR MAKERS' TENONING-MACHINE.—This machine (Fig. 135) is for tenoning doors and sash or cabinet-work, being adaptable to these or any similar classes of tenoning.

There are four cutter-heads on this machine, two for cutting down the tenons and two termed cope heads, which are for shaping the shoulders of the tenon for molded or beveled edges. All the working parts are driven from one shaft. The main heads are driven by one belt, which is kept under proper tension by an idler-tightener, governed in its vertical movement by a balance-weight acting over a sheave-wheel, the whole being self-adjusting.

The main heads are adjustable separately, their supports being gibbed to a vertical stand placed at the end of the main frame of the machine. The lower head-support is attached to the upper support by a screw, by which the thickness of the tenon is gauged. The upper head-support is regulated in its height by a screw in the top of the vertical frame,

Digitized by Google

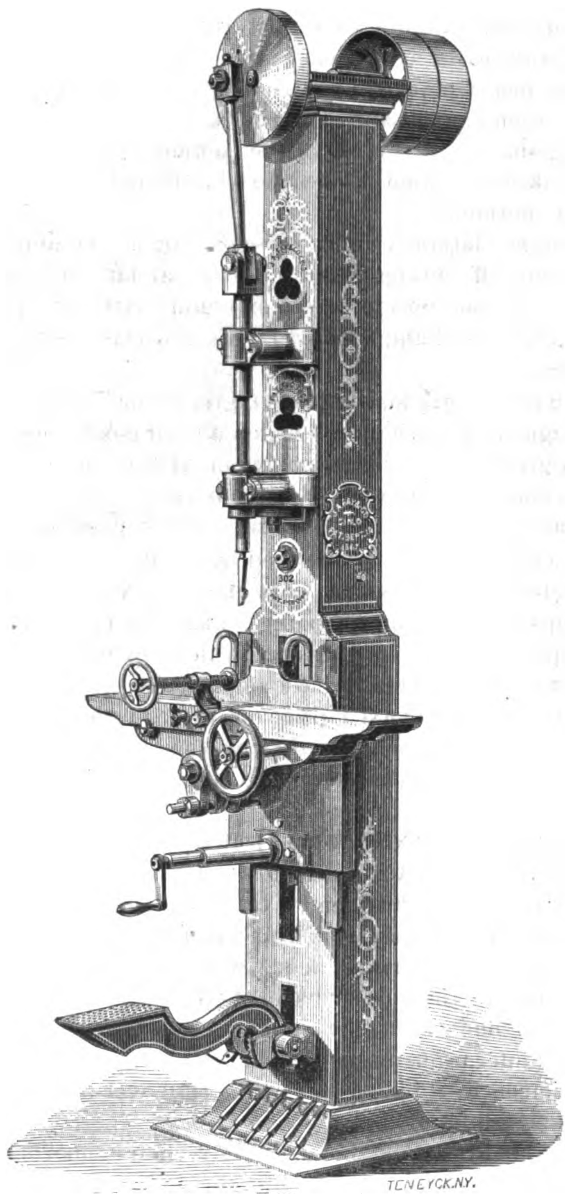


Fig. 134.—No. 2 compound bed-mortising machine.

Digitized by Google

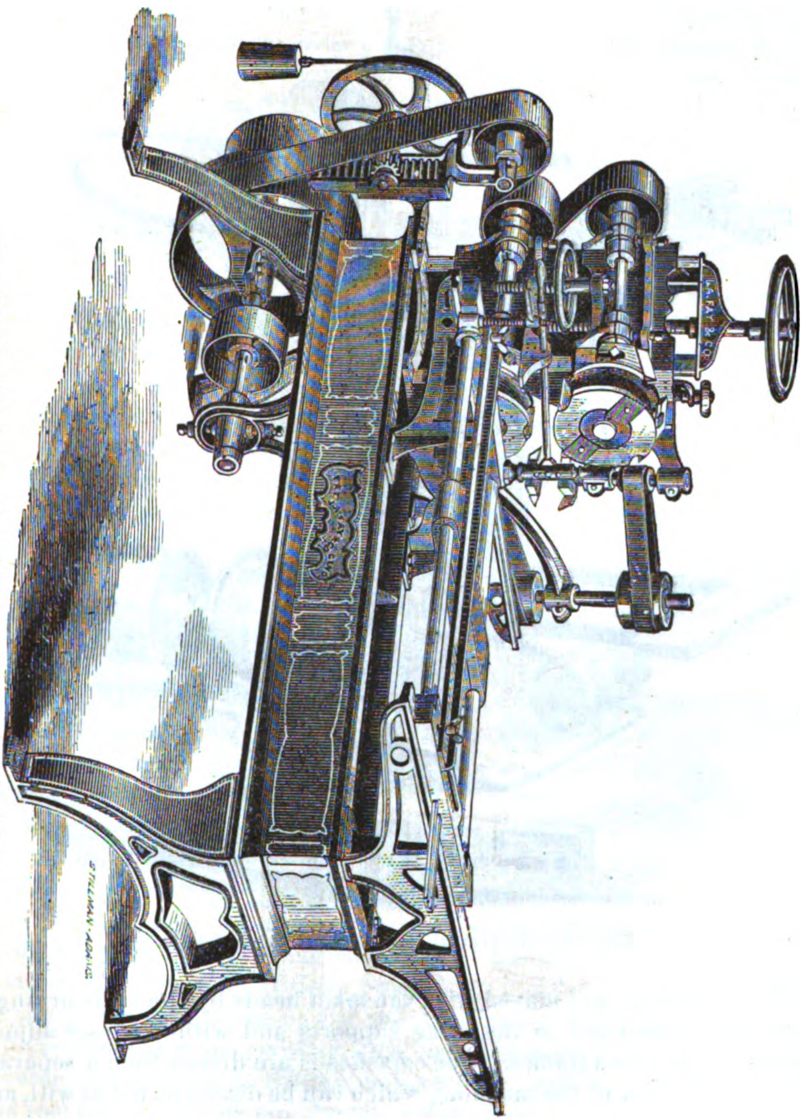


Fig. 135.—Builders' and sash and door-makers' tenoning-machine.

which also raises both heads simultaneously and gauges the depth of the tenon. The upper head-shaft has an end adjustment for making the shoulder longer or shorter.

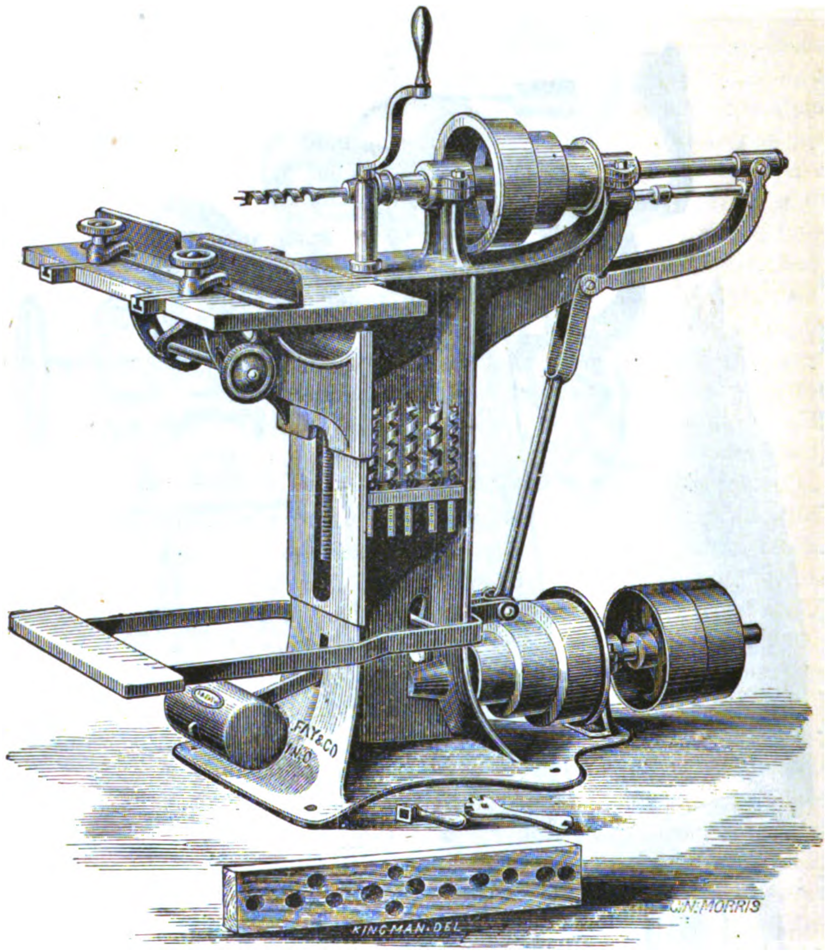


FIG. 136.—Universal horizontal boring-machine.

The cope-heads are moved with the main heads by the same arrangement, being fastened to the same supports and with separate adjustments on their own frames. The cope-heads are driven from a separate shaft at the back of the machine, which can be disconnected at will, and either pair of heads run separately.

The table remains upon the same horizontal plane, and is movable past the cutter-heads on planed ways. The table has stops to gauge the lengths and a lever for retaining the material in its position. It is

Digitized by Google

arranged for tenoning at an angle, and in all its parts its adaptability is evident.

UNIVERSAL HORIZONTAL BORING-MACHINE.—This boring-machine, (Fig. 136) is one of a class most generally in use. The boring-spindle travels in a fixed horizontal line, the material being adjusted upon the table to the desired position or angle. The power is conveyed to the boring-spindle through the cone-pulleys, and the speeds arranged by the position of the belt upon them. The augers are held in the boring-spindle either by a universal chuck or held in the socket by a set-screw.

The auger is advanced to the work by depressing the treadle, and recedes by the action of a weighted lever attached to the treadle, which returns it to its proper position.

The table is raised and lowered by means of a screw, and is adjustable to any angle up to 45°, and held to its position by a hand-wheel screw. The fence upon the table is also adjustable to any angle or position upon its face by the bolts, which move in slotted grooves.

The column of this machine is of webbed flanged section and substantial design, and the general construction and finish of the machine shows it to be one of great power and usefulness.

268. BRITISH WOOD-WORKING TOOLS were, as has already been remarked, distinguished, like their other machinery, by their strength and solidity. They were given plenty of metal, strong frames, excellent forms, and the best of workmanship. They precisely meet the demands of the British market, as the tools found in the markets of the United States meet the demands for which they were created. The abundance of capital in Great Britain, the comparatively great amount of labor put upon their more expensive timber, and the general inclination, everywhere observed, to make work substantial and durable, which is a consequence of this condition of the British market, cause the practice by builders of machinery to differ in a marked degree from that of our own tool-makers, who are compelled to deal with purchasers to whom money is worth from 7 to 10 per cent., and who work timber which is supplied plentifully and at a low price.

269. Messrs. T. ROBINSON & CO., of Rochdale, England, had a very extensive and very interesting collection of tools, which were excellent illustrations of the finest British practice.

Among these tools was one of the Armstrong dovetailing-machines, an invention which has, with justice, been considered one of the most valuable of those which British makers have imported from America. This tool consists of two circular saws carried on arbors so inclined that the two saws are nearly in contact at their lower sides, and are separated by some distance at the top. On the edge each disk carries its peculiarly-shaped saw, which cuts radially during a part of its revolution, and then, turning at right angles to the disk of the saw, the teeth cut in a line parallel to the axis. Thus they enter the wood, cutting the

Digitized by Google

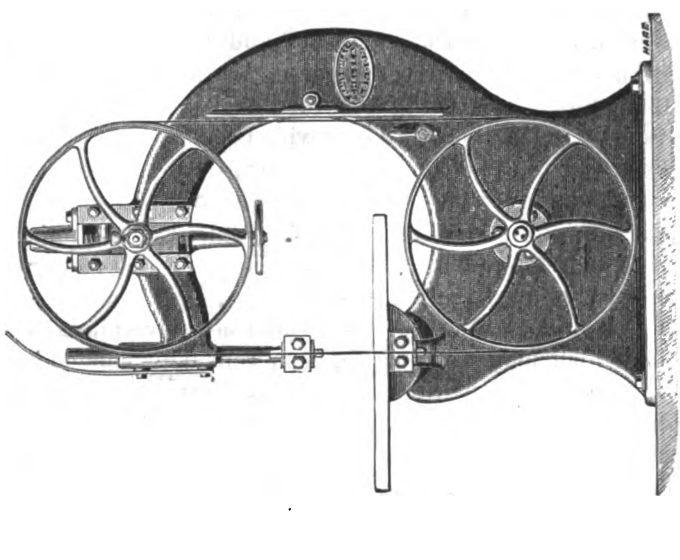


FIG. 137.—Plain band-saw.

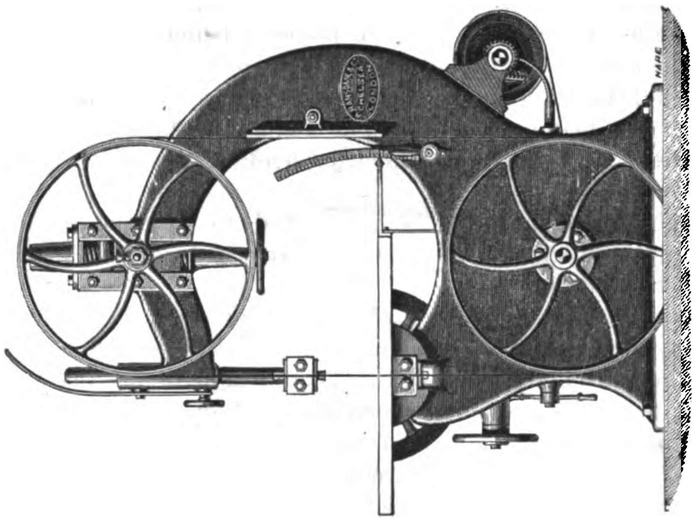


FIG. 138.—Band-saw with self-acting canting-table.

Saw-sharpening machine.

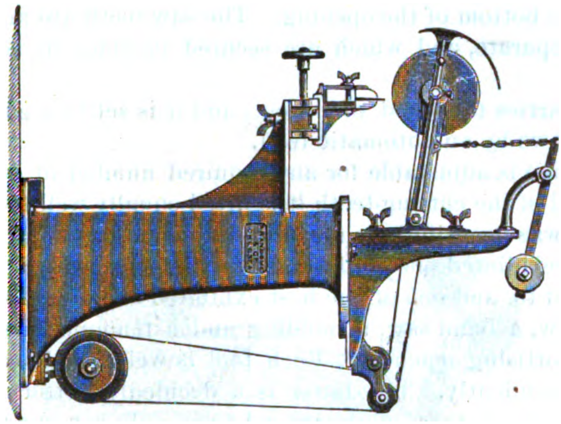


FIG. 139.—Side elevation.

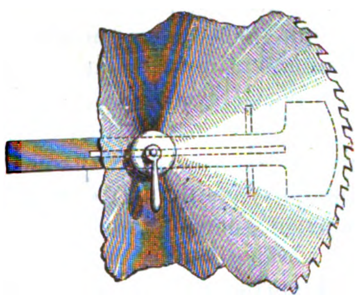


FIG. 141.

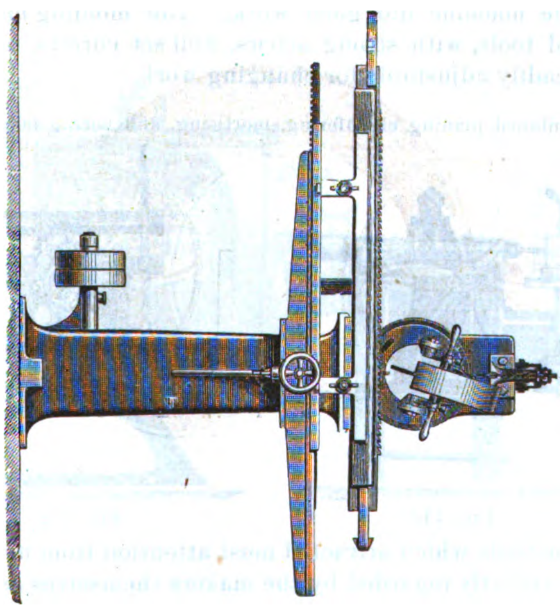


FIG. 140.—Front elevation.

flanks of the dovetail, and then, at the proper instant, the turned edge traverses the bottom of the opening. The saw-teeth are made on strips which are separate, and which are secured in place by screws on the disks.

A table carries the wood to be cut, and it is set to a gauge and fed across the saws by an automatic feed.

The machine is adjustable for any required number of dovetails, and by a reversal of the cutting-teeth it is fitted equally well to cut the pins.

This tool was beautifully made, and did magnificent work.

This firm exhibited one of the "general joiners" which have already been referred to, and one of the best exhibited examples. It contained a circular-saw, a band-saw, a molding and a tenoning machine, a boring and a mortising machine. Each tool is well fitted up, and can be driven independently. The latter is a decidedly better arrangement than that of some other exhibitors, who can only run one tool by starting up all, absorbing an excess of power, and causing a waste by wear and tear. On the molding-machine we noticed a device which seemed familiar; it was the method of adjustment adopted by Rogers, and the band-saw was, in some respects, similar to that of the American firm, Fay & Co., exhibited in the United States section; and our attention was called to the same device used by both for backing up the blade—a loose steel disk, which may continually change the line of bearing.

The independent mortising-machine was another well-made and excellent tool. The chisel works squarely and strongly, but the reversing mechanism is not as well arranged a device as some of the others. The frame and table are well put together, and all parts are nicely proportioned. The machine did good work. The molding-machines were equally good tools, with strong arbors, well-set cutters, heavy frames, and were readily adjustable for changing work.

Combined planing, chamfering, mortising, and boring machine.

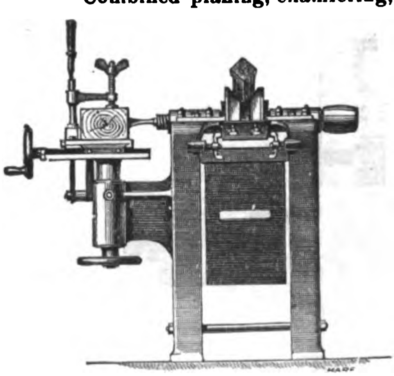


FIG. 143.

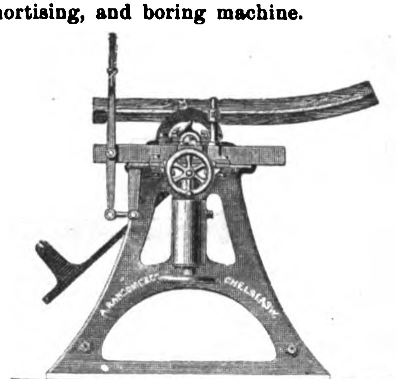


FIG. 142.

One of the tools which attracted most attention from mechanics, and which was evidently regarded by the makers themselves as one of their best machines, was a "semi-portable log-frame," of which style there

Digitized by Google

FIG. 144.

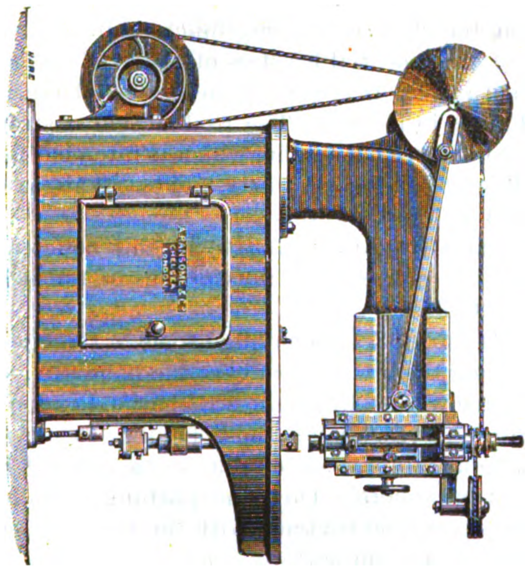
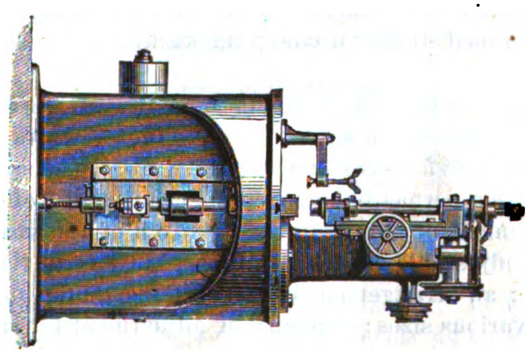


FIG. 145.



Universal molding, shaping, and recessing machine.

were several other excellent illustrations in the other exhibits of this section.

The saws were carried in the usual vertical saw-frame, which was mounted in a set of cast-iron vertical guides, which are rigidly and strongly secured to the bed which carries the table. The whole machine is, as the builders say, "self-contained," and can be carried about like one of the more familiar portable steam-engines, which are also termed "portable." It requires no foundation, and those exhibited were simply laid down upon the floor of the machinery-hall. A set of balance-weights is one of the essential features of the machine, and they are so well proportioned and set that hardly the lightest shake can be detected while the machine is in motion. The feed-motion is strong and adjustable to all the work of the machine, which is intended for cutting both logs and boards up to widths of thirty inches. This saw-frame was of wrought iron and well put together.

A band-saw and a fret-saw exhibited in this collection were plain tools, well made, but not as good illustrations of the best work of the firm as the other tools.

279. Messrs. RANSOME & Co. exhibited some of the finest tools in this section, and among them was prominent the band-saw, similar to that built in the United States by Messrs. Richards, London & Kelley, and other tools of designs resembling those familiar to our manufacturers. The band-saw, being a duplicate of that in the United States section, requires no description here. The same packing-boxes for holding the blade in line, the same steel backing, with the tallow-reservoir, and the same proportions are seen in both.

In securing efficiency in the band-saw, and combining rapidity and accuracy of operation with small expenditure of power, the following requisites are aimed at by Messrs. Ransome & Co., and are attained successfully:

A strong, heavy frame; a minimum diameter of wheel of 30 inches for small saws, 42 inches for saws of 2 or 3 inches width of blade, and of 6 feet and upward for saws of 6 inches width; wheels turned inside and out to secure a perfect balance; pulley-covers of well-fitted leather, and an arrangement for adjusting the position of the saw-blade on the pulley-wheel; adjustable guides to support the saw at the sides and to back it behind; an arrangement by which these guides may be fitted to saw-blades of various sizes; capacity of adjustment for saws of various lengths by raising or depressing the top pulley; a method of keeping a constant strain upon the blade, as its length is altered by changing temperature, using a spring or a weight; saws of uniform dimensions in cross-section, size and shape of tooth, and of uniform temper.

The hollow standards, the peculiarly roomy table, and the methods of adjustment already referred to when considering the same form of machine as exhibited by Richards, London & Kelley, of Philadelphia, are admirably adapted to securing these *desiderata*.

Digitized by Google

The plain machine (Fig. 137, page 266) is used for all ordinary sweep-cutting. The machine (Fig. 138, same page) with canting table is extremely useful for sawing out pieces of varying bevel. These machines are all supplied with Perin's blades.

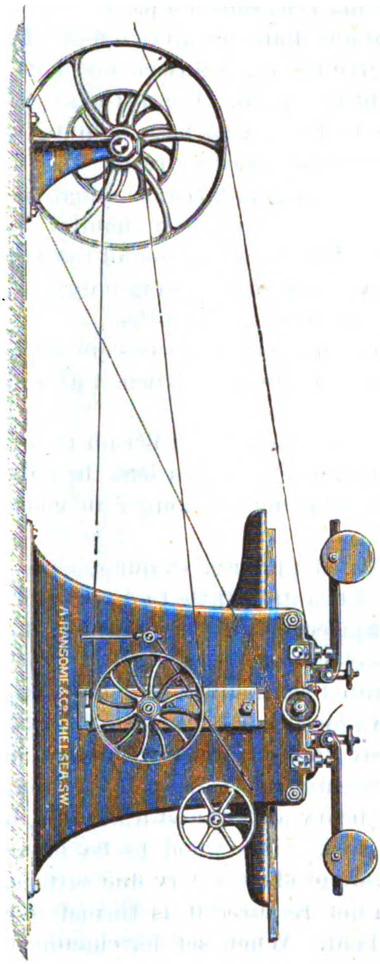


FIG. 146.—Panel-board-molding machine.

The saw-sharpening machine of this firm is a neat and valuable tool. This machine sharpens saws by means of a revolving emery-disk, and is fast superseding the old plan of sharpening by hand with files. It will top, gullet, and bevel either frame, cross-cut, or circular saws, with any form of tooth, so as not to require touching with a file. The grinding-disk works in a counterbalanced swinging carriage, which is brought down by hand to the saw, as required. This carriage can be set at any required angle, so as to give any amount of lead to the tooth, and the same disk can be used for gulleting, topping, or beveling. Members of the International Jury were informed that wheels for this machine had been made of the new Ransome artificial stone, with excellent results. The engravings (Figs. 139, 140, 141, page 267) show the machine as set for sharpening frame-saws, the saw being held in a cast-iron vise, which is moved along under the disk with a rack-and-pinion motion, worked by a hand-wheel. Another vise, shown separately in the wood-cut, is provided for circular saws of any diameter up to 6 feet. Both these vises work on a pivot, so as to give the tooth any required bevel. Fig. 139 is a side, and Fig. 140 a front elevation. Fig. 141 is an enlarged view of the saw.

The experience of firms who have adopted these machines, as the makers claim, shows the following results:

(1.) An enormous saving in labor, as a man at the machine will do as much work as six men sharpening by hand.

(2.) A saving equal to the whole cost of the saw-files formerly used for sharpening by hand, each disk costing only a few shillings, and lasting in constant work for about two months.

(3.) An advantage in having the saws always of the same depth in the gullet; for whenever a saw is sharpened at the machine, it is always gulleted in the same proportion.

Besides the above advantages, it is said to be found in practice that the action of the disk positively hardens the cutting-points of the teeth, and the saws last considerably longer in consequence without being sharpened.

Ransome's combined planing, shaping, chamfering, mortising, and boring machine is a beautiful little tool, which does good work on either straight or curved pieces. It is shown in Figs. 142 and 143, page 268, in end view and side elevation.

It is specially suited for planing, shaping, chamfering, and mortising the framing of wagons, carts, and machines constructed of timber, and it will work any kind of timber with equal facility.

The cutter-spindle runs in two pairs of very long, self-lubricating bearings, and revolves below a light cast-iron table, having a slot through which the cutters work. The wood to be planed is passed over the table, and the cutters produce a very fine surface. The table works on a hinge, and when not required it is turned over out of the way, as shown in the wood-cut. When set for chamfering, two circular angle-brackets are fixed over the cutters, and the piece is laid between them with the edge downward. The angle-brackets can be fixed at any distance from each other, and the cutters remove as much of the wood as falls below the aperture between them. The mortising and boring arrangement is similar in construction to that of the "general joiner," and it will make mortises or bore holes in any kind of timber with great speed and accuracy. Two lads can work at the machine at the same time, one mortising or boring, while the other is planing, shaping, or chamfering. A pair of collars are frequently attached to one end of the spindle to take a small saw for ripping, cross-cutting, or grooving, in which case a table made of hard wood is mounted on the mortising-

Digitized by Google

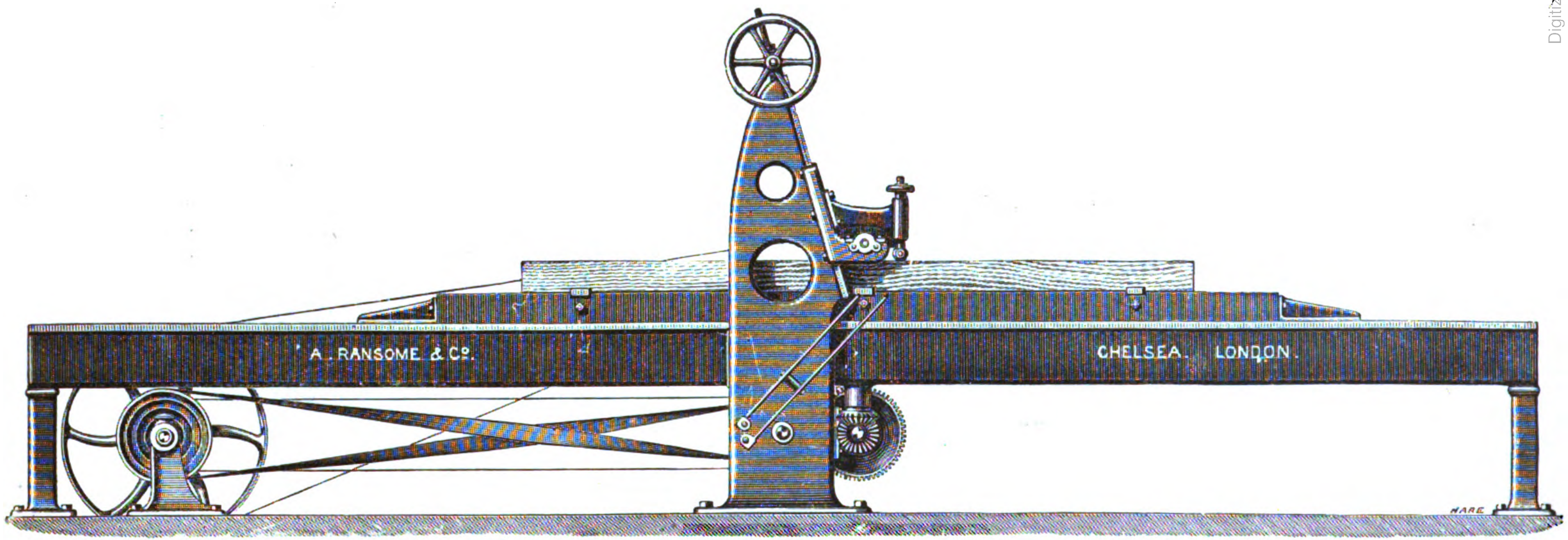
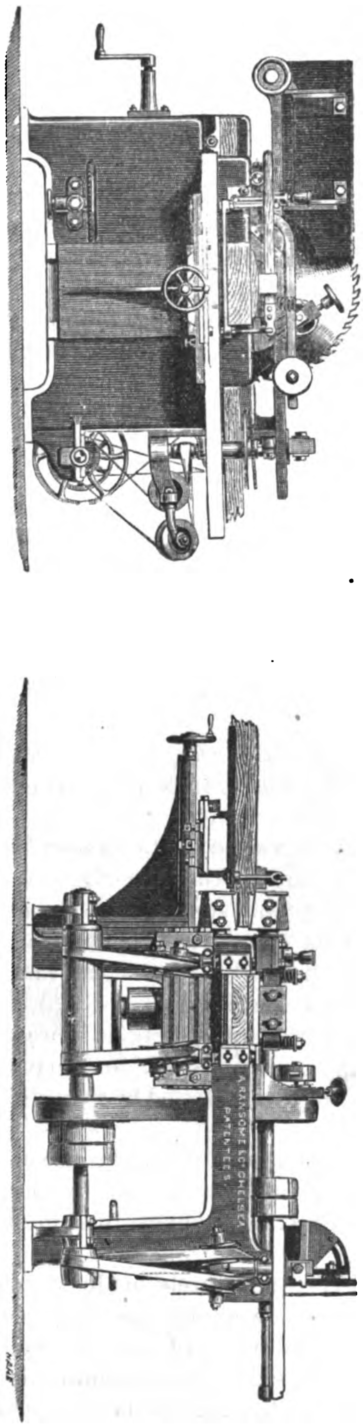


FIG. 147—Ransome & Co.'s planing and trying-up machine.

Digitized by Google

Digitized by Google



FIGS. 148, 149.—Ransome & Co.'s "complete joiner."

Digitized by Google

slide, and thus serves as a small saw-bench with a rising and falling table.

The universal molding, shaping, and recessing machine is adapted to cutting circular or twisted moldings, sticking circular and straight sash-bars, molding, rebating, and grooving straight or curved frames, and many similar kinds of work.

The cutter-spindle is mounted on a slide, as seen in Figs. 144 and 145, page 269, and driven like the cutter in a shaping-machine as built for metal-working. The amount of travel is readily adjustable, and the tool is fed downward by the usual feed-device.

The panel-board-planing machine (Fig. 146, page 271) is intended for planing and surfacing thin boards and panels, and leaves the surface as smooth as if finished by hand with the smoothing-plane. It takes boards two feet wide and up to two inches thick. It is applied to railroad-car work, door-paneling, and to smoothing up small work of all kinds.

The cutters are screwed to a long wrought-iron adze-block, having a spindle of mild-centered cast-steel running in self-lubricating bearings specially constructed for high speeds. The boards are fed through the machine by two pairs of rollers, all of which are driven, and being perfectly smooth, they do not mark the surface of the wood. This allows boards, after being planed on one side, to be turned over and again passed through to plane the other side, without sustaining the slightest damage from the rollers.

The pressure-apparatus is so arranged as to hold the board firmly close to either side of the block, thus preventing any vibration in it while under the action of the cutters.

The rate of feed can be varied instantaneously while the board is passing through the machine by the two diagonal levers shown in the engraving, which also stop and start the feed, and the table can be readily adjusted to suit for boards of different thicknesses by turning the hand-wheel which is shown in front of the machine. The rates of feed range from 15 to 30 feet a minute.

The planing and trying-up machine (Fig. 147, preceding) is intended for truing-up carpenters' and joiners' "stuff," and to produce a very smooth, finished surface. The cutters are carried by a wrought-iron "adze-block," driven at high-speed.

The spindle is of steel, and runs in long bronze bearings. The spindle is hard on the exterior, but inside is of a soft temper, thus, as the makers claim, combining stiffness with toughness, and giving an excellent bearing-surface.

The "brasses" are very accurately made and fitted. The bottom brasses are slotted on the lower side, and a piece of felt is inserted in this slot, and extends downward into a large oil-chamber. Oil-grooves lead the oil back from the bearing into this chamber, and a free-flowing and uninterrupted lubrication is obtained, which is the more rapid as the speed increases.

Digitized by Google

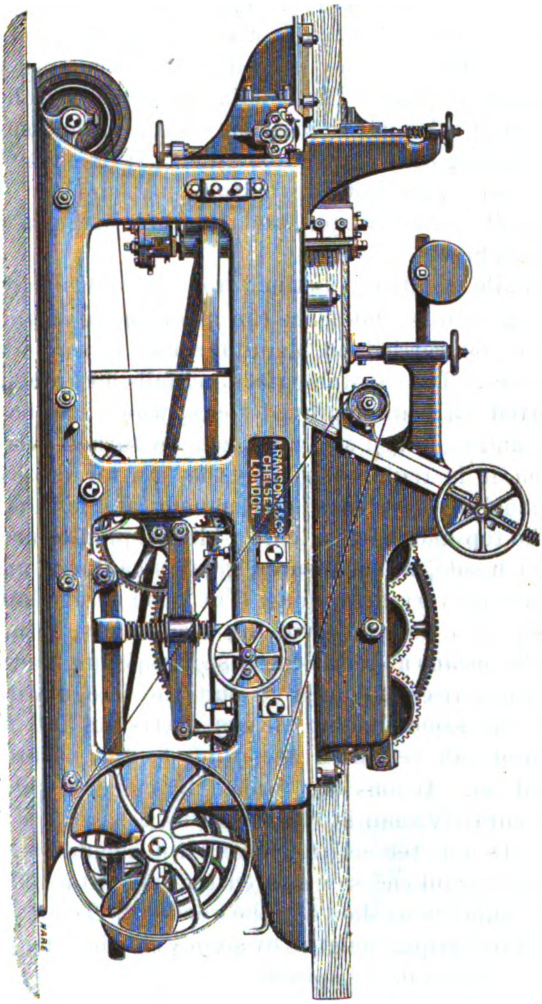


FIG. 150.—Combined planing and moulding machine, (large size.)

Both feed-rollers are driven, and the rate of forward feed may be varied from 10 to 30 feet per minute; the return-motion is about 40 feet per minute. The feed may be adjusted at any moment, and while the machine is in motion, by shifting the diagonal levers seen at the side of the tool on the upright. These levers also stop, start, and reverse.

Messrs. Ransome & Co. exhibited a good type of "complete joiner," (Figs. 148, 149, page 273) which is, however, peculiar to themselves. It contains a well-set circular saw, strongly driven at 1,800 revolutions per minute, and fitted with a fence, which is so attached that it can be readily set aside when the saw is used for cross-cutting and the whole table-top is required clear. The molding-machine is well put together. It can trim all four sides of the piece at once, and the tools and feed are well driven, enabling heavy cuts to be taken. It takes in timber 7 inches by 4. The cutters make 4,500 revolutions per minute. The tenoning-machine is equally well arranged, and the whole makes a strong, handy, and efficient machine.

The saw-spindle is entirely distinct from those which carry the planing and molding cutters, and hence the operations of sawing and planing or molding can be carried on simultaneously or separately, as at two distinct machines. The saw-table rises and falls for grooving, rabbeting, &c., and is fitted with an improved fence, which can be set at any required angle, and is hinged so that it can be turned over at the end of the table when it is required to use the saw for cross-cutting. The planing and molding apparatus is permanent, and is thus always ready for work. The top and bottom cutter-block spindles are supported in bearings on each side, which insures great steadiness, and enables the machine to turn out very clean work. The wood being planed or molded, is fed through by a pair of revolving feed-rollers, both of which are driven, by which means a greatly-increased propelling-power is obtained. The top feed-roller rises and falls to suit the irregularities in a rough board, and at the same time it always exerts its full feeding-power. The rate of feed can be varied according to the nature of the wood being operated on. Tenons are formed by cutters, which finish them much more accurately than is the case where saws are employed for this purpose. Double tenons are cut and the shoulders scribed, at one operation, by a "drunken" saw and cutter-disk attached to one of the upright cutter-spindles, as shown in the wood-cut. Tenons can be formed with shoulders of unequal lengths by simply shifting the position of one of the tenoning-blocks on its spindle.

All of the cutter-spindles are of the best mild-centered cast-steel, and the bearings are specially constructed to stand high speeds, being fitted with a self-lubricating arrangement.

The planing and molding machines of this firm (Fig. 150, page 275) are among the best, if not the very best, in the Exhibition. The two exhibited were capable, respectively, of taking timber 12 by 4 inches and 7 by 3 inches in section. The builders state that they make three other sizes, varying from 16 by 6 inches down to 4 by 2 inches.

Digitized by Google

The feed-table carries a guide for the timber; the pressure-bars are weighted, except a bridge pressure-bar, which is set down by screws. Where the table extends beyond the lower cutter, it may be let down, turning on a hinge, and thus ready access obtained to the knives. There are four feed-rollers—one fluted, the remainder smooth—all driven from a pulley fitted for four speeds. There are top, bottom, and side cutters, which may be worked simultaneously on all four sides of the piece. These cutters are all readily accessible. The rate of feed may be varied from 12 to 35 feet per minute.

The tenoning-machine is one of the best of this fine collection of exhibits. It is simple in construction, the cutters well balanced, and driven strongly and at high speed. The feed-table is light, but quite substantial, and is carried on friction-wheels between guides. The tenons can be cut without laying them out by measure, after proper adjustment.

The distance between the upper and lower cutters is adjustable by two hand-wheels, one of which raises both, and the other of which alters their distance apart.

In all of these machines in which the cutters are driven at high speed the practice of Messrs. Ransome & Co. seems somewhat in advance of their competitors, and, in speed of cutters, they are fully up to the most radical among our own makers. They in some cases drive their cutters at 5,500, and even 6,000 revolutions per minute.

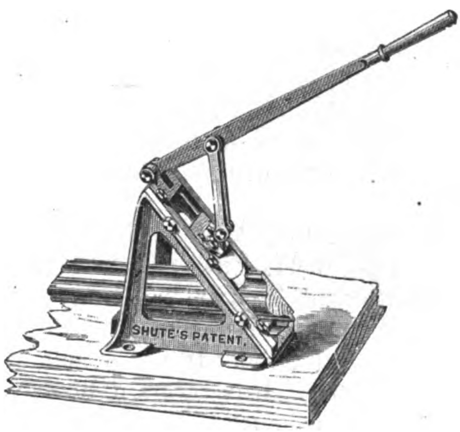


FIG. 151.—Shute's mitering-machine.

In adopting these speeds they have evidently been made familiar with the ordinary difficulties of balancing, of effective lubrication, and of attaining absolute security of connection of all parts. They have succeeded remarkably well in securing smooth motion of tool and feed, large, well-adjusted bearing, and great stiffness of framing. Low steel is used for centers. It was not stated whether they were, as they should have been, ground to shape. The firmness with which the work is held in these machines is an essential and well-maintained feature.

Digitized by Google

The mitering-machine (Fig. 151) is of the form known as Shute's. It is neat in design, compact, well arranged, works excellently, and is, as the writer is informed by engineers familiar with the British market, in extensive use. The makers state that they have sold one thousand of them. This is one of the tools which one of the German builders has copied as exactly as others have duplicated several American tools.

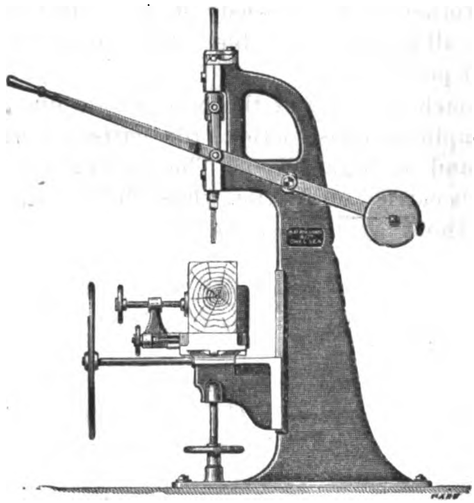


FIG. 152.—Hand-mortising machine.

An excellent hand-mortising machine (Fig. 152) is another of the neat tools here shown, Its table is capable of moving in any direction, and has its bearing precisely below the chisel, thus obtaining a firmness of support which could not otherwise be attained. The chisel has a reversing motion, and its supporting-bar is counter-weighted. It did good work.

A larger machine, (Figs. 153, 154,) driven by power, was exhibited, which is one of the finest tools of the kind seen at Vienna, and is, in general form, that of Richards, London & Kelley, of Philadelphia.

The chisel is fixed in a sliding bar, driven by a crank-wheel below by means of a strong connecting-rod. It has a hollow back and wings, which clear the hole perfectly. It is reversed by a cord carried on a pulley mounted on the spindle, much as a planer feed-wheel is arranged, this cord being driven by a pulley on the driving-shaft. Check-studs limit the range of rotation, and its operation is exceedingly beautiful.

The table has motions in all directions, and the work is adjusted by its motions. The chisel makes 600 blows per minute.

Ransome & Co.'s portable log-frame (Fig. 155) is a strong and well-designed saw-frame. Fifteen saws are carried as a maximum, and they can be set so as to cut up logs 14 inches in diameter. The frame is well balanced, and runs very smoothly. It is driven by two rods, one on each side the machine.

Digitized by Google

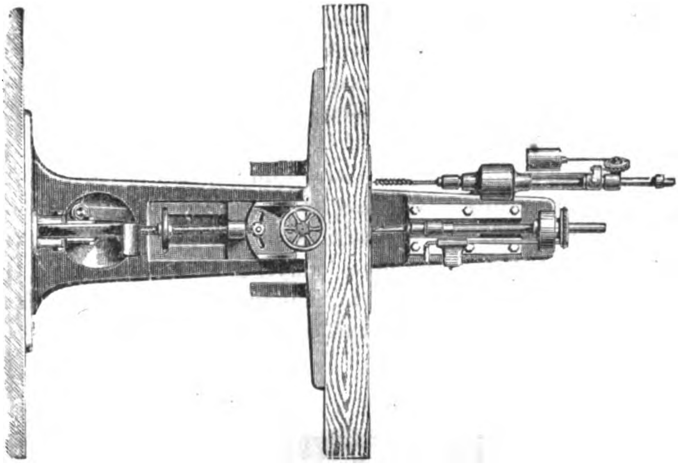


FIG. 153.

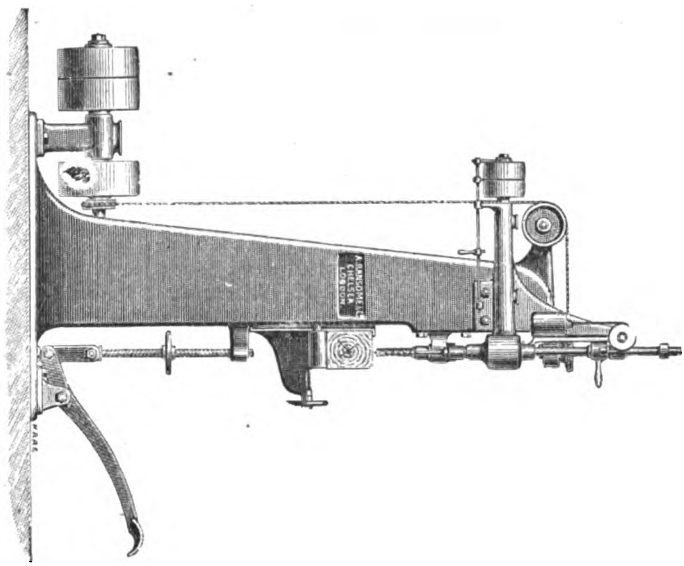


FIG. 154.

Richards's mortising-machine.

A silent feed is used here, as in several other similar tools exhibited by other makers. It is driven by a pin on a sector fitted to a main driving-crank.

The driving-gears of the feed are out of the way within the main frame. The rollers are weighted heavily, yet with conveniently-adjustable weights. The rate of feed is variable between 1 and 3 feet per minute.

The self-acting circular-saw bench (Fig. 156, page 281) is made with tables of from $5\frac{1}{2}$ to $7\frac{1}{2}$ feet length, and from $2\frac{3}{4}$ to $3\frac{1}{2}$ feet width, requiring from 6 to 10 horse-power to drive them. The saws make from 800 to 1,000 revolutions per minute.

The feed-motion is driven by the saw-spindle, and is variable between 15 and 60 feet per minute. The feed-line is coiled on a drum, seen under the table, and, with all its gearing, is boxed in and preserved from injury by dust and dirt. The fence may be set at any angle, and may be nicely adjusted by a screw. It is taken off when not needed. The saw-spindle is of steel, running in three long bronze bearings.

The little molding-iron grinder (Figs. 157, 158) is intended to grind

FIG. 157.

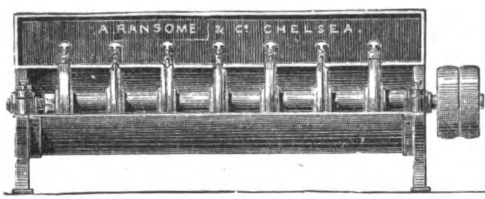


FIG. 158.

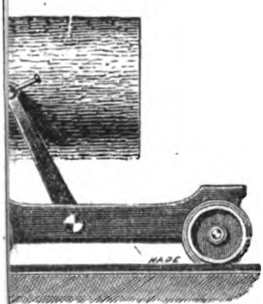
Molding-iron grinder.

molding-irons of any pattern, without drawing their temper, and subsequently rehardening them. The spindle carries seven small grindstones of different thicknesses. These are turned up to fit the shape of the irons. Water is supplied through brass cocks, one of which is placed over each stone.

On the panel-planing machine was an attachment which is deserving of especial mention. A suction-pan was applied to the conduit which conveyed the chips and dust from the machine, and the strong draught which it created drew in a current from all sides which effectually prevented any escape of such usually annoying particles. The workmen were thus enabled to do their work with accuracy and comfort, the dust was conveyed entirely away from the tool and expelled where it could do no harm and cause no annoyance, and the sanitary benefits of its use are, as the exhibitors claimed, no small inducement to its adoption. This apparatus, which the makers call their "pneumatic conductor," is shown in Figs. 159 and 160. It will be seen to be very similar to that adopted by the Tanite Emery-Wheel Company, of Stroudsburgh, Penn., for their Newman Emery-Wheel Planer.

271. Messrs. WORSSAM & CO., of Chelsea, exhibited a collection of wood-working machinery which was also most excellent in design, ma-

Digitized by Google



Digitized by Google

Digitized by Google

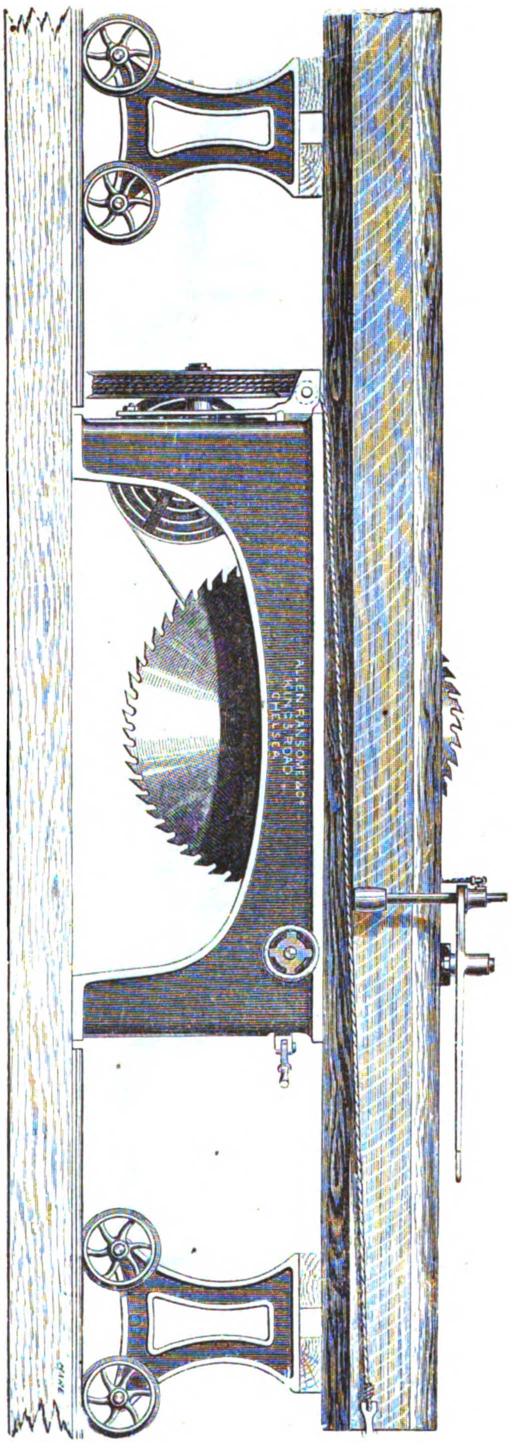


FIG. 156.—Ransome & Co.'s self-acting saw-bench.

Fig. 159.

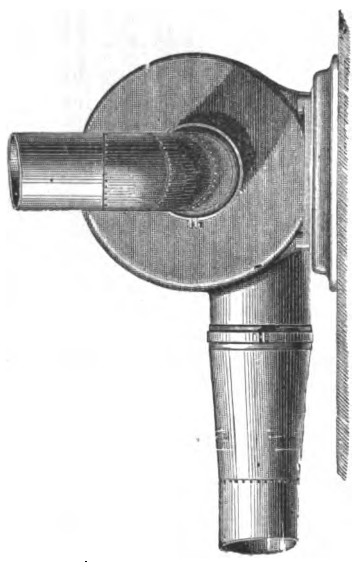
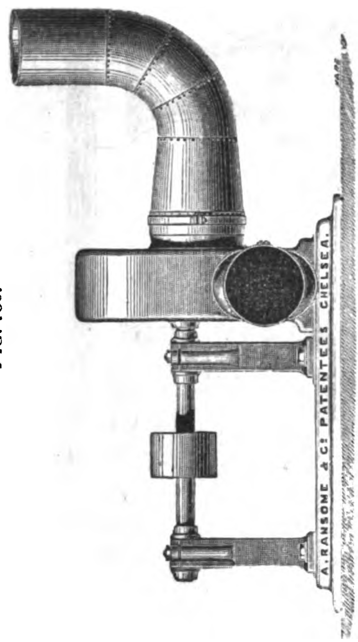


Fig. 160.



Ransome & Co's pneumatic conductor.

Digitized by Google

terial, and workmanship. They were rarely equalled, and in some respects they were in advance of their competitors.

Their parqueting-machines were good illustrations of their specially interesting work. One was a grooving and the other a surfacing machine. The latter was a face-plate lathe, having a strong, well-supported spindle, carrying a face-plate of good size. The tool was carried in a slide-rest which was well supported, and the whole design was as simple as could be desired, and as strong and stiff as is necessary in such work. The piece of work to be surfaced is secured to the face-plate, and the slide-rest carries the cutter in a line from the center outward, and *vice versa*, with perfect accuracy, leaving the surface well finished. In the first-mentioned machine, the block to be grooved is mounted on the table, with the edge to be cut extending beyond the table, which is then driven along its slides on the frame, and the work, coming in contact with the rotating cutter, is, at one motion, trued up and the groove cut. This little tool is also stiff and strong, neat and cheap, and does rapid work.

The portable log-frame is a good machine also, resembling somewhat that already described.

Worssam's "general joiner" is a combination of tools intended for use where such a tool as that of Ransome & Co., already referred to, should be wanted. Here, however, the same shaft drives all the tools in the combination, an arrangement which necessitates starting all to drive one, and thus a serious wasteful consumption of power is inevitable, unless a vast amount of work is done upon this one tool, and in such well-distributed variety as to keep all parts of the combination employed. But, in the latter case, it would be far best to purchase independent tools, in order to insure freedom from interference of one piece of work with another, if for no other reason.

In this machine, tenons are cut by two small circular saws mounted at the proper distance from each other, and two other saws, set on a vertical axis, cut the shoulders. The work is fed vertically, and no inconvenience is experienced, except with unusually large pieces. The molding-machine in this combination is not as generally applicable as are some other machines, as it can only work one side, and that the top. The saw-table is well placed, and is fitted with a fence for ripping, and with a cross-cutting plate which can be worked handily, after turning the fence down.

A trying-up machine was exhibited in this collection, which seemed a good tool. It was used for surfacing, molding, and planing. It was intended especially for heavy work, but, by making a change of pressure-rolls, could be used on thin material.

272. Messrs. Powis, James & Co. exhibited a collection of wood-working tools which were excellent representatives of a standard, and, perhaps, somewhat conservative British practice. Like nearly all of the tools in this section, they were plain, neat, well made, substantial, good working tools. There were fewer peculiarities of detail than in the exhibits already described, but the makers were evidently among

Digitized by Google

the best, and deserved the position which they claim of leading makers of generally-used forms of wood-working tools.

Their saw-frame was solid and convenient, the planing and molding tools were well gotten up, and their whole department was well arranged and well cared for. Compared with the tools in the United States section, they illustrate well the peculiar differences of practice of the two nations.

273. THE FRENCH SECTION contained some excellent machinery. Without displaying the singular ingenuity of American manufacturers in adapting machinery to special purposes, and without exhibiting that solidity of design and that remarkable conscientiousness in doing good work which distinguishes the best British builders, the French, nevertheless, exhibited some fine work and some excellent machines.

Probably no nation has recently progressed more rapidly in this branch of industry than they. But a few years ago, this business was in the hands of a few unintelligent mechanics, and their work was of the worst possible description. To-day, the best of their machinists' work is seen in this department, and France stands only second to Great Britain and the United States. They do better work, and are far more original in design than their neighbors.

274. PERIN'S BAND-SAW.—The firms of Perin & Co. and of Arbey & Co. are especially deserving of notice.

The former is known throughout the world as the first to make a successful band-saw, and as having, for a long time, been the manufacturer of this now standard and invaluable tool.

The band-saws exhibited at Vienna (Figs. 162, 163) were of good design and execution, and would have called for especial commendation had they not been subjected to the disadvantage of a comparison with the beautiful American tools already described. They had no provision for taking up the extension produced by the rise of temperature consequent upon unintermitted working.

M. Perin informs the writer that he considers this provision, which is deemed so important by American manufacturers, useless, since, when a saw becomes warm enough to stretch sufficiently to slip on its pulleys, it is too warm to be used safely. The fact, however, that other builders go to considerable expense in adding this superfluous device, as M. Perin considers it, is probably very good evidence that it is decidedly advantageous.

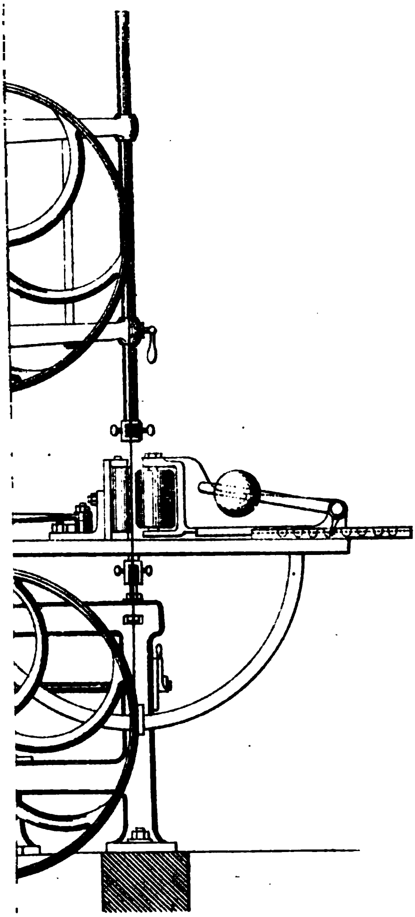
M. Perin exhibited a variety of excellent blades. The manufacture of band-saw blades is claimed to be almost entirely a French industry. The finest band-saw blades in the Exhibition were those of Dougoujon ainé, 37 Rue de Lyon, Paris.

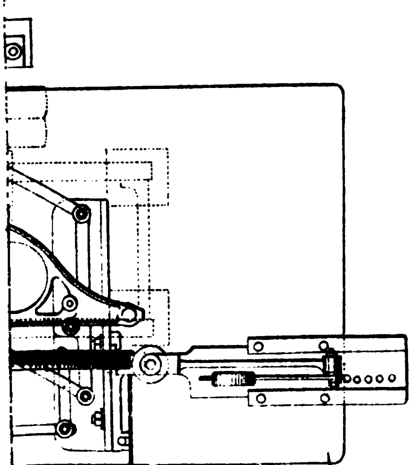
The steel used is sometimes English, often French, but the manufacture of the blades is carried on principally at Paris.

275. ARBEY'S PLANING-MACHINE.—The display made by Messrs. Arbey & Co. was excellent. The most noticeable exhibit was the planing-machine, (Fig. 163,) with helicoidal blades, which has already been mentioned.

Digitized by Google

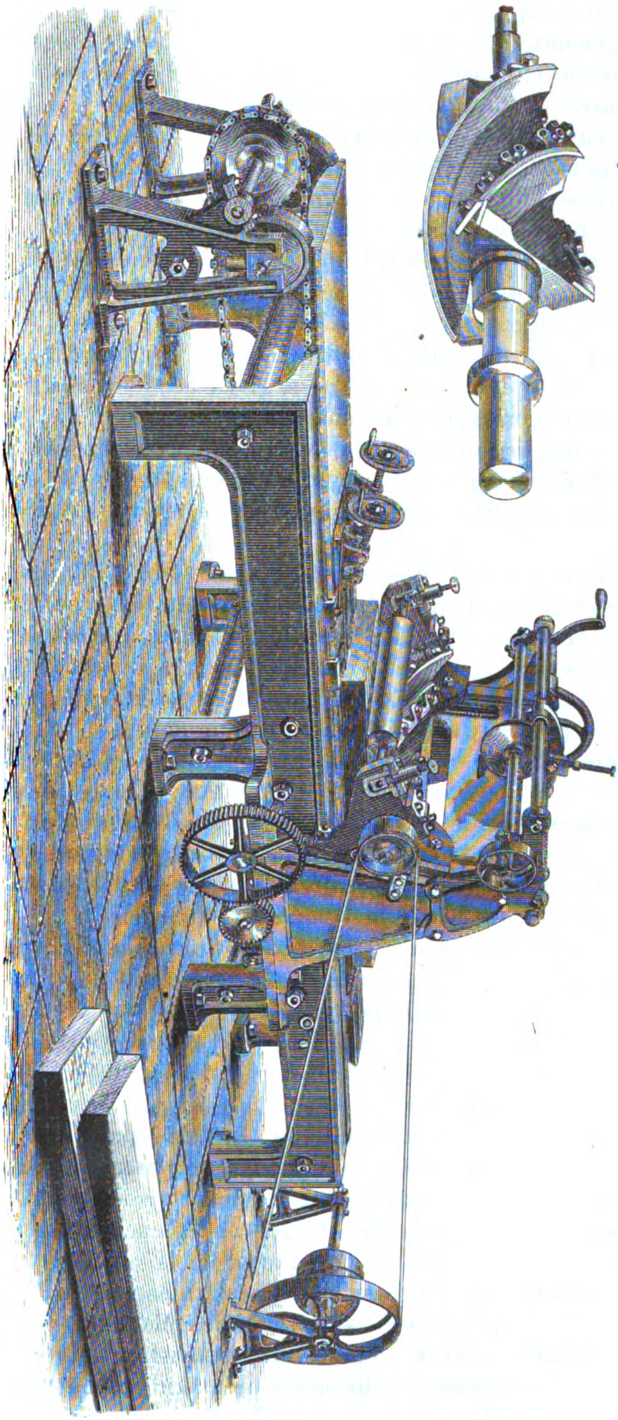
Machinery etc.





Digitized by Google

Digitized by Google



Spiral cutter-block.

FIG. 163.—Arbey & Co.'s planing and trying-up machine, (with spiral knives and sharpening attachment.)

Digitized by Google

The exhibitor claims for this machine that the form of the blades and the arrangement of the helices, which are placed in such a manner that before one edge ceases cutting the next commences, produce perfect regularity of motion and a uniform expenditure of power, presents the cutting-edges at every point in its path at the best angle for doing its work, and that the smoothness of the draw-cut thus made gives a surface which does not require the use of a finishing-tool.

The smoothness of motion secured enables the machine to do its work properly without being secured upon a massive foundation. The shavings are all thrown behind the machine, and do not annoy the attendant or clog the gearing.

The use of such thin blades as these, which are but one or two millimeters (.04 to .08 inch) in thickness, gives economy of first cost and but little trouble or expense for sharpening.

The really original device in the design, the principal feature being an American invention, was probably the use of a traversing emery-wheel, which sharpens the blades when in place, and without removal from the machine.

This seems to be a very important addition, and will probably insure the success of the machine. It enables the workman to sharpen the blades with great accuracy and rapidity, and makes it a matter of certainty that the surface of the wood will be left by the tool a perfect plane, and that, the machine being once in proper adjustment, the board will be left of precisely even thickness throughout.

Still another valuable feature of this planing-machine is that it may be supplied with a variety of cylinders and correspondingly-formed blades for various kinds of work. These "*porte-outils*" can be kept in a rack or a case by the machine, one or another being used as occasion requires. The expense of a considerable stock of the various kinds required for general use would be comparatively small.

These tools have been already largely used, and it is claimed that they work equally well on pieces of any size, straight-grained or cross-grained, with the expenditure of little power and without jar.

276. The accompanying illustration (Fig. 163) exhibits one of these Arbey planing-machines. Until within a few years these machines were always made with the old-fashioned straight knives. They are now mostly fitted with these Mareschal and Godeau's patent spiral cutters, which are claimed to be both theoretically and practically superior.

The fewer the number of fibers cut at once, in wood-working, the better and easier the operation. It is largely on this account that machines fitted with spiral knives are supposed to prove so efficient.

The principal features of these machines are as follows:

(1.) The pitch of the knives is such that the end of one comes opposite the beginning of the other. The result is that the knives are cutting during the whole revolution, the machine making about two thousand turns per minute. This does away with shocks on the bearings—the principal cause of heating. The knives always present the same angle to

Digitized by Google

the wood, which is such as to allow cutting across the grain, even if knotty, and permits planing parquet flooring already put together.

As the knives are always cutting equally, vibration is entirely done away with* and wear and tear diminished; wood up to 26 inches width can be planed with a very slight increase of power. The shavings are all thrown to one side of the machine, instead of clogging up the working parts.

(2.) The knives used are very thin, from one to two millimeters, (.04 to .08 inch,) and quite flat; they are pressed closely to the spiral cutter-block by the back-iron and nut, and do not project more than 2 or 3 millimeters, (.08 to .12 inch.) They are very economical, not only on account of their cheapness, but of the short time required to sharpen them.

(3.) By a very simple arrangement they are sharpened in their places by the emery-wheel. The sharpening is perfectly accurate, as the wheel has only to be set and then allowed to run. As good work cannot be turned out without sharp knives, this improvement cannot be too highly estimated.

The machines with fixed tables are used for parquet flooring, moldings, and thin boards that do not require trying up.

Special machines are made for recessing railway-sleepers, for cask-making, and for cutting long tenons.

These planing-machines with spiral knives work wood, whether broad or narrow, thick or thin, along the grain or across it, without vibration and with very small power, and with great saving in sharpening and in wear and tear.

A large number of these machines have been supplied to the French government and to private firms.

M. Arbey exhibited a beautiful little fret-saw, and some equally creditable work done by it.

277. THE AUSTRIAN SECTION contained some excellent machinery, principally of designs which are everywhere standard. Austria in some portions is heavily timbered, and the manufacture of wood-working machinery promises to be an important industry. Pfaff & Co., of Vienna, had an exceptionally fine exhibit of saws.

The importance of securing the most efficient wood-working machinery, and at the same time the least expensive in first cost as well as in operation, in a timber-producing country like ours, it is impossible to overestimate, and our people may well be congratulated that our manufacturers are exhibiting so much intelligence and energy in meeting the wants of the country. It is not impossible, however, that they are doing their work too well, by facilitating the working of wood to such an extent that the destruction of our forests will, ere many years, produce evils so serious as to more than compensate those advantages which we are accustomed to consider of pre-eminent importance.

* To such an extent that these machines can be put down on a common floor, as was done at the arsenals of Cherbourg and Brest.

Digitized by Google

CHAPTER XI.

TEXTILE AND MISCELLANEOUS MACHINERY.

TEXTILE MACHINERY AT VIENNA; THE AVERY WOOL-SPINNER; ROSS' PICKER-MOTION; GENERAL CHARACTER OF EXHIBITS; SILK-MANUFACTURE IN SWITZERLAND; SEWING-MACHINES—ATTACHMENTS, AND METHODS OF MANUFACTURE; THE SELLERS ROTARY PUDDLER; THE SELLERS STEAM-HAMMER; B. & S. MASSEY'S STEAM-HAMMER; THE WOODBURY BRUSH-MACHINE; STEPHENS' PARALLEL VISE; BIGELOW'S SHOE-MACHINERY; THE BILLINGS & SPENCER CO.'S DROP-FORGINGS; TILGHMAN'S SAND-BLAST; WEST'S TIRE-SETTER; MILLER'S PIPE-BENDING MACHINE; WARTH'S CLOTH-CUTTER; DARLING, BROWNE & SHARPE'S MEASURING-APPARATUS; THE MORSE TWIST-DRILL COMPANY; THE SCOTT GEAR-MOLDING MACHINE; JONES & LOUGHLIN'S COLD-ROLLED SHAFTING—METHODS OF ITS MANUFACTURE; COLD-ROLLED BRONZE OF S. B. DEAN AND OF GENERAL UCHATIUS; CHARACTER OF ORDINARY BRONZE; BRONZE CAST IN CHILLS; UCHATIUS'S THEORY; ALLOYS BEST ADAPTED FOR CASTING IN CHILLS; BEST METHODS OF WORKING BRONZE—UCHATIUS'S METHOD—USE IN ORDNANCE—TESTS—EFFECT OF STRETCHING BEYOND THE ELASTIC LIMIT; OTHER APPLICATIONS OF COLD-ROLLING; COMPARISON OF STEEL WITH COLD-ROLLED BRONZE; UNDERHILL'S ANGULAR BELT; HYDRAULIC FORGING; FORGED LOCOMOTIVE WHEELS; APPLEBY & BRO.'S AND J. H. WILSON & CO.'S STEAM-CRANES; HORTON'S LATHE-CHUCKS; GERMAN OPINION OF AMERICAN TOOLS.

278. A considerable display of the machinery of textile industry was exhibited at Vienna, but it was not rich in novelties.

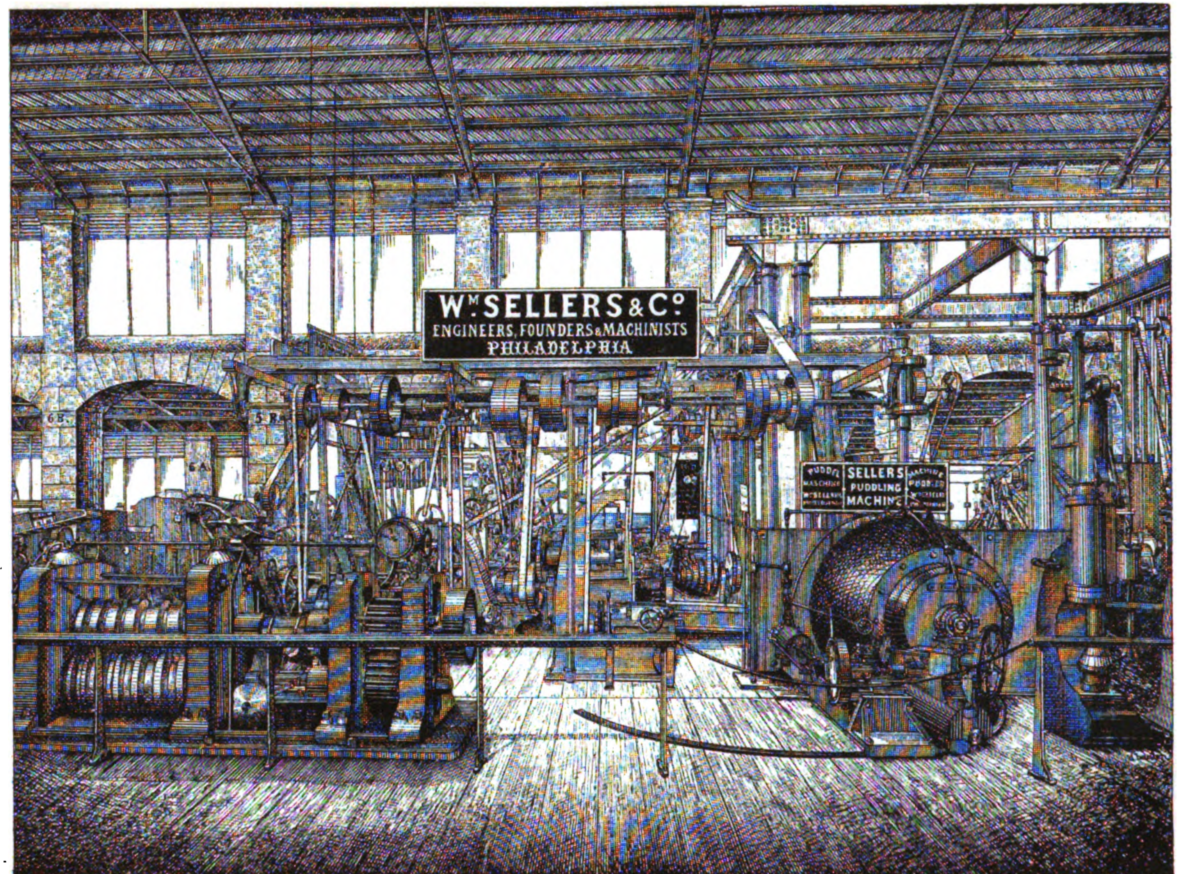
Of wool-working machinery there was far less exhibited than of cotton-machinery. The machines were of well-known standard forms, and only attracted attention by fineness of workmanship or the neatness of finish. A considerable number were in operation, particularly in the British and in the Belgian sections, and, as a rule, their performance was all that could be asked. Platt Bros., of Oldham, England, and Bede & Co., of Verviers, were the prominent exhibitors. The former exhibited the only wool-comber noticed by the writer. The wool-comber of the late Cullen Whipple, of Providence, R. I., an American invention recently introduced into the British market, was not shown, although probably a much better machine for all lengths of staple.

279. THE AVERY WOOL-SPINNER.—A machine in the United States section attracted more attention, and seemed generally considered to be of more promise than any other wool-working machine exhibited. This was the "Avery continuous wool-spinner," an invention of Mr. Luther W. Felt.

"This machine," says Dr. Grothe, "excited great admiration among woolen manufacturers, on account of its seeming to accomplish in a very small space, and with great economy of construction, a better pur-

Digitized by Google

Vienna Exhibition 1873. Machinery etc.



Digitized by Google

Digitized by Google

pose than machines of ordinary types. Avery's spinning-machine for corded yarn is more similar to the original spinning-machine of Hargreaves than any other construction so far introduced. It appears that in this sense Avery's invention shows a retrocession, but in reality it must be acknowledged that it is a progress. Avery's invention is not only an important contribution toward the long-sought solution of the problem of effecting the continuous spinning of corded yarns, but it also utilizes parts of former machines which are themselves of value. We know that four or five years ago the too-willingly rejected simple arrangements of Hargreaves' machine had to be again adopted; that, indeed, nearly the whole of this machine was reproduced, but with the difference that the nipping-apparatus is fixed and the spindles movable. However, these experiments gave satisfactory results only for ordinary wool. Avery must have carefully observed Hargreaves' nipping-apparatus, and it is evident that he decided to remove the objections to which it is open."

This machine was exhibited at the Annual Exhibition of the American Institute at New York in 1871, and was there given a high award, the justice of which was fully confirmed by that given at Vienna in 1873. The wool-spinner exhibited was a small machine of rather rough design, but of good workmanship, and was proven to be capable of doing excellent work, even on wool containing a considerable proportion of shoddy. The roving is fed from the spool by a revolving drum driven from the pulley-shaft, and is delivered to peculiarly-constructed wheels, which seize it at the proper moment and release it again as the spinning occurs, and the required draught is thus given. The drum and the cage-wheel with which it acts revolve at the same speed. The roving, as delivered, hangs down loosely until sufficiently twisted, when the next motion delivers a new supply and takes up that already twisted.

280. The action of the machine is quite a simple, but a very ingenious, combination of movements. It cannot, however, be fully described without elaborate drawings. It is one of the most important and promising of recent inventions in this department. A machine in the Belgian section was intended to accomplish the same object, but it was of quite different construction, and seemed far less effective.

The Avery spinner was simple in construction, quite well made, and did good work. The wool was of short staple, and from it a yarn was made, very fine and even, and comparing well with yarn made by the best machines of ordinary construction. A large percentage of shoddy can be worked in. The machine was stated to be capable of doing its work better and quicker, at one-half the expense, and to occupy one-fourth the space of the best of other machines. It was stated by experts to make very little waste, and to require comparatively little power. The machine was one of the most perfectly original inventions exhibited.

281. Messrs. Bede & Co. and C. Martine, of Verviers, each presented a fine collection of wool-machinery, and among them were some observ-

able improvements in matters of detail which were considered by many visitors to be unusually creditable. The British machinery of Platt Bros. was unexcelled by anything at Vienna, and many American manufacturers think it superior to that built in this country by our best makers. The fact that our own manufacturers of such machinery are gaining in competition with their British rivals would, if correctly stated, however, indicate the contrary.

Austrian and German builders exhibited some excellent machinery of this class, and the Swiss makers were at least fully their equals.

282. The greatest variety of textile machinery was found among the looms.

Mr. LESTER E. ROSS, of Providence, R. I., exhibited his independent picker-motion on a loom driven by Allen's friction-clutch pulley, and both devices attracted much attention. The workmanship of the apparatus was exceedingly creditable to the manufacturers—the Star Tool Company, of Providence, R. I.—and the loom, at 250 picks per minute, does excellent work. The peculiar feature of this loom was the mechanism by which the shuttle carrying the woof was propelled.

The earlier method of accomplishing this was by a cam or lug attached to and revolving with the shaft of the loom, and which gave a sudden blow, the force of which depended upon the speed of the loom. The speed of the loom being momentarily increased or diminished, from whatever cause, the shuttle would be thrown with greater or less force, as the case might be, and, consequently, no uniform motion of the shuttle could be obtained without absolute uniformity of speed. By means of this improvement, however, perfect uniformity of motion is given the shuttle, as it is propelled by a force independent of the speed of the loom, and it is hence called an "independent shuttle-motion." The shuttle is driven by a series of springs coiled upon a shaft. After each motion of the shuttle from side to side, the springs are strained up by means of a cam, and the power is "let off," at the proper time, by the same cam.

It is claimed for this new motion:

(1.) That looms to which it is applied can be run at any speed, from one pick to two hundred and fifty picks per minute, or at any possible speed required.

(2.) That variations in the speed of the loom, however great or sudden, will not affect the operation of the shuttle, and that such variations will require no re-adjustment of straps, boxes, or any other part of the loom.

(3.) That a better fabric must be produced, since the tension of the filling is not affected by the speed of the loom, and no jar is made on the lay-beam by the pick.

(4.) That less waste is made, since the force of the shuttle is not varied by the motion of the loom, and the cop, therefore, is not liable to be broken.

Digitized by Google

(5.) That the cost of the motion is less than that of any other shuttle-motion in use.

(6.) That the expense of operating the loom will be greatly lessened, since the shuttle-motion is more durable, there being no point liable to wear, no breaking of picker sticks or straps, no sudden shock, as by the blow of the cam in other motions, and less liability to "shuttle-smashes," because there is no danger of the shuttle's bounding back, or failing to "box," from variations in the speed of the loom, and since the cost and delays incident to repairs are consequently greatly reduced.

(7.) That less power is needed, and less time, attention, and skill on the part of the operator required to run the loom.

(8.) That it is adapted to all kinds of looms, and may be easily applied to old looms without alteration.

283. PLATT BROTHERS exhibited in the British section a cotton-gin designed especially for the woolly seed of upland cotton. It did excellent work, cleaning the seed well, and without breaking up the fiber seriously. The general form resembled somewhat a gin exhibited recently at the American Institute Exhibition, and the use of weights instead of springs to force the rollers against the knife was claimed to insure good work, even in unskilled hands, securing a uniformly-applied pressure and certainty of action. The gin was stated to be able to work off 120 pounds per hour of clean cotton from upland seed, and 200 pounds from sea-island cotton-seed.

The exhibit of textile machinery was, as a whole, far more remarkable for its magnitude than for novelty. In the exhibit of Bede & Company, the use of friction-gearing was an innovation which, if as successful as it is claimed to be, will be largely imitated.

The exhibition at Vienna of one of our best card-setting machines, of our harness-making machines, of some of our well-known inventions, and standard machinery in this department, would have added immensely to the interest of the United States section of the exhibition contained in the machinery-hall.

284. THE SILK-MANUFACTURE is with us a comparatively youthful branch of industry, although a few manufacturers have, in isolated cases, been long engaged in it. Naturally it had no representation in the United States section. France and Switzerland had very interesting exhibits of silk-working machinery, and it was easy to trace the whole process of silk-manufacture, from the winding of the fiber from the cocoon to its final appearance in the woven goods.

The process of spinning was remarkably well and largely illustrated in the Swiss section. It is quite different from cotton or wool spinning, and consists merely in twisting together the requisite number of fibers to produce the desired size of thread. The "drawing," which is so important a part of the process of spinning textile materials of short fiber, is not necessary or possible here. Among the silk-looms were several very fine specimens, which were at work weaving silks of various widths and patterns.

Digitized by Google

Switzerland exhibits some examples of waste-silk-working machinery. As the fiber is, in this case, much broken up, and resembles more nearly those more familiar textiles, cotton and wool, the process of working is intermediate between that by which new silk is worked and the ordinary method of working long wools.

If we may judge by what was shown at Vienna and by the statistics given in Part II, the silk-manufacture of Switzerland must be a large and an exceedingly important branch of that nation's industry.

285. SEWING-MACHINES can hardly be classified with the textile machinery, but they are hardly second to them in importance, and they appeared in every section of the machinery-hall in wonderful variety and in great numbers. The more important were of American make, or were copies, made with great accuracy frequently, of American machines. The manufacturers of Great Britain and of the continent have imitated our methods of manufacturing, and often produce exceedingly creditable work. The exhibit of sewing-machines in the United States section was very extensive, and all of our standard machines were well represented. This was one of the most attractive departments of the whole *Welt-Ausstellung*, and interested all classes of visitors. Examining carefully the construction of these machines, and comparing those of foreign make, it is soon discovered that where defects occur in the latter they are generally the result of a lack of knowledge of the proper distribution of material. The machines were made of standard forms, and their parts were always made to gauge and were interchangeable; but still the fits were sometimes a little loose, and the neat adaptation of the special qualities of steel and of iron, or of case-hardened iron, which invariably distinguishes the American productions, were sometimes not seen in the foreign copies.

286. The large number of ingenious and convenient attachments which accompany the American machines is also one of their distinguishing characteristics. The foreign manufacturers do not invent them, and they are somewhat slow in adopting those invented in the United States. It is not at all remarkable that, notwithstanding the fact that so many sewing-machines are now built in Europe, many thousands are still annually exported from America. Even the humble cottagers of Bohemia and the semi-civilized people of Russia and of Turkey are now becoming purchasers of these universally-useful little "labor-savers." A resident of Sweden states that the poor peasants of that country also are succeeding, frequently, in satisfying the ambition, which is common to all, of possessing an American sewing-machine. The sewing-machine has thus become one of the most important aids in the advancement of civilization. Increase of production and the decrease of prices are matters of great moral as well as commercial importance. The expiration of the last of the important patents upon essential details will soon take place, and these very desirable consequences must soon follow.

287. VARIOUS UNCLASSIFIED EXHIBITS.—Besides the machinery

Digitized by Google

noticed in the preceding sections of this report, there were many exhibits which deserve more than a passing mention.

In the exhibits of Messrs. Sellers & Co. were included a Morrison steam-hammer, embodying improvements devised by the builders, a novel revolving puddling-furnace, and a 12-inch rolling-mill train.

The latter was simple in construction, well proportioned, and well built. Its neatness and its substantial appearance secured for it much commendation.

The SELLERS ROTARY PUDDLER was a most interesting and ingen, ious machine. The heat was intended to be supplied by a gas-furnace- the flame being directed into the puddling-furnace at the upper portion, and after eddying downward within the egg-shaped vessel, passed out at the end at which it had entered, through an opening below that which afforded ingress.

The puddling-furnace was therefore open only at one end. This construction secures greater strength in the shell, a more eliable adhesion of the lining, and some important advantages of manipulation.

The furnace was supported by "friction-wheels" at one end and on a horizontal pivot at the other. The power required to produce its rotary motion was comparatively small.

A small horizontal steam-engine was mounted by the side of the furnace, on the same supporting-frame. The whole apparatus was carried by this frame, which was pivoted at the end nearest the open end of the furnace, the pivot-bolt being placed a little on one side and beneath the furnace-mouth.

The engine was so attached that it could be used either to revolve the furnace or to swing the whole machine about the pivot-bolt. A neat little device permitted reversing promptly, and every change could be made with great facility. The material and workmanship, as well as the general design, fully sustained the reputation of the makers.

In operating this furnace, a man stands upon a little platform on the main frame by the side of the engine, and, after first allowing the furnace to become well heated up, he sets the engine in motion and swings it into a position at right angles to the face of the flue-wall.

The pig-iron is then charged. Messrs. Sellers & Co., instead of charging solid metal, as is customary elsewhere, melt the pig-iron in a cupola-furnace, and run molten iron into the puddling-furnace, thus shortening and cheapening the process, and saving the furnace-lining from the serious abrasion consequent upon careless charging with solid pig-metal.

The furnace is then run back into position and set in revolution; the gas-flame having been given an oxidizing character, the process of decarbonization goes on until the iron balls up, as in the Danks and other "rotary" puddling-furnaces.

The ball of sponge is removed by first turning the furnace away, as when charging, and handling the balls with properly-arranged apparatus.

Digitized by Google

The details of the method of working and handling the metal, as practiced at the Messrs. Sellers's iron-works at Edgemoor, near Wilmington, Del., are exceedingly ingeniously planned, but a description would be out of place here.

288. In SELLERS' MORRISON STEAM-HAMMER (Fig. 165) the weight is principally in the piston-rod, which is made very large both above and below the piston, but largest below. The piston is welded to the rod. The heads of the steam-cylinders form the guides, preventing the lateral movement of the hammer, and one side of the upper portion of the rod is planed flat to prevent turning.

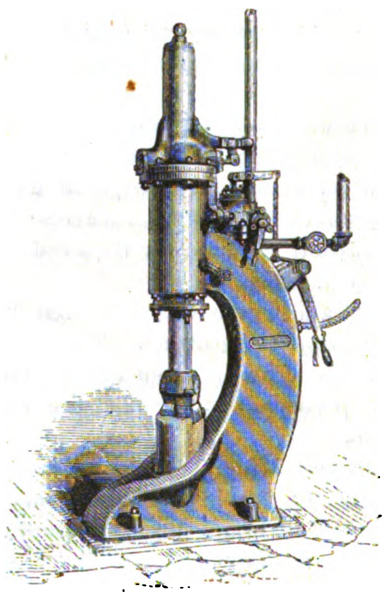


FIG. 165.—Sellers's "Morrison" steam-hammer.

The hammer-head is secured to the rod by a circular key, a ring of wedge-shaped cross-section, but which is readily loosened by removing the top die and striking a light blow on the anvil-block.

The valve-movement is automatic, or a hand-motion is used, as desired. In the former case, the motion is obtained by two opposite grooves of varying depth cut into the rod, in which grooves a yoke is fitted, which, bearing on the inclined surfaces forming the bottoms of the grooves, is given a motion which is transmitted to the valve. The line of motion passing through the center-line of the rod, there is no tendency to twist the latter.

The valve is balanced. A supplementary valve permits choking the exhaust where quick, light blows are wanted, as in finishing work.

The tool is admirable in every respect. Sellers & Co. also exhibited their latest style of Giffard injector for feeding boilers. This wonderfully beautiful and ingenious yet simple device owes much of its pres-

Digitized by Google

ent effectiveness to this firm, who are the licensees in the United States. The self-adjusting device by which the apparatus adjusts its own water-supply is hardly less important and beautiful than the main inventions.

Mr. CHAS. CHURCHILL, of New York, exhibited a considerable variety of metal-products, including the standard metal-workers' tools. One of the most novel was the STEPHENS' PARALLEL TOGGLE-JOINT VISE.

This neat and ingenious device is constructed in a considerable variety of forms by the Colt Armory Company, of Hartford, Conn. It is illustrated in the accompanying sketches. Fig. 166 represents the tool

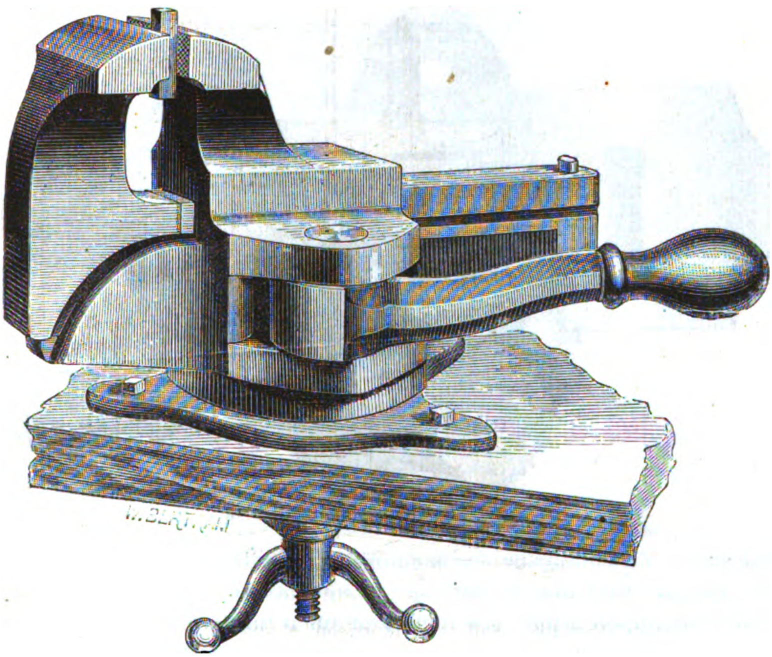


FIG. 166.—Stephens' parallel vise.

as usually mounted on the work-bench, on a swivel, and capable of taking any desired position for convenience in working upon the piece held in its jaws. As shown, the jaws are closed upon the work and the handle thrown up against the side of the slide.

Fig. 167 is a plan in part section, showing the mechanism by which the handle clamps the piece in position. The toggle G G^1, the tooth-bar *t*, the spring S, the cam C and handle H, carrying a hook, M, are the peculiar and essential parts of the device. The sliding-bar B B is provided with a steel rack, T, and engages the tooth-bar *t* when the vise is in use.

The work being placed in the vise and the jaws brought up into position to clamp it, the handle H is thrown outward, the hook M slips off the projection *m*, and the spring S, acting upon the point U, forces the tooth-bar *t* into contact with the rack T. Continuing the outward motion of the handle, the cam C comes in contact with the projection *n*, straightening the knee-joint, and, by driving the sliding-bar backward, forces the movable jaw firmly against the work, holding it in place with great force. The vise is very quick in action, handy, strong, and very powerful in its grip. It has very little friction, and would seem likely to prove durable. The work is released easily by the slightest reverse motion of the handle. The manufacturers have a remarkably large variety of attachments and of modified forms of this vise, fitted for the peculiar demands of the several trades.

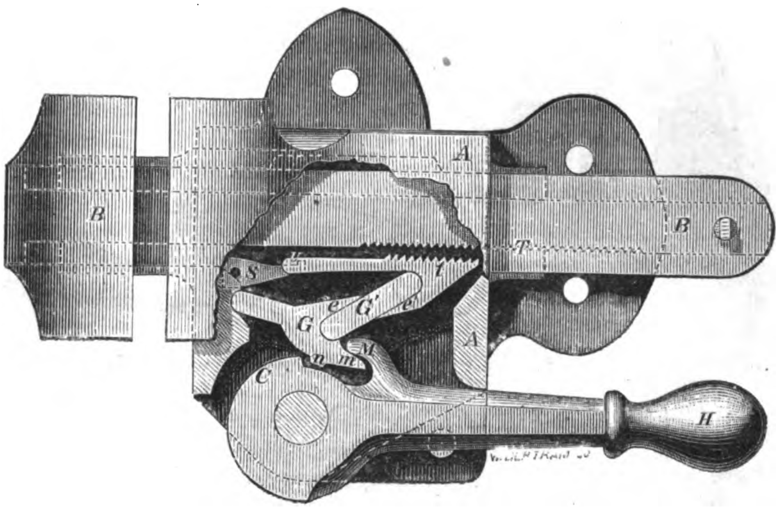


FIG. 167.—Stephens's parallel vise.

The swivel on which the vise is mounted, as shown above, (Fig. 166,) is a very elegant and simple device. It consists of a plate which may be bolted or clamped upon the bench or on a table, and carrying on its upper face a ring of wedge-shaped section. A similar ring is cast on the upper part of the swivel, which fits into the first-named ring. A bolt passes through both, and its nut is turned by means of projecting arms. On setting it up, the two rings are clamped together, and, the inclined surfaces coming snugly against each other, the vise is held firmly, and can neither turn nor shake.

The exhibitor, in his circulars, gives a comparison of the relative extent of rubbing-surface in this and in the common screw-vise, making them as one to nearly nine hundred, and estimates the required time of opening and closing to be as one to fifty. The taper attachment for holding tapers is one of the many neat and handy attachments which are supplied with these vises. Fig. 168 exhibits its construction better than can any verbal description.

The BILLINGS & SPENCER MANUFACTURING COMPANY, of Hartford, Conn., exhibited a great variety of parts of machinery, solid forgings

GENERAL LIBRARY University of MICHIGAN

for sewing-machines, guns, and small tools. They were all made in drop-presses—a class of tools described when referring to the exhibit of Messrs. Stiles & Parker. These were very fine specimens of this kind

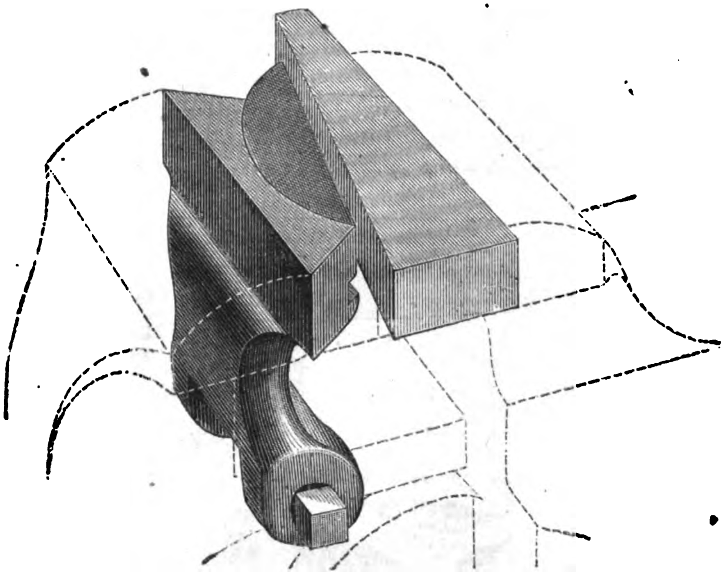


FIG. 168.—Taper attachment for irregular work.

of work, and many of them were master-pieces of accurate forms and intricate shapes. This firm have made a specialty of this kind of work and have succeeded in producing some pieces of work which could only have been made by a very skillful workman, if it could have been done at all by hand. The heavy blow of the drop-press, forcing the metal, at a single stroke, into the die, does its work so quickly that the metal has no time to cool, and therefore so thoroughly that no defects of internal structure can be produced or can remain if originally present. It does its work so accurately that every piece is the precise counterpart of every other piece made in the same dies, and each is precisely of the size and form demanded. It does its work so rapidly and cheaply that, where the number of pieces to be made is sufficient to justify the making of the dies, there is no comparison in economy between this and the ordinary method of hand-forging.

The use of the drop-press was first introduced into general use among the jewelers, and among manufacturers of the light, thin cases used for daguerreotypes, and makers of similar products. The tool was next applied to special operations in gun-making, and in making bolts, nuts, and small rivets. It has now become so generally used that tool-builders find a considerable market for the styles of this machine which each makes in some variety. Several firms are making a regular and an extensive business in supplying drop-forgings to sewing-machine companies, makers of fire-arms, and other manufacturers who make exten-

Digitized by Google

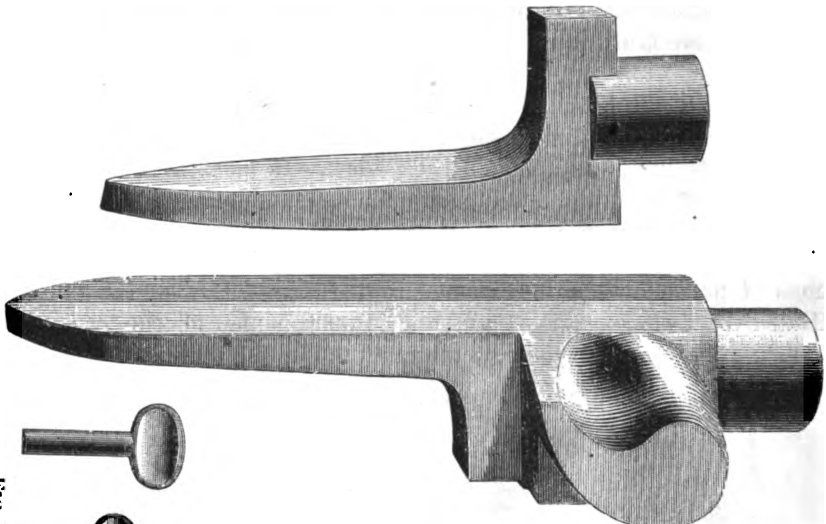


FIG. 169.—Rifle-breech pins.

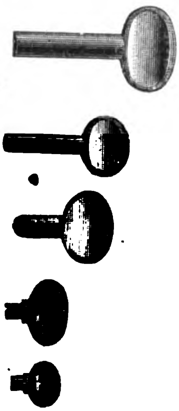


FIG. 170.—Thumb-screws.

FIG. 171.—Milling-machine cranks.

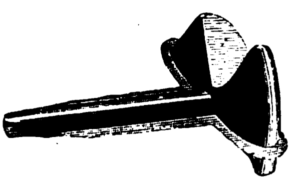


FIG. 175.—Wilcox & Gibbs sewing-machine hooks.

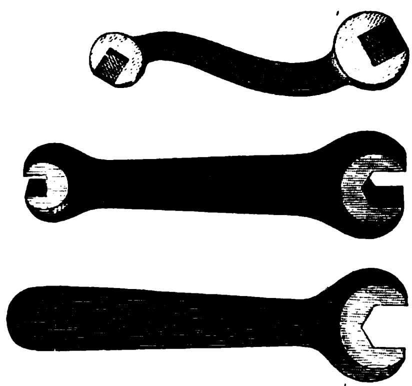


FIG. 172.—Machine-wrenches.

FIG. 176.—Key.

FIG. 173.—Machine-handles.

sive use of small iron and steel parts in their work, in great numbers and of precisely similar form and size. The Billings & Spencer Company are well known in the United States as among the largest and most successful makers of drop-forgings, and nothing shown in other sections of the Exhibition, or, indeed, in the manufacturing establishments of Europe, so far as the observation of the writer has enabled a judgment to be formed, equals their work. In fact, the business does not seem to have taken definite form there as it has in our country; but it is not probable that, thoroughly awakened as European manufacturers have, of late years, become to the importance of the peculiar modifications of practice which have come to distinguish the industries of the United States in so marked a manner, that this modification of practice in forging will remain long peculiar to the United States.

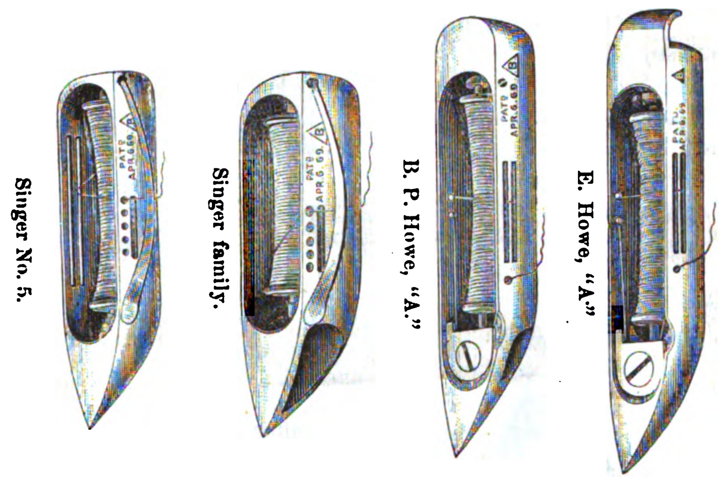


FIG. 174.—Sewing-machine shuttles.

Figs. 169 to 176 exhibit some of these interesting specimens and the most important and most difficult forms. The rifle-breech-pins (Fig. 169) and the shuttles (Fig. 174) are remarkably fine examples of this kind of work. This firm either furnish these pieces in the rough or finished.

289. Messrs. B. & S. Massey exhibited several fine steam-hammers in the British section. They state that their small hammers are specially designed for smiths' work of every kind, and are applicable for the lightest descriptions of forgings, such as have usually been made by hand.

In consequence of the almost endless variety of purposes to which they are adapted, steam-hammers are economical even in the smallest smiths' shops, and even with only a single fire. Some of their principal advantages are:

A great saving in wages, as one smith with a steam-hammer can do as much as two or three without it, and for the smaller sizes he will not need an assistant.

Digitized by Google

Great economy in fuel, as, at one heating of the iron, so much more work can be done than is possible by hand.

Economy of iron, since scrap-metal, which is commonly almost useless, can be worked up into forgings of good quality.

The forgings may be so accurately finished as to require little labor in fitting and turning. In many cases the saving is said to amount to 50 per cent., or even more, defraying the cost of the hammer in a few months.

All of the hammers of Messrs. B. & S. Massey are double-acting, and will strike lightly or heavily, quickly or slowly, long or short strokes, and elastic or dead blows, as desired. Large hammers are usually made by them to work by hand only; but the smaller ones are ordinarily arranged so as to work both self-acting and by hand. They work without jar or shock.

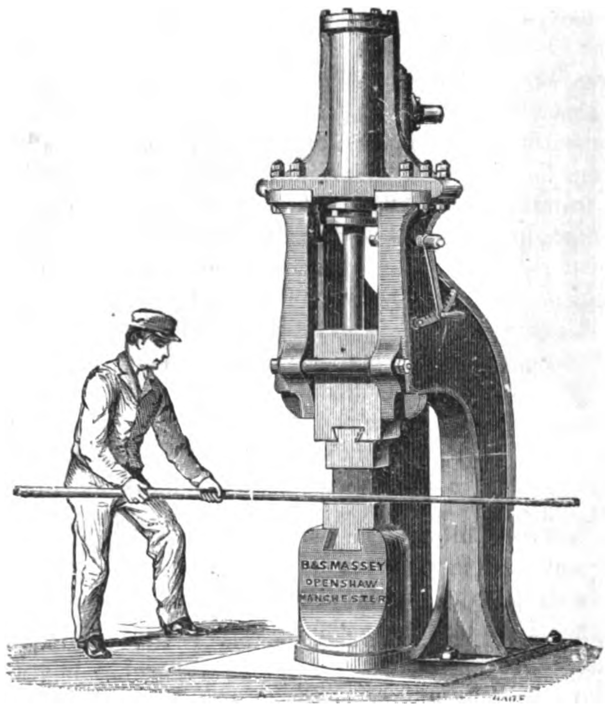


FIG. 177.—Massey's 5-cwt. steam-hammer.

Their 5-cwt. steam-hammer, for general smith-work, (Fig. 177,) is specially designed for the use of smiths, whether for machine-making, engineering, gun-making, ship-work, railway-work, agricultural-implement work, or any other class for which smith-work is used.

The construction of steam-hammers which are commonly employed for the heavy work in connection with which the steam-hammer is best known, are not well adapted for smiths' use, but the one represented in Fig. 177 is said to be found remarkably convenient and easy of manipu-

Digitized by Google

lation. The form of the framing allows the smith to stand on three sides with equal facality, so that if standing in the middle of the workshop, men from different sides can with ease bring their work under it. And as the framing consists of two separate standards, with a clear wide space between them, a long bar can be passed between them and laid across the anvil in either direction.

The gearing for working the valves is a combination of "self-acting" and "hand-worked" gearing. The "tappets," or "cams," or "sliding wedge," usually employed in the self-acting gear of hammers, are entirely dispensed with, and thereby the excessive noise and wear which they produce are obviated. The mechanism consists of a hardened roller, fixed upon the back of the "tup," or hammer-head, sliding up and down the face of a curved lever, which is supported at its upper part by a stud, and kept always in contact with the roller by means of a spiral spring; it moves a valve-spindle, and regulating-valve upward and downward at every rise and fall of the hammer. The distance traveled by the piston is regulated by a lever, fixed upon the stud, which carries the curved lever, and by moving which this stud is elevated and depressed, thus altering the points at which the steam is admitted to or liberated from the cylinder. This regulating-lever is fitted on the outside of the framing in a position convenient for handling, and is provided with a guard-plate and spring for retaining it in any desired position. The regulating-valve is in the form of a double piston, hollow through the center, so as to be open from end to end. The steam is admitted and released through a number of ports, arranged around the valve on all sides, so that the valve is held in perfect equilibrium, and as a very slight movement of the valve uncovers a large area of the ports, the steam enters and leaves the cylinder very quickly, and causes the hammer to deliver its blows with great rapidity and force. With a fair pressure of steam, of from about 40 to 60 pounds per square inch, the hammer will, when desired, strike about 250 blows per minute, and the length of stroke can be varied at pleasure from the maximum, 21 inches, down to about 2 inches, the changes being effected without checking the hammer.

For many purposes the self-acting stroke is not so useful as a slow and heavy "dead" blow, in which the steam does not begin to lift the piston until the full force of the blow has been expended. Ordinarily in "self-acting" hammers this quality of blow is either not attainable at all or only imperfectly, and with difficulty; but in this hammer there is a hand-lever in a convenient position, connected directly with the valve, by means of which perfectly "dead" blows can be delivered instantly, the change from "self-acting" to "hand-working" being effected without the slightest interruption. For stamping, punching, and any other purposes for which heavy deliberate blows are required, this is of importance.

The pistons of these hammers are forged in one solid piece with the piston-rod, and fitted with Ramsbottom's steel packing-rings. The "tup"

Digitized by Google

is of hammered scrap-iron, and moves between guides formed in the framing.

The anvil-block is a separate casting of great weight, and turned in the lathe in the part which passes through the base-plate, the hole in the latter being bored out to fit it, thereby preventing the inconvenience caused by the anvil-block moving from its true position or settling down on one side.

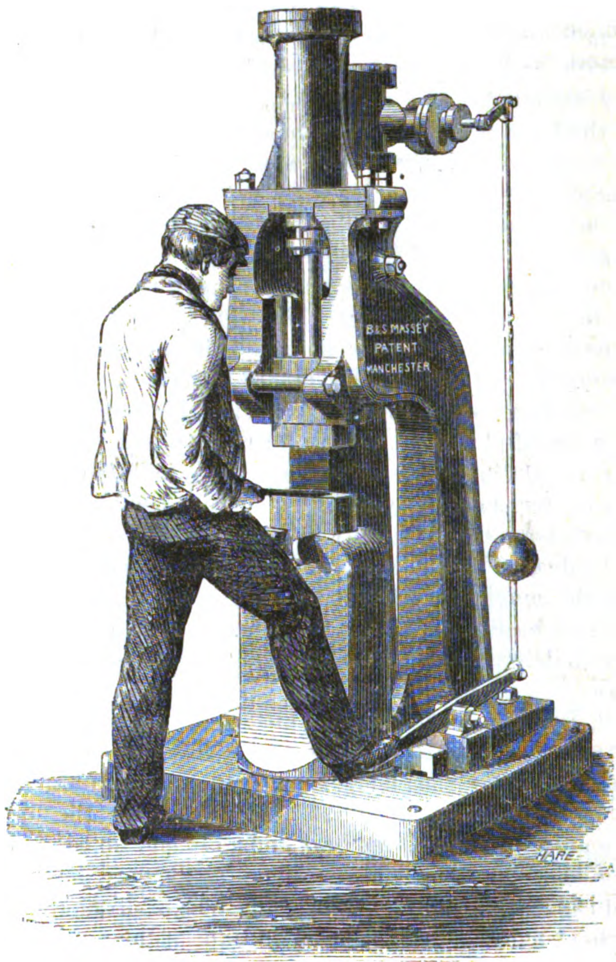


FIG. 178.—Masseys' ½-cwt. steam-hammer.

Fig. 178 is an illustration of a ½-cwt. steam-hammer; is much used for forging files, spindles, bolts, cutlery, and other small work.

For file-forging, the first steam-hammer known to have been used was, it is said, made by B. & S. Massey for Messrs. T. Turton & Sons' Sheaf and Spring Works, Sheffield; and though the opposition of the trade-unions threw much difficulty in their way, the use of small steam-ham-

Digitized by Google

mers is rapidly superseding hand-forging. For many purposes, these little hammers are fitted with "foot-levers," by means of which the workman is enabled, without assistance, to start and stop them, and to regulate their speed and force, while leaving both hands free for the manipulation of his work.

For other purposes, when there is a greater variety in the shape of articles to be made with the hammer, the foot-lever is omitted, as the workman could not conveniently make use of it. This hammer, it is stated, can be worked up to a speed of about 400 blows per minute. The maximum length of stroke is 11 inches.

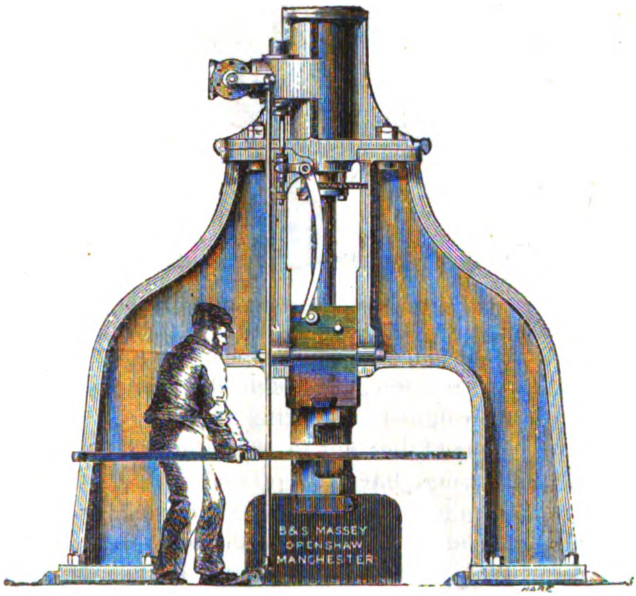


FIG. 179.—Massey's steam-tilting-hammer.

The 1½ cwt. steam-hammer is used for medium smith-work. The construction of this hammer is, with small exceptions, similar to the 5-cwt. one already illustrated in Fig. 177. It is used for the lighter kinds of general smith-work, such as bars and shafting, up to about 3 inches in diameter.

This hammer was exhibited at work at the Exhibition, the 5-cwt. hammer being too large to work there, on account of the vibration produced by its powerful blows.

Fig. 179 represents the steam-tilting-hammer for steel. They are of great strength in all their parts, with large cylinders, short stroke, simple, self-acting valve-gear, and very rapid action. The sizes range from 1 to 20 cwt.

Fig. 180 illustrates the steam-hammer for wheel-making, copper-work, &c. For any work which requires great width and height under the framing, this form of hammer is specially suitable. For wheel-making

Digitized by Google

and heavy copper-work, the hammer is usually worked by hand, as shown in the engraving, the gear being so arranged as to leave the space below the framing quite unobstructed. The sizes are 10 to 15 cwt. They are capable of striking 300 blows per minute. The height under the framing is 11 feet.

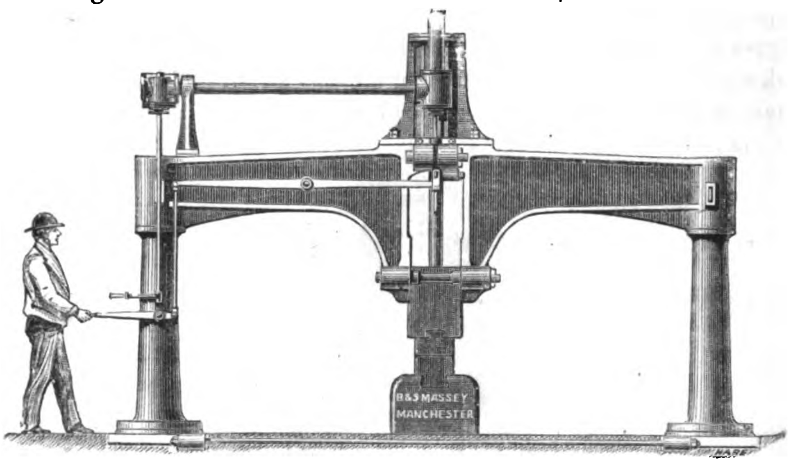


FIG. 180.—Massey's steam-hammer.

Fig. 181 illustrates the 3 cwt. special steam-stamp. This is a steam-hammer of peculiar arrangement, introduced years ago by the Messrs. Massey, and specially designed for forging articles of which large quantities are used, by means of dies cut to the form of the finished article. The stamp is not self-acting, but is regulated either by the foot or by the hand. When left to itself with the steam turned on, it rises to the top of its stroke and remains in that position until the valve is brought down by the hand or foot of the attendant. It then delivers a single "dead-blow," and rises again, as before, leaving the lower die clear for the removal of the finished article and the introduction of the hot iron for a new one. The upper die is fixed rigidly in the tup or hammer-head, the lower one being adjusted by strong poppet-screws until it exactly coincides with it. The tup is fitted between slide-bars which guide it down upon the lower die, and, with a stamp of adequate size, the forging can be finished at a single blow with a great degree of accuracy. Special arrangements are introduced for facilitating the adjustment of the dies, for removing bolts and similar articles from the dies, for preventing the piston from striking the cylinder-cover, and for adjusting the slides so as to compensate for the wear caused by friction.

The 5-cwt. stamp will, with great ease, as claimed by the exhibitors, make a bolt 1¼ inches diameter, with large square head 2¾ inches diameter and 1 inch thick, and with very deep square neck, at *a single blow*.

The principal sizes of these stamps weigh from ½ to 10 hundred-weight.

Fig. 182 illustrates some of the work done by these tools, such as

Digitized by Google

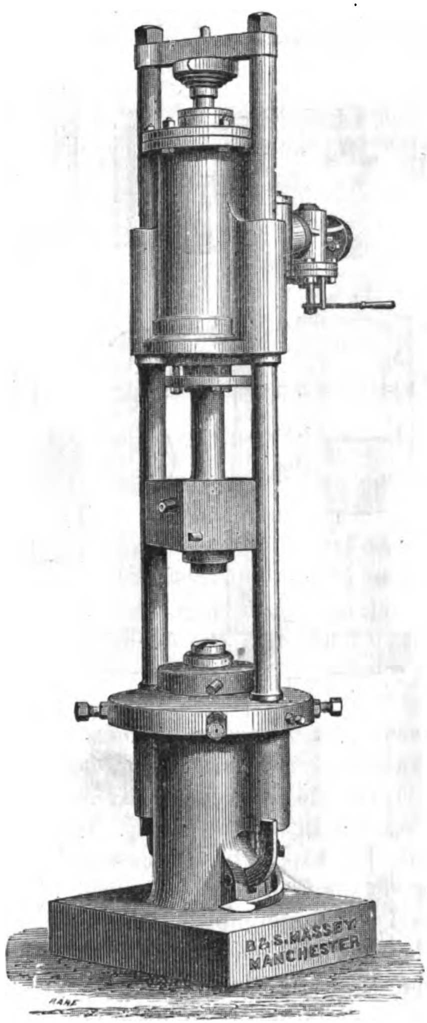


Fig. 181.—Massey's steam-stamp.

Digitized by Google

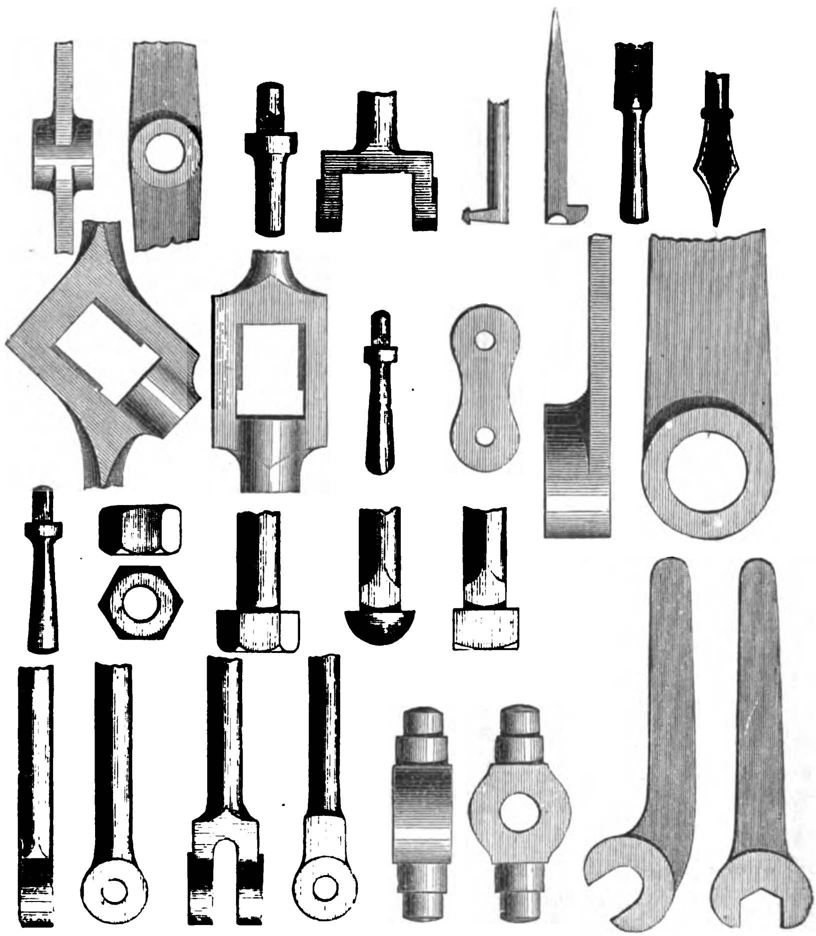


FIG. 182.—Specimen forgings made with Massey's steam-stamps.

Digitized by Google

Digitized by Google

Digitized by Google

screw-keys, spanners, bolts, rivets, nuts, gun-locks, joint-ends, spear-heads, levers, bosses, and other pieces.

290. Mr. H. C. Covert, of New York, exhibited the WOODBURY BRUSH-MACHINE, in operation in the American section, making brushes of every size and kind. This machine (Fig. 183) is purely automatic. It forms the bristles into bundles of suitable size, winds a fine wire about the part which is to enter the back in such a way that it forms a screw-thread. It is then screwed into the back, and so firmly that no force can extract it by a direct pull, the bristles themselves breaking before the hold in the back can be broken.

The material to be worked in this beautifully-ingenious machine is first drawn in between the teeth of a comb, A, Fig. 183. This comb is taken out of the machine for this purpose, and, there being duplicate combs, empty ones can be filled while the machine is at work, so that it may run without intermission. The comb, when placed in the machine, slides in guide-ways, being actuated by a traverse motion, which, as fast as one space is emptied of its material, brings another up to the mouth of a twisted channel, B, into which the bristles or other fibrous material is forced by a feed-movement very much resembling the four-motion feed on sewing-machines, the teeth of which engage the entire rank of fibers.

The office of the twisted channel is to bring the rank of fibres from the vertical into the horizontal position. In this position it reaches the divider C, where a portion of the rank of fibres is compressed by a spring, so as to insure the proper quantity in the bunch which the divider separates. This divider, which is attached to and forms a part of the tube which carries the bunch, has imparted to it, by suitable mechanism, a vertically-reciprocating movement. As it rises, the peculiarly-shaped point D separates from the rank of bristles enough to form a bunch, and as the separated portion cannot rise, the divider, in its further upward movement, brings the bunch down along the inclined way or channel E to the bottom F of the way; here it lies directly under the doubling and twisting plunger G, shown in details in Figs. 185 and 186.

The plunger G now descends, and, engaging the bunch in a hollow in its lower end, forces it down and doubles it in the manner shown in Fig. 185.

Meanwhile the wire I, Fig. 186, has been drawn off and straightened, preparatory to being thrust through a slot in the plunger at H, Fig. 185, and between the ends of the looped bristles, which being accomplished, it is cut off in a short length, as shown in Fig. 186.

The plunger and tube now descend together to the block, carrying with them both bunch and wire. On the interior of the tube is cut a female screw-head. The plunger is caused to turn on its vertical axis during the descent, which winds the wire about the bunch of bristles in the form of a screw-thread, as shown in Fig. 186. Continuing the same

Digitized by Google

FIG. 184.

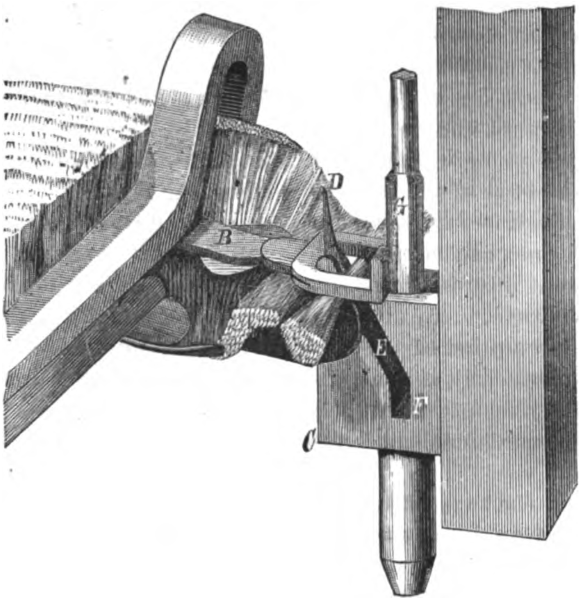


FIG. 186.

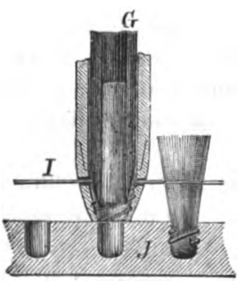
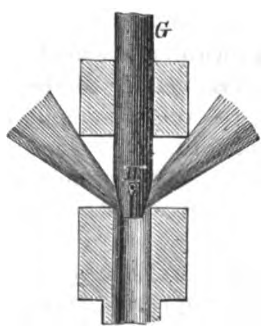


FIG. 185.



Woodbury brush-machine.

Digitized by Google

rotating movement without descending farther, it then screws the wire bunch into the block J, Fig. 183, the lower cut end of the wire plowing a thread in the hole; then when the bunch has entered to a proper depth, a slight turn of the plunger in the reverse direction takes the twist out of the bristles, and the upper cut-end of the wire engages the wood. The plunger is then withdrawn, and the same operation is gone through with a succeeding bunch, and so on, till all the holes in the block are filled.

The block lies on its back on a table made adjustable to any angle, so that the bunches may be inserted obliquely as required, the pitch of the table being regulated by the notched arc M and other appliances, readily manipulated by the operator.

While one bunch is being inserted, the point of the guide K is inserted into the next suceeding hole by the operator, and as soon as the bunch is inserted, this guide automatically draws the hole with which it is engaged directly under the plunger to receive its bunch, accurately centering it and obviating the possibility of mistake. The guide then releases itself from the hole, which immediately receives its bunch, and so on, till the block is filled.

Seventy-five to eighty bunches per minute is said to be an easily maintained rate.

The machine works, as stated, tampico and all other vegetable fibre used for filling brushes, as well as bristles, and the knots or bunches are inserted in hard rubber with the same facility as in wood.

An ordinary scrubbing-brush block can be filled in one minute.

291. A collection of boot and shoe machinery exhibited by HORACE H. BIGELOW, of Worcester, Mass., and by the REVERSIBLE BOOT-HEEL COMPANY, of Providence, R. I., was hardly less ingenious, and attracted nearly as much attention as the pail and barrel making machinery already described.

The accompanying cuts will illustrate the machinery used by the Bigelow Heel Compressing and Attaching Company. By their system of compressing heels, a more uniform, solid, and perfectly shaped heel is claimed to be obtained than by any other method in use.

The lifts are first tacked together, after which they are placed in the machine and compressed in a mold of the required size. Fig. 187 illustrates the heel-compressing machine. "Thus," says the inventor, "the heel is made thicker by being compressed on the sides, gaining thereby a lift on each heel. Instead of wasting the stock by trimming it off; it is compressed into the heel. The holes are made in the heel and nails set while the leather is under pressure. A better heel can be made from the same stock, with either pieced or whole lifts, than by any other process, while at the same time the heel is more solid, uniform, and durable. It is not necessary to use a rand on any kind of boot or shoe having a low shank. The heel being concaved sufficiently in the machine to fit on the shank, uniformity in nailing is secured. A better and smoother burnished edge

Digitized by Google

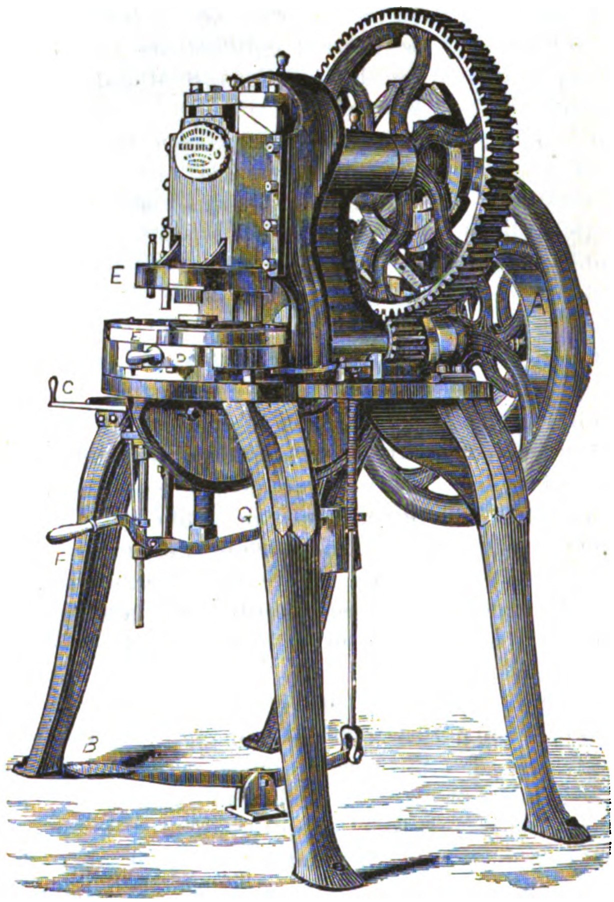


FIG. 187.—Heel-compressing machine.

Digitized by Google

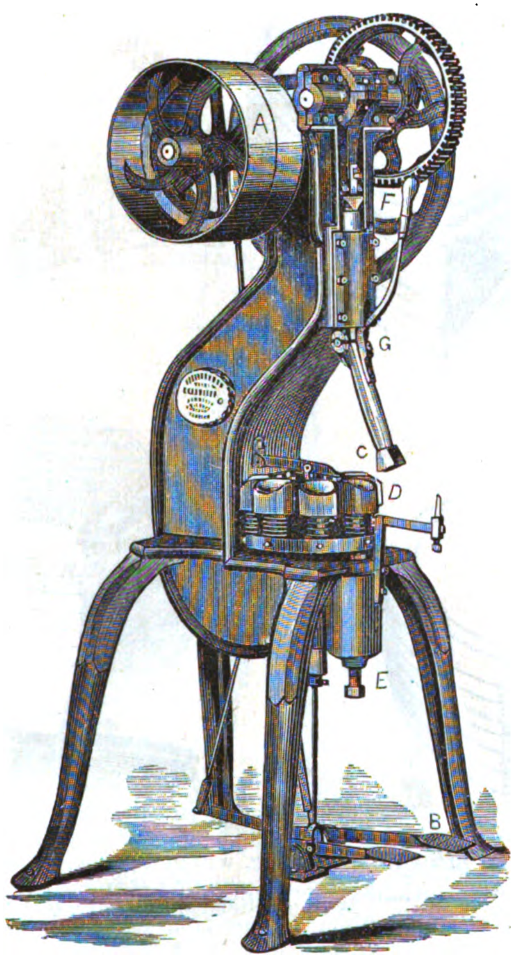


FIG. 188.—Heel attaching machine.

Digitized by Google

can be obtained. Great rapidity in its operation is an important feature; a man can put on with a hammer 400 pairs a day of compressed heels, effecting a great saving of labor. This machine compresses 1,500 pairs daily." The compressing-machine has two 18-inch pulleys, 4-inch face each, (tight and loose,) and runs 180 revolutions per minute.

FIG. 189.

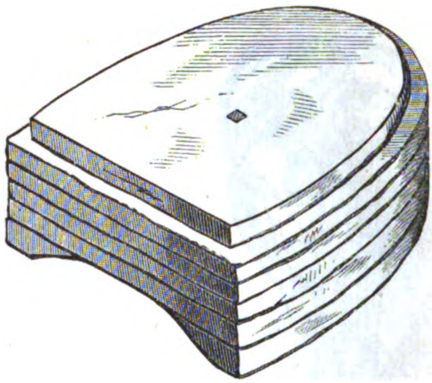


FIG. 190.

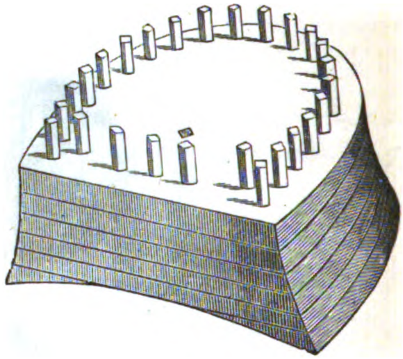


FIG. 191.

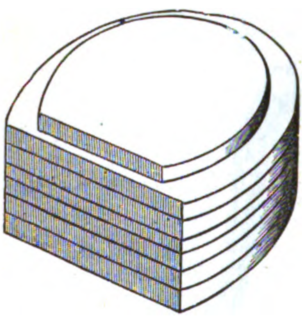
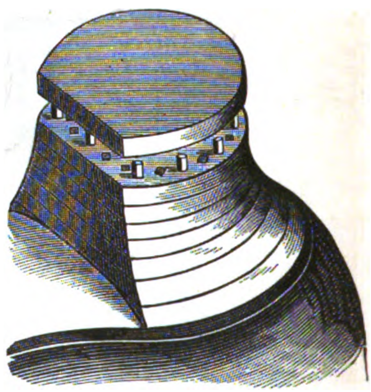


FIG. 192.



Heels in process of construction.

Fig. 188 is the attaching-machine, which is used to heel boots and shoes of every description, either nailed or blind-nailed. This machine puts on heels more uniformly and truer than can be done by hand, with a remarkable rapidity of operation, and effects a great saving of labor. It has the merit of simplicity in its construction, and of being easily adjusted to heels of any size. The heels are beveled and need not be smoothed after being put on. One man can heel 1,500 pairs per day. This machine has two 18-inch pulleys, 4-inch face each, (tight and loose,) and runs 180 revolutions per minute.

Manufacturers not having power and those who buy their heels make a great saving by using the compressed heel. They are rapidly attached with a hammer, saving labor in heeling and trimming, and preserving

Digitized by Google

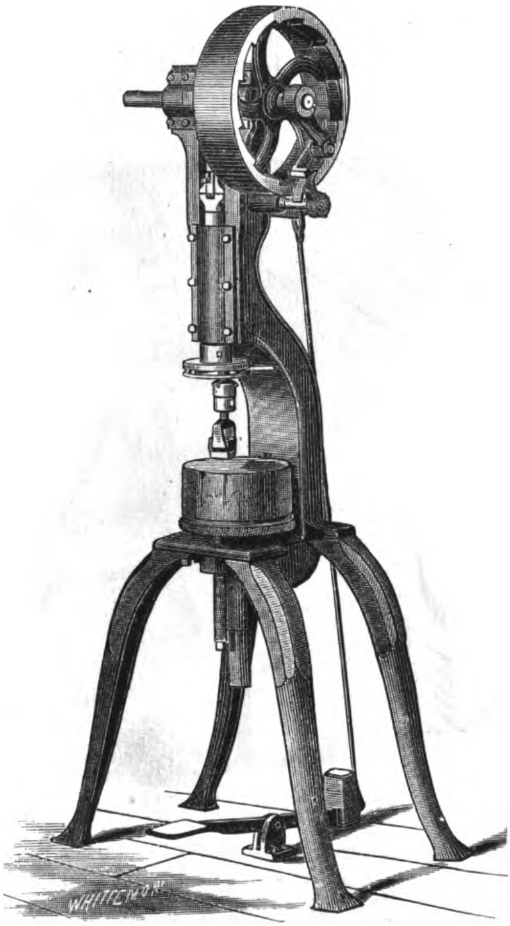


FIG. 193.—Heel-cutting machine.

Digitized by Google

the uniformity and solidity of the heel, producing better work, and at low cost. Figures 189, 190, 191, and 192 represent the heel in various stages of construction, from the blank heel to that ready to receive the blind top-lift, which is also adjusted by the attaching-machine.

Fig. 193 represents the heel-cutting machine, which is adapted for cutting outsoles, insoles, heeling, counters, shanks, &c., and can be used with dies having handles or without. The large size has a 20-inch circular revolving block; the die is fastened in a chuck over the block, and can be moved about as desired. The block is worn evenly by the constant revolving motion; the wear is taken up by raising the screw under the machine. The small machines are simple in construction, and can be operated by a boy or girl.

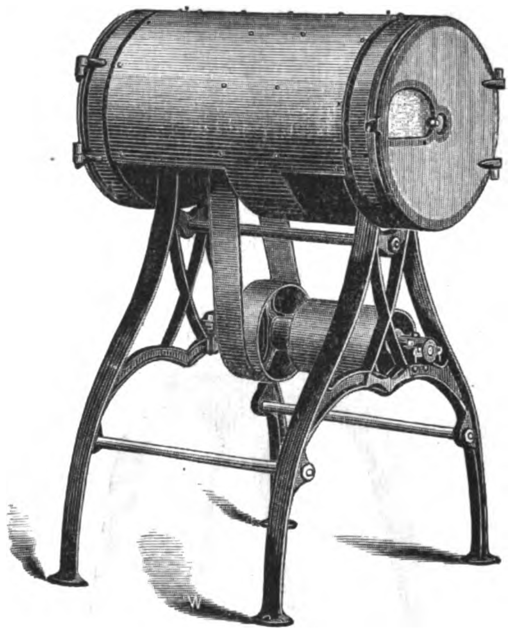


FIG. 194.—Heel-filing machine.

Fig. 194 represents the heel-filing machine, which has an arbor passing through the cylinder, and on each end of the shaft an emery-wheel 14 inches in diameter. The heels are filed on the face of the wheels. The cylinder has a fan inside which carries away the dust.

If desired, an operator can work on each end of the machine.

The wheels are covered with glue and emery; as the emery wears off another covering can be added, and so continued.

The wheels are cleaned by soaking in water; the emery is saved and used again.

Figs. 195–199 represent the different chucks used in the cutting-machine. Fig. 195 is used for holding a heel-die, with raised handle. When the die is filled with the lifts, the operater removes them from the

Digitized by Google

FIG. 195.

FIG. 196.

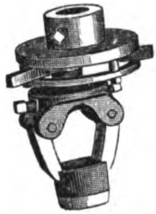


FIG. 197.

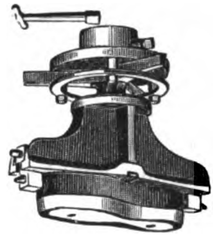


FIG. 198.

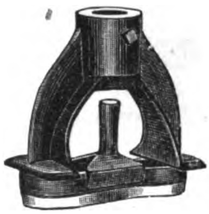
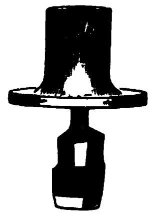


FIG. 199.



Chucks for cutting-machine.

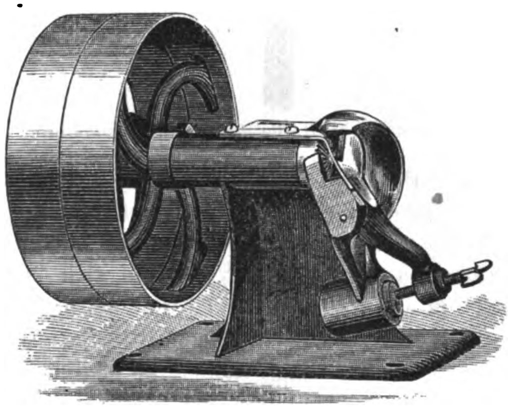


FIG. 200.—Rand-turning machine.

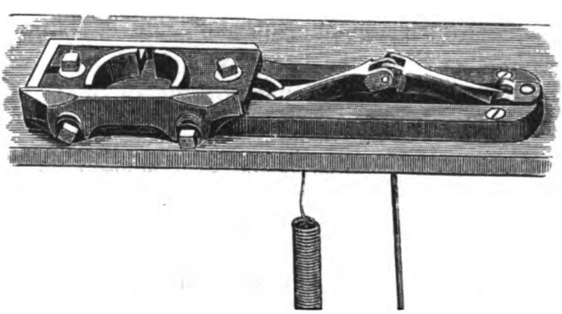


FIG. 201.—Heel-building machine.

Digitized by Google

top. Fig. 196 is used for holding a die without handle, for cutting heel-lifts or shank-pieces. The pieces are removed as in Fig. 195. Fig. 197 is used for holding a sole-die without handle. The die has a spring to throw out the sole and leave it on the cutting-block. Fig. 198 is used for sole-dies with or without handles, the die passing into the opening in the chuck. The dies for this chuck are not attached as in the former, and can be changed easily. Fig. 199 is used for handle-dies, for cutting heeling, shanks, or soles. The die for this chuck is attached.

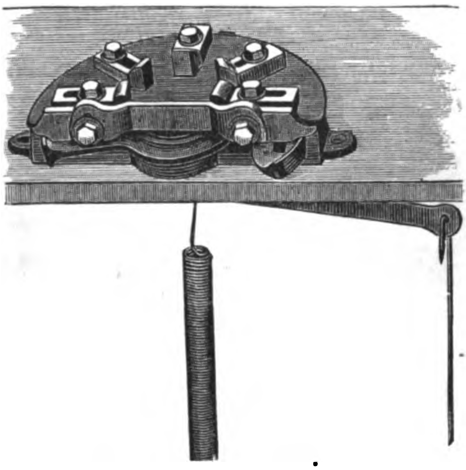


FIG. 202.—Adjustable heel-building machine.

Fig. 200 illustrates the rand-turning machine. This machine is very valuable, in connection with the compressing-machine, when a rand is used. A good rand can be turned at the rate of 6,000 per day.

Fig. 201 represents a heel-building machine with jaws, and Fig. 202 an adjustable heel-building machine. These machines are well adapted for tacking up heels, either whole or pieced lifts. The jaws in Fig. 201 are made to correspond with the various sizes of heels, and of Fig. 202 are movable.

Fig. 203 illustrates a machine for cutting off rands, and is used in connection with the compressing-machine.

Fig. 204 is a "jack" used in shaving the heels off smooth.

292. TILGHMAN'S SAND-BLAST was anxiously looked for by the jury, but, although finally set at work, was not put in operation until after their adjournment.

The sand-blast process has attracted more attention from both scientific men and mechanics than probably any contemporary invention. It was first exhibited in the United States at the American Institute Exhibition of 1871, and a committee of judges, consisting of three gentlemen selected from among our most distinguished men of science, recommended the award of the great Medal of Honor of the Institute.

The judges, Messrs. F. A. P. Barnard, president of Columbia College;

Digitized by Google

Alfred M. Mayer, professor of physics in the Stevens Institute of Technology, and Henry Morton, president of the latter college, reported that the process was "designed to execute ornamental inscriptions in *intaglio* or relief; or complete perforations in any kind of stone, glass, and other hard and brittle substances; or to cut deep grooves in natural rocks, in order to facilitate the process of quarrying; or to make circular incisions around the central mass of rock in the process of tunneling; or to remove slag, scale, and sand from the surfaces of metal-castings; or to clear the interior surfaces of boilers or boiler-tubes of incrustations; or to cut

FIG. 203.—Machine for cutting rands.

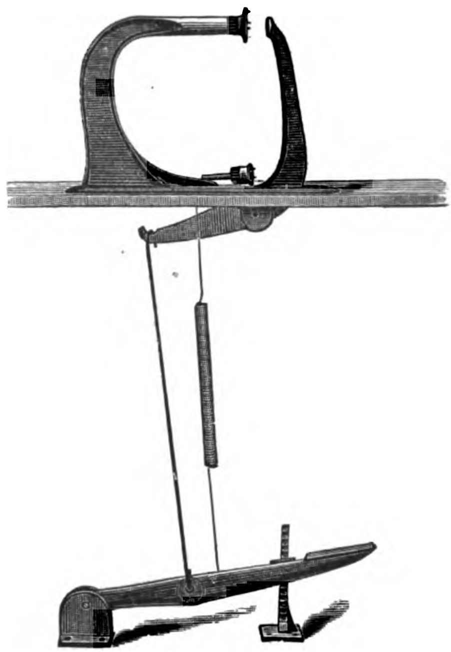


FIG. 204.—Jack for shaving heels.

ornaments or types from wood as well as stone; or to depolish the surface of glass, producing, by the use of stencils or other partial protections, such as the bichromatized gelatine of photographic negatives, every variety of beautiful figures, including copies of the finest laces and the most delicate line-engravings; or to prepare copper plates in relief for printing, by making gelatine photographic pictures upon smooth surfaces of resin or pitch, cutting them out by the blast and afterward molding from them and electrotyping the molds.

"This process is without precedent.

* * * * * * * *

"The utility of this invention is apparent in the statement above given of the processes to which it is applicable. It is regarded by the judges as being one of the most remarkable and valuable inventions which the age has produced.

Digitized by Google

"Considering, therefore, the great originality, importance, and value of this process, and the great variety and diversity of applications, both useful and ornamental, of which it is capable, the judges unanimously recommend that the great Medal of Honor of the Institute be conferred upon the ingenious inventor, as a well-merited distinction."

Professor Egleston, experimenting upon the effect of the sand-blast on harder materials than the sand itself, found the following as the loss of weight and the time required to produce it:

Material.	Weight.	Loss.	Time.
	Grains.	*Grains.*	*Min.*
Corundum	1.49000	1.16979	½
Emery	16.65000	4.9532	1
Topaz	2.0970	1.9707	1
Topaz, (pebble)	9.774	2.1499	1
Black diamond	1.2607	.0372	3
Do	1.2235	.0497	5
Do	1.2607	.0869	8

The emery contained some iron-ore.

A "jet of sand" impelled by steam of moderate pressure, or even by the blast of an ordinary-fan, depolishes glass in a few seconds; wood is cut quite rapidly; metals are given the so-called "frosted" surface with great rapidity. With a jet issuing from under 300 pounds pressure, a hole was cut through a piece of corundum, 1½ inches thick, in 25 minutes. Etching on glass is beautifully done.

The fracture of a hard body like diamond by a comparatively soft body like sand seems, at first thought, very remarkable; yet, it is daily paralleled in ordinary experience, and is illustrated most strikingly by the fact that "water continually dropping will wear away a stone."

Prof. Osborne Reynolds was the first to publish an analytical investigation* of the principles involved in this machine. †

* Philosophical Magazine, Fourth Series, Vol. 46, No. 307, p. 337.

† The following is the basis of the analysis: At the time of impact the pressure is independent of the magnitude of the masses, and is determined by their density and hardness. The character and mode of action of the surface-particles, and not of the whole mass, determines, at very high velocities, the effect of impact. Then, if

v = the velocity of surface-particles of a body;

λ = its modulus elasticity;

d = the "heaviness," *i. e.*, the weight per cubic foot;

p = pressure at contact in pounds per square foot;

$$p = v\sqrt{\frac{\lambda d}{g}}$$

For, if x represent the original distance of a surface point of impact from a given point, P, within the mass, and $x - \xi$ its distance after a time, t,

$$\frac{d}{g} \times \frac{d^3 \xi}{d t^2} = -\frac{d p}{d x} \text{ and } p = -\lambda \frac{d \xi}{d x};$$

hence,

$$\frac{d^2 \xi}{d t^3} = \frac{g\lambda}{d} \cdot \frac{d^2 \xi}{d x^2}$$

and

$$\xi = f\left(\sqrt{\frac{g \lambda}{d}}\right) - x.$$

293. THE WEST TIRE-SETTER (Fig. 205, page 320,) was exhibited by the Mowry Axle and Machine Company, and was one of the most striking novelties seen, even in the United States section.

It consists of a strap made up of several thicknesses of thin steel, and capable of being "set up" by a very powerful screw worked by a belt. A wagon-wheel placed within this ring or strap, with its tire perfectly loose, was clasped by it, and a few turns of the screw drew the strap so tight as to "upset" the tire, although perfectly cold, securing it more firmly than it would have been if shrunk on in the usual way, and producing, at the same time, any desired dishing of the wheel. It worked very finely.

The avoidance of the usual injury to the wheel by burning, and of the consequent insecurity of hold due to this injury of the surface of the wood where in contact with the tire, are important and evident advantages due to the use of this machine. It was considered one of the best tools exhibited.

294. SAMUEL A. MILLER exhibited a rough but effective little machine for bending stove-pipe elbows, which particularly interested several members of the jury.

When $x = 0$

$$\xi = f\left(\sqrt{\frac{g\lambda}{d}}\,t\right), \quad \frac{d\xi}{dx} = -f^1\left(\sqrt{\frac{g\lambda}{d}}t,\right.$$

$$\frac{d\xi}{dt} = \sqrt{\frac{g\lambda}{d}}.f^1\left(\sqrt{\frac{\lambda}{d}}t\right), \text{ and } \frac{d\xi}{dt} = v;$$

then

$$p = \lambda f^{\cdot 1}\left(\sqrt{\frac{g\lambda}{d}}\right)t\Big) = \sqrt{\frac{g\lambda}{g}}v. \quad \text{Q. E. D.}$$

If

v = velocity of impact;
λ^1 = elasticity of the second body;
d^1 = density of the second body;

$$p = \frac{\sqrt{\lambda^1 d^1}}{\sqrt{g}}.(u - v);$$

and, when the material is the same,

$$v = \frac{u}{2}.$$

If they were of different materials,

$$p = \sqrt{\frac{\lambda d}{g}}v = \sqrt{\frac{\lambda^1 d^1}{g}}(u - v),$$

$$v = \frac{\sqrt{\lambda^1 d^1}}{\sqrt{\lambda d} + \sqrt{\lambda^1 d^1}}u.$$

In the case of liquid impact]

$$p = \frac{v^2 d}{2g}.v^2,$$

and

$$\frac{d^1}{2g}(u - v)^2 = \sqrt{\frac{\lambda d}{g}}v.$$

Digitized by Google

It consisted of a pair of sets of clamps which seized the pipe, and, turning on horizontal axes, forced it to bend at each operation through a small angle. The pipe was then released and a new hold taken at a point a little farther along, and the operation repeated until the pipe had been given the required bend.

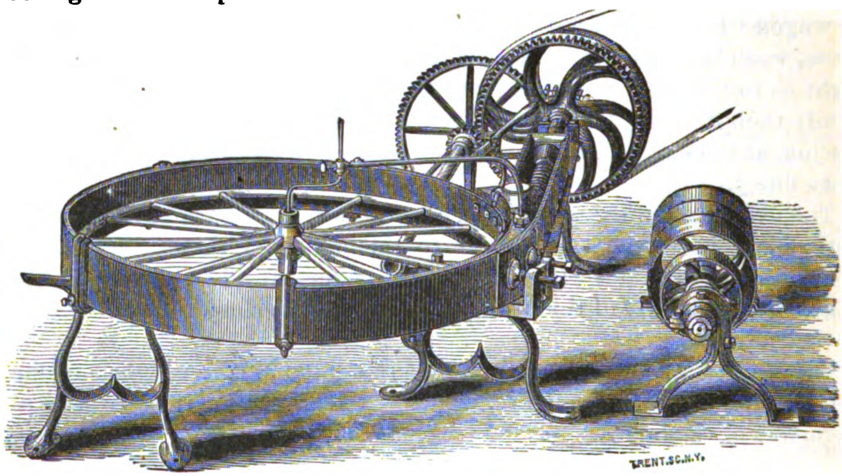


FIG. 205.—West's tire-setter.

ALBIN WARTH exhibited in the United States section a machine for cutting cloth, which seemed remarkably well adapted for cutting out clothing for makers of "ready-made" stock or for use wherever large quantities of cloth are to be cut.

It consisted of a knife rising and falling with a rapid reciprocating

---

In illustration, glass striking upon glass, and

$$d = d^1 = 150$$
$$\lambda = 1,152,000,000$$
$$p = 1,440,000;$$

$$v = \frac{8 \times 1,440,000}{\sqrt{150 \times 1,152,000,000}} = 27\tfrac{1}{2} \text{ feet per second,}$$

which would just crush the surface, and, as Professor Reynolds notes, corroborates the statement that a pressure of blast of 4 inches of water is sufficient to produce cutting on glass.

For solids,

$$p = \frac{\sqrt{\lambda\, d}\, v}{\sqrt{g}} + \frac{v^2 d}{2\,g},$$

in which the last quantity in the second member of equation has no effect, as it is equilibrated by the inertia of the surface-particles.

Using lead,

$$d^1 = 712$$
$$\lambda^1 = 720,000 \times 144$$

but the maximum resistance by lead to crushing only reaches 576,000, and this value is taken for λ. Then $u = 250$ and $v = 30$, nearly, indicating that it requires eight times as much velocity to abrade glass with lead as with glass.

Digitized by Google

Digitized by Google

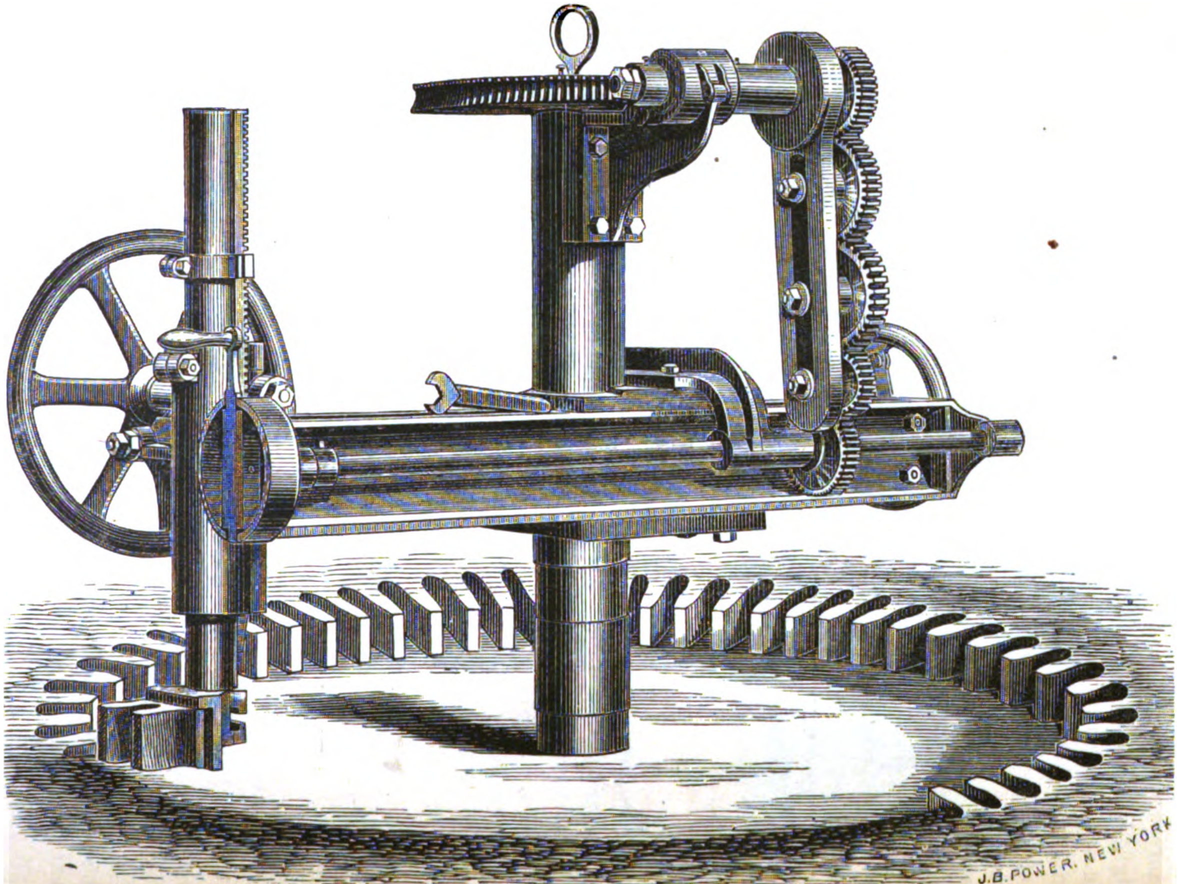


FIG. 206.—Scott's gear-molding machine.

Digitized by Google

motion, its inclined edge cutting the cloth with the same action as is obtained with ordinary shears. The cloth, single or in many thicknesses, was drawn against this knife, the operator following the line marked on its surface with the cutter's chalk.

In a later modification the device is made even more convenient and more rapid in its operation. The knife and its stand are made very light, and mounted on a broad base, which is moved about on the table in any direction almost as readily as the cutter's shears. Motion is communicated to the knife by round belting carried along a simple and ingenious combination of link-work, which accommodates itself to a wide range of traverse of the knife. Cutting a dozen thicknesses of heavy woolen goods with much less effort on the part of the workman than is ordinarily demanded in cutting a single thickness with shears, and working with vastly greater rapidity, this neat little device accomplishes a most important advance in its department.

The measuring-instruments of Messrs. DARLING, BROWNE & SHARPE were among the finest of all exhibits of accurate workmanship and fine finish. They exhibited a very complete assortment of their rules, gauges, and other instruments. They have no rivals at home or abroad in the manufacture of the finer classes of mechanics' measuring-tools.

THE MORSE TWIST-DRILL COMPANY exhibited their beautiful tools. These neat instruments are now considered as essential to good work in every machine-shop in the United States, and are gradually finding their way into European workshops.

295. A very interesting and valuable invention was exhibited in the British section by George L. Scott. This was the SCOTT GEAR-WHEEL-MOLDING-MACHINE, illustrated in the accompanying engraving, Fig. 206, which is furnished by the agents in the United States.

It consists of a strong column mounted upon a base-plate, which latter is imbedded in the sand below the matrix of the mold to be made. The column carries a cross-head which can be turned in the horizontal plane by the worm and gear seen at the top. A handle seen at the extreme right turns a series of change-wheels, by means of which the arc through which the arm swings may be made any desired fractional part of the circle, as in that more familiar machine, the gear-cutter.

At the extremity of this arm or cross-head is a vertical bar, which may be conveniently elevated or depressed by a handily-arranged worm-wheel.

It may also be carried inward toward the column, or outward, as may be desired, by a screw which is moved by a hand-wheel, seen at the extreme left.

On this vertical bar, at the lower end, is a plate, to which may be secured the patterns—two teeth such as it is proposed to use in the wheel to be made.

The method of operation is as follows:

The pattern of the teeth being properly secured to the foot of the sliding

Digitized by Google

vertical bar, the latter is adjusted horizontally until the pitch-line on the teeth comes precisely to the proper distance from the center of the main column, and thus swings in the pitch-circle. The bed is properly prepared by smoothing it up at the level of the lower edge of the proposed rim of the casting, seen in the illustration. The bar carrying the pattern is next lowered until the lower end of the latter touches the bed. The two teeth then are in position, and the intervening space is molded and the ends of the teeth make their impress. Raising the bar until the pattern clears the sand, the molder next turns the handle until the index-wheel has thrown the cross-head through an arc corresponding with the pitch, and the bar then being dropped, one tooth falls into the space between a tooth already molded and its neighbor. The next tooth is then formed, and the process continuing, the whole rim is finally completed. The machine is then removed, and the wheel center and arms are molded in the usual way, and the casting is made.

The rapidity and exactness with which this machine can be made to do its work are quite remarkable, and it will undoubtedly find its way into use very rapidly. It is already introduced into the United States by the NEW YORK MOLDING-MACHINE COMPANY.

The great advantages offered by the use of such a machine, aside from the efficiency of the apparatus itself, are the saving effected in cost of the exceedingly nice work of making the patterns of the wheel-teeth; the avoidance of the taper required in making the ordinary pattern so as to "draw" well; the retention of the hard chilled "crust" of the metal, which is far more durable than the finished surface of ordinary teeth, which have necessarily been "cut" to obtain the desired accuracy of form, and the avoidance of the risk and damage usually incurred from the working of patterns under the varying hygrometric conditions of the atmosphere.

Hall's bench-vise, described in art. 266, properly belongs in this class of miscellaneous exhibits of machine-tools.

296. MESSRS. JONES & LOUGHLINS exhibited their cold-rolled shafting. This process is shown, by experiments of Major Wade, the late Chief Engineer Whipple, United States Navy, William Fairbairn, and other authorities, to give an immense increase of strength and elasticity and a considerable increase of hardness.

The experiments of the writer have shown this to be accompanied by, and to be perhaps due to, a singular elevation of the elastic limit of the material.*

The following is Fairbairn's tabular statement, followed by others not less interesting and instructive:

* See Transactions American Society of Civil Engineers, 1874; Journal of Franklin Institute, 1874; Van Nostrand's Eclectic Engineering Magazine, 1874, &c.

Digitized by Google

EXPERIMENTS ON THE INCREASE OF COHESIVE STRENGTH IN COLD-ROLLED IRON.

Made by William Fairbairn, Manchester, England.

Condition of bar.	Tensile strength per square inch.		Elongation of 10 inches.	Ratio of strength, the black bar being taken at 1,000.
	Pounds.	*Tons.*	*Inches.*	
Black bar from rolls	60, 746	27, 119	2. 20	1, 037
Bar turned down to 1 inch diameter	58, 628	26, 173	2. 00	1, 000
Bar rolled cold to 1 inch diameter	88, 230	39, 388	0. 79	1, 505

REPORT OF COMMITTEE OF THE FRANKLIN INSTITUTE, PHILADELPHIA.

Tensile strength.

Sample No. 1, inferior quality, broke at..49,510 pounds per square inch.
Same bar polished and condensed.......66,862 pounds per square inch.
Sample No. 2, broke at..................57,350 pounds per square inch.
Same bar polished and condensed.......92,623 pounds per square inch.

35,273; increase, .61.

Torsional strength.

Sample No. 3, $1\frac{5}{16}$ diameter, twisted at a strain of 587½ pounds on a lever 25 inches long.

Same bar polished and condensed, 1¼ in diameter, twisted at a strain of 1,000 pounds on a lever 25 inches long. Increase, 413½ pounds = .97.

REPORT OF MAJOR WM. WADE, U. S. A.

Average results obtained from numerous experiments made with bar-iron rolled while hot, in usual manner, compared with the results obtained from the same kinds of iron rolled and polished while cold, by Lauth's patent process.

	Iron rolled while— Hot.	Iron rolled while— Cold.	Ratio of increase by cold-rolling.	Average rate per cent. of increase.
TRANSVERSE.—Bars supported at both ends; load applied in the middle; distance between the supports, 30 inches.				
Weight which gives a permanent set of one-tenth of an inch, viz:				
1½ inch square bars	3, 100	10, 700	3, 451	} 162½
Round bars, 2 inches diameter	5, 200	11, 100	2, 134	
Round bars, 2½ inches diameter	6, 800	15, 600	2, 294	
TORSION.—Weight which gives a permanent set of 1 degree applied at 25 inches from center of bars.				
Round bars, 1½ inches diameter and 9 inches between the clamps	750	1, 725	2, 300	130
COMPRESSION.—Weight which gives a depression and a permanent set of one-hundredth of an inch to columns 1½ inches long and ⅝ inch diameter	13, 000	34, 000	2, 615	161½
Weight which bends and gives a permanent set to columns 8 inches long and ⅝ inch diameter, viz:				
Puddled iron	21, 000	31, 000	1, 476	} 64
Charcoal bloom iron	20, 500	37, 000	1, 804	
TENSION.—Weight per square inch which caused rods ⅝ inch diameter to stretch and take a permanent set, viz:				
Puddled iron	37, 250	68, 427	1, 837	} 95
Charcoal bloom-iron	42, 439	87, 396	2, 059	
Weight per square inch at which the same rods broke, viz:				
Puddled iron	55, 760	83, 156	1, 491	} 72
Charcoal bloom-iron	50, 927	99, 203	1, 950	
HARDNESS.—Weight required to produce equal indentations	5, 000	7, 500	1, 500	50

NOTE.—Indentations made by equal weights in the center and near the edges of the freshly cut ends of the bars were equal, showing that the iron was as hard in the center of the bars as elsewhere. (This fact accords with the statement that the density of the metal is not appreciably changed by this process.—R. H. T.)

Digitized by Google

297. The method of manufacture consists in first reducing the bars in the ordinary manner to a size exceeding by an eighth of an inch or less that to which they are to be finished. They are next allowed to cool, and are immersed in a bath of dilute acid, by which the exterior coating of oxide is removed. They are then washed and sent to the cold-rolling mill. The rolls are very strongly built, and are finished with great accuracy, and given a very fine surface. The bars are passed through the rolls several times until they are brought precisely to gauge. They are turned over at each pass, and, when finished, have all the accuracy of size that could possibly be given by turning; they are at the same time thoroughly burnished.

The demand for cold-rolled metal is quite large. It is used principally for shafting and for finger-bars for mowing-machines.

This process of cold-rolling has been long known to have a remarkable effect in stiffening and strengthening some of the metals. Cold-hammering, which is similar in its effect, has been practiced by blacksmiths from an early date, when they desired to produce stiffness in a piece of iron. Wire-drawing has always been found to harden and stiffen the metal, making it necessary to anneal the wire between successive operations.

298. A similar effect is produced upon some of the alloys. Mr. S. B Dean, of Boston, Mass., was engaged fifteen years ago in experiments upon the strengthening and hardening of bronze for guns by a somewhat similar method. He succeeded in increasing the density from 8.3 to 8.5 in some cases, and augmented the strength fifty per cent., obtaining a metal capable of resisting a tensile stress of above 40,000 pounds per square inch.

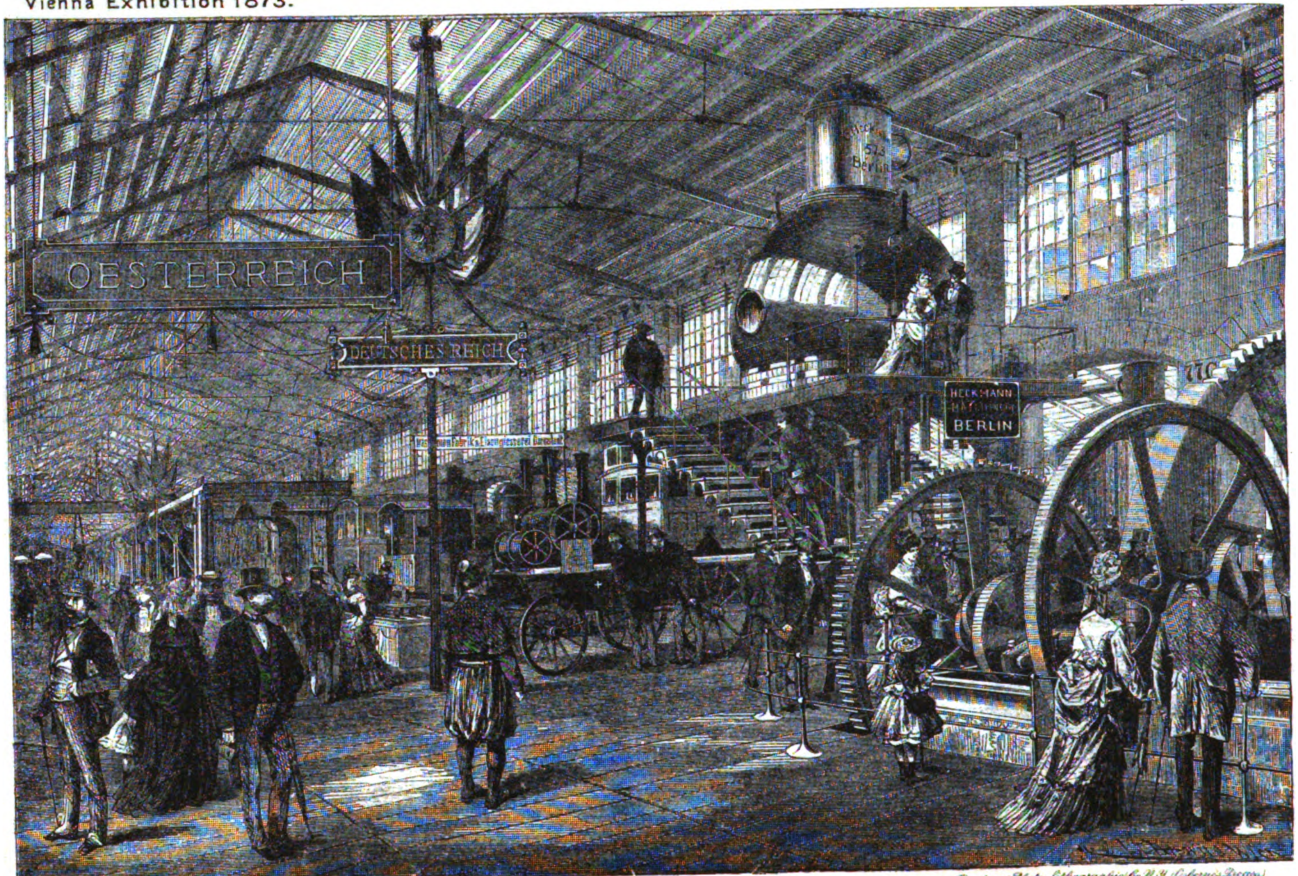
More recently General Uchatius, the director of the arsenal at Vienna, has been experimenting in the same direction. Since the return of the writer to the United States, that officer has furnished him a description of the process and results, of which the following may serve as an abstract.*

299. Ordinary bronze for guns is an alloy, consisting of about 90 parts, by weight, of copper, and 10 parts of tin. Since the atomic weight of copper is 63.4, and that of tin 118, the above proportions of the alloy correspond to a combination of 1 equivalent of tin with 17 equivalents of copper. It becomes, however, more exact, if we take 90.6 parts, by weight, of copper, and 9.8 parts of tin. But experiment shows us that it is questionable whether these two metals form a chemical compound in these atomic proportions. When large melted masses of this alloy solidify, it becomes evident that an alloy which is poorer in tin begins to crystallize first where it touches the mold, its composition being about 92 parts, by weight, of copper, and 8 parts of tin, or 1 equivalent of tin to 21 equivalents of copper; while an alloy richer in tin is

* Col. T. T. S. Laidley has furnished to the Army Ordnance Bureau a translation of a lecture upon the same subject by General Uchatius. (See Ordnance Notes, No. XL.)

Digitized by Google

Vienna Exhibition 1873. Machinery. etc.



American Photo-Lithographic Co. N.Y. (Osborne's Process)

Fig. 207.

Digitized by Google

Digitized by Google

pressed from the former, and solidifies last. This latter alloy, then, forms in the inside of the casting, and also enters the cracks which sometimes form in the outer wall.

This behavior in fusion of alloys rich in tin was also noticed in the numerous researches on alloys of copper and tin made by Alfred Riche, and published in the "*Annales de Chimie et de Physique*," tome 30. M. Riche noticed that all alloys of copper and tin, except those whose compositions correspond to the formulas $Sn\ Cu_3$ and $Sn\ Cu_5$, undergo a refusion at the moment of solidification. An alloy richer in tin is separated, so that different compounds are to be found at different points in the casting. When the alloy consists of tin and copper in the proportion of 1 to 5, this refusion occurs to but a slight extent, but when the composition is different it becomes a very serious matter. Even the property of the tin of oxidizing easily seems to exhibit itself in this case, as it diminishes the chemical affinity of the metals still further, and thereby assists their separation.

As a proof of the occurrence of these conditions in alloy, we may mention that rich bronze, of a very homogeneous character, is always found in the smaller parts of bronze castings; for example, in the cascabel or in the trunnions of a gun. This bronze contains about 8 per cent. of tin, while the body of the gun is penetrated by thin sheets of tin. An 8-inch tube was made at the Royal Imperial arsenal, for which 28,000 kilograms (61,600 pounds) of metal were employed at once. The greatest diameter of this casting was about 0.84 meter, and the proportion of tin at this part was 8 per cent. on the outside and 12 per cent. on the inside.

The reason why bronze with 8 per cent. of tin has not yet been employed for guns is that its wear is greater than even that of 10-per-cent. bronze. "Gun-metal" has long been employed because of its great tenacity and consequent safety, and also because it has the advantage of cheapness and ease in working. Its strength has satisfied the demand nearly up to the present time, and it has, therefore, been retained in the manufacture of field-pieces, in spite of its tendency to bulge and to burn out. Modern requirements, however, will no longer permit its application as formerly.

From an accompanying table of properties of types of gun-bronze, we find those of ordinary gun-bronze, as compared with Krupp's steel for guns, to be—

	Bronze.	Steel.
Tenacity	2,260 kilograms per square centimeter, (32,092 pounds per square inch.)	4,800 kilograms, (68,160 pounds.)
Elastic resistance	400 kilograms per square centimeter, (5,680 pounds per square inch.)	900 kilograms, (12,780 pounds.)
Extension when broken	15 per cent	21.4 per cent.
Hardness, (depth of indenture)	12.5 millimeters, (½ inch)	10.5 millimeters, (.42 inch.)

Digitized by Google

We see that the tenacity as well as the limit of elasticity of cast-steel is almost twice as great as that of ordinary bronze, which has even less ductility than steel. If the properties of bronze could not be further improved—wrought iron being unreliable as gun-metal—we would necessarily be compelled to accept steel. But, fortunately, new wants are generally supplied in time by the progress of science and art.

300. We may next consider a new modification of gun-bronze, which is much superior to ordinary gun-bronze, according to the annexed table of gun-metals, and for which General Von Uchatius has proposed the name "steel-bronze," on account of the resemblance of its properties to those of cast-steel.

If, instead of employing sand, we used iron chills of a corresponding thickness of material, the process of solidification takes place with such rapidity that the alloy rich in tin cannot separate, and the bronze becomes perfectly homogeneous.

The quality of this homogeneous bronze is given in the typical table of gun-metals under the head of "Chilled-bronze, natural."

The absolute strength rose to 3,050 kilograms, (43,310 pounds per square inch,) the elastic limit remained at 400 kilograms, the hardness (depth of indenture) at 12.5 millimeters, (.5 inch,) while the amount of stretch before breaking, or the ductility of the material, rose to 40 per cent. These improvements in the quality of bronze are a step forward in bronze-casting, but it is, nevertheless, not sufficient to satisfy modern requirements. A gun-barrel cast in this manner would not burst, for the ductility of the material at 40 per cent. is enormous, but it would not be capable of resisting the pressure of the gas; and, since the elasticity is not greater than with ordinary bronze, the gun-barrel would bulge out. The hardness also remained unchanged, and it is therefore not enough to cut the grooves in the sabots of the shot.

301. General Von Uchatius next tried to roll a piece of the chilled bronze cold. This could be done quite well, although considerable power was necessary. Not the slightest crack was produced, even when stretched to the amount of 100 per cent. of its original length. When the bronze had stretched 20 per cent., it attained the strength, hardness, and elasticity of steel, as can be seen from his table of gun-metals, under the heading of "Chilled bronze, rolled." The numbers are as follows:

The tenacity, 5,066 kilograms per square centimeter, (71,937 pounds per square inch.)

The elastic resistance, 1,700 kilograms per square centimeter, (24,140 pounds per square inch.)

The hardness, (depth of indenture,) 10.2 millimeters, (.41 inch.)

It is evident that if this characteristic of chilled bronze, of assuming the properties of steel when rolled, could be employed on the inner surface of gun-barrels, the process would be of great value. By examining the table of gun-metals, he remarks the peculiarity that all tough metals assume a much higher elasticity when they are stretched beyond

Digitized by Google

their elastic limit.* For, when a substance is permanently changed by exterior forces, its molecules have been, at least partially, pushed be-

* This fact was noted by the writer in 1873, immediately after returning from Vienna, and announced to the American Society of Civil Engineers in the following note, published in the Transactions, 1873:

AMERICAN SOCIETY OF CIVIL ENGINEERS.

A note on the resistance of materials, by Prof. Robert H. Thurston, member of the society, read at the regular meeting, November 19, 1873.

On the 13th ultimo an apparatus for determining the torsional resistance of materials, which I had designed for use in illustration of my course of instruction, and to which I had fitted an automatic recording-attachment, was exhibited to the National Academy of Science, at the late session held at this place, for the purpose of showing the peculiar adaptability of the machine for the determination and analysis of the action of physical and molecular forces in resisting stress, and to illustrate the bearing of experiments already made upon scientific investigations of molecular relations.

At the close of the meeting a test-piece of wrought iron was left in the machine, exposed to a strain which had passed the limit of elasticity, and with a distortion of 45°, the intention being to determine whether, as has been suspected by some writers and by many engineers, "viscosity" is a property of solids, whether a "flow of solids"* could occur under long-continued strain just equilibrating, when first applied, the resisting power of the material, or whether the "polarity" of Professor Henry is an absolutely unrelaxing force.

The metal was left under strain twenty-four hours, and had not then yielded in the slightest degree. This result, and the results of other similar experiments since made confirming it, indicate that metal strained far beyond the limit of elasticity, as above described, does not lose its power of resisting unintermitted static stress.

The important bearing of this fact upon the availability of iron, and of steel, which also behaves similarly, for use in constructions exposed to severe strains, is readily seen.

After noting the result obtained as stated, it was attempted to still further distort the test-piece, when the unexpected discovery was made that its resisting power was greater than when left the previous day, an increase of resistance being recorded amounting to about 25 per cent. of the maximum registered the preceding day, and approximating closely to the ultimate resistance of the material. Repeated experiments, continued up to the date of writing, confirm the following previously undemonstrated principle, that iron and steel, if strained beyond the limit of elasticity and left under the action of the distorting force which has been found just capable of equilibrating their power of resistance, gain resisting power to a degree which has a limit in amount, approximating closely, if not coinciding with, the ultimate resistance of the material, and which had a limit, as to time, in experiments hitherto made, of three or four days.

Releasing the piece entirely and again submitting it to the same force immediately does not produce this strengthening action.

There is some evidence, that is confirmed by theoretical dynamic principles, that the increase of strength noted is not accompanied by a change of resilience, but that the gain of resisting power is at the expense of a proportional amount of ductility.

The diagrams obtained during this research will be presented at a future time, when the investigation shall have been completed.

The interest and importance attaching to the discovery of the principles above enunciated, to our profession as well as to science, will, I hope, justify the presentation of this note.

* Mon. H. Tresca: Sur l'Écoulement des Corps Solides. Paris, 1869–'72.

Digitized by Google

yond the limit of their stability, and have assumed new and more or less stable positions. The change in the positions of the molecules consists of a constant and a temporary part, which latter belongs to the elasticity of the new form. The material attains a new stable equilibrium of the molecules, but at the same time a greater elastic resistance.

In this fact we may also find the explanation of a phenomenon observed at several places. A bronze barrel which was not strong enough to resist its charge, and which, therefore, bulged out, still retained its form after long-continued use. It could even be weakened, by turning off on the outside, without losing its power of resisting charges. The natural chilled bronze has its limit of elasticity at 400 kilograms, (5,680 pounds per square inch,) and permits a stretch of 0.0004 of its length; while, if a permanent set of 0.00441 of its length is produced, its elastic limit becomes 1,600 kilograms (22,720 pounds per square inch) and its stretch within the elastic limit, 0.00192. The rolled chilled bronze attains its limit of elasticity at 1,700 kilograms, (24,140 pounds per square inch;) and has an elastic extension of 0.0017 of its length, while a permanent stretch of 0.00018 of its length raises the limit of elasticity to 2,400 kilograms (34,080 pounds per square inch) and its elastic extension to 0.00252.

This advantage is as great with steel, wrought iron, and, in general, all extensible metals, as may be seen from the table for gun-metals, but it has never before been taken advantage of for the production of guns.

302. The following principle was enunciated by General Von Uchatius as a theory of working a gun-barrel from a homogeneous, very ductile, and tough metal. It is based upon results obtained by precise measurements upon the properties of the metals:

I. The work performed by the pressure of the gases of the exploded powder, and destroying the fit of the shot by enlarging the bore, should be performed originally by mechanical means, and to a far greater extent than will be produced by the heaviest charge. By this means the elastic limit of the metal of the barrel is increased to such an extent that the smaller pressures of gas produced in discharging the gun have no effect.

II. The surface of the bore must be submitted to a process resembling rolling to such an extent as to give it the necessary hardness.

By this process of mechanical working of the casting the material is not overstrained, as has been frequently asserted. Its properties are not injured; on the contrary, as this extension goes on in the cold state, and not while warm, the molecules take new and stable positions, refining the metal. Its properties are, therefore, improved.

Drawn tubes, piano-wires, &c., are of similar nature, and have also been extended. They are, nevertheless, sound and reliable.

303. Before proceeding to the method of working on the casting, it was necessary to solve two very important problems, namely:

(*a.*) Which alloy of copper and tin is best suited for chilled casting?

(*b.*) How can the quality of the metal at the inside, or nearest the

Digitized by Google

bore, be made to correspond to that of the alloy at the outside, so that the metal can be subjected to the process of rolling?

In order to determine the best quality of alloy, a small cast-iron chill was made, of 25 millimeters (1 inch) and 50 millimeters (2 inches) width in the clear, and 25 millimeters (1 inch) thickness of sides, into which the following alloys were cast:

12 per cent. bronze.
10 per cent. bronze.
8 per cent. bronze.
6 per cent. bronze.
10 per. cent. bronze, with 2 per cent. addition of zinc.
10 per cent. bronze, with 1 per cent. addition of zinc.
8.5 per cent. bronze, with ½ per cent. addition of zinc.

The last of these alloys is that which the French firm of Lavissière exhibited at the Vienna Universal Exposition in the year 1873, and which attracted the attention of professional men by its uniform and homogeneous appearance and by its peculiarly excellent properties.

Two rods were cut from each of these castings, and these were rolled out until they acquired the hardness of steel. It became evident, during this process, that the 12 per cent. bronze could not bear rolling, and therefore the tests were limited to the remaining alloys.

It was found necessary to continue the rolling of the rods in order to reach the hardness of steel; with the—

10 per cent. bronze, to an elongation of 20 per cent.;
8 per cent. bronze, to an elongation of 30 per cent.;
6 per cent. bronze, to an elongation of 50 per cent.;

with the—

10 per cent. bronze and 2 per cent. zinc, to an elongation of 10 per cent.;
10 per cent. bronze and 1 per cent. zinc, to an elongation of 15 per cent.;
8.5 per cent. bronze and ½ per cent. zinc, to an elongation of 20 per cent.;

The results of the tests made can be seen from the following table:

Alloys.	Tensile strength.		Elastic limit.		Elongation within the elastic limit in 0.00001.	Set in per cent. of length.
	Pounds per square inch.	Kilograms per square centimeter.	Pounds per square inch.	Kilograms per square centimeter.		
10 per cent. bronze	71,937	5,066	24,140	1,700	174	1.5
8 per cent. bronze	73,840	5,200	19,880	1,400	140	2.5
6 per cent. bronze	77,532	5,460	18,460	1,300	128	3.5
10 per cent. bronze and 2 per cent. zinc	42,884	3,020	8,520	600	89	0.5
10 per cent. bronze and 1 per cent. zinc	59,214	4,170	14,200	1,000	120	0.7
8.5 per cent. bronze and ½ per cent. zinc	53,960	3,800	21,300	1,500	157	1.7

These tests showed that, in general, the 10 per cent. as well as the 8 per cent. and 6 per cent. bronzes are capable of being employed in the new method of making gun-barrels, while the addition of zinc is of no

Digitized by Google

use whatever, but, on the contrary, decreases its value to no inconsiderable degree.

The 8 per cent. bronze was judged to be the best for large castings, and this one has, therefore, been taken as the basis for steel-bronze.

304. A number of trials were made to determine what method of casting and cooling would make the inner layers of the casting homogeneous, and which would have the necessary toughness for standing the treatment to which they were to be subjected later. These trials required much time and patience, and were so extensive that they cannot be enumerated here. The result of all these trials, that is, the method of casting which fulfilled the object in question, and which was, therefore, adopted, cannot be communicated, as it is kept a secret by General Von Uchatius.

Simultaneously with these trials, those castings whose quality was shown to be good, by the appearance of the fracture, were subjected to the mechanical treatment. A hydraulic press was employed for this purpose, its capacity being 100,000 kilograms, (220,000 pounds.)

305. The following is a short sketch of the main features of the method which has been employed for making gun-barrels since September, 1873:

At the beginning of the year 1874 a work was published entitled "*Esperienze mechaniche sulla resistenza dei principalia metalli da bocche da fuaco, di G. Rosset,*" &c. This work produced the impression, in many minds, that the experiments of General Von Uchatius were in imitation of those there described. This is, however, clearly disproved by the fact that these trials were already begun at the end of the year 1872, and that the improved method of casting had been determined upon in September, 1873. The priority of invention of this method of casting and of the following mechanical treatment is, therefore, undoubtedly to be attributed to General Von Uchatius.

The castings were 260 millimeters (10.4 inches) thick, 300 millimeters (12 inches) long, having a bore of 80 millimeters (3.2 inches) diameter. They were conical and turned down at one end to 180 millimeters (7.2 inches) diameter. They were then placed vertically under the plunger of a hydraulic press, which was then driven through it. The surface of the press-plunger was of well-hardened steel, and was a slightly-tapering cone, thus increasing the diameter gradually. But, since the resistance increased with the enlargement of the barrel, the difference between the diameter of the plunger and that of the last-formed barrel must decrease gradually. Six plungers were employed in succession, of which the first increased the bore by 2 millimeters (.08 inches) and the last by ½ millimeter (.02 inch).

The original diameter of the bore, 80 millimeters, (3.2 inches,) was thus increased to its normal size of 87 millimeters, (3.88 inches;) that is, the increase amounted to 7 millimeters, (.28 inch,) or 8.75 per cent., while the exterior diameter of the casting was increased by 2 per cent. The surface of the bore which was thus produced had a hardness, when

Digitized by Google

measured by indentation, of 10.5 millimeters, (.42 inch,) or equal to that of gun-steel; it was as smooth as a mirror, and only needed rifling. It was further remarked that the same result as to hardness was produced at the end which was weakened by turning down, which would seem to indicate that the outer layers of guns do not come into play at all when firing.

306. We have remarked before that the principal advantage of the new method of manufacturing guns was to be found in the fact that the barrels may be cast of a very tough and homogeneous material. They are then bored out a little smaller than the required size, and brought to gauge by driving in steel cones which increase successively in diameter.

The concentric layers of the cylinder are all strained beyond their former limit of elasticity by the forcing into them of these plungers, and they are thus given a greater elasticity. At the instant that the plunger is passing through, the layers are all strained beyond their original elastic limit, and up to a new limit of elasticity. After the plunger has passed through, the inner layers not only return to their new positions of equilibrium, but they are pressed back even further by compression due to exterior layers. The diameter of the bore is decreased, after the last plunger has passed through, from 87 millimeters (3.48 inches) to 86.652 millimeters, (3.47 inches,) or by about 0.004.

The whole barrel is also rolled, especially the inner layers, as an increase in length takes place, as well as an increase in diameter. With a field-piece, this elongation amounts to from 10 to 12 millimeters, (.4 to .48 inches,) or about 6 per cent., the elasticity, strength, and hardness being thus still further increased. The ductility of the inner layers especially is decreased by this rolling process; but it is an advantage to exchange some ductility for other properties, with a material like homogeneous bronze, which has an extensibility of 50 or 60 per cent.

In firing, the bore of the gun is suddenly slightly enlarged. As long as this enlargement of the bore does not exceed 0.004 of the diameter, the form must remain unchanged, like a spring which has been strained within its elastic limit. Only when the shock of the discharge increased the diameter beyond this amount, would the limit of elasticity of the barrel be passed, and a permanent increase of the bore take place. But since the bore can only be enlarged to the extent of 0.004 of its diameter, by a force equal to the pressure exerted by the last plunger—that is, 2,400 atmospheres—it may confidently be expected that the barrels produced in this manner will come up to the requirements, particularly as the tension of the gases at the discharge of a field-piece only amount to two-thirds of that pressure.

307. The material of the first two experimental barrels of steel-bronze had the following properties:

Digitized by Google

Properties of steel-bronze.	Test-barrel No. 1, near the—		Test-barrel No. 2, near the—	
	Bore.	Exterior surface.	Bore.	Exterior surface.
Tensile strength per 1 square centimeter, in kilograms	4, 250	3, 320	4, 250	3, 320
Tensile strength per 1 square inch, in pounds	60, 350	47, 144	60, 350	47, 144
Limit of elasticity per 1 square centimeter, in kilograms	1, 100	500	1, 100	700
Limit of elasticity per 1 square inch, in pounds	15, 620	7, 100	15, 620	9, 940
Stretch, ultimate, in per cent. of length	16. 5	50	16. 5	50
Stretch, elastic, in per cent. of length	0. 306	0. 060	0. 306	0. 060
Section at the point of rupture, which was originally taken = 1. 00	0. 56	0. 50	0. 56	0. 50
Hardness, depth of indenture, in millimeters	10. 6	12	10. 6	12
Hardness, depth of indenture, in inches	. 42	. 48	. 42	. 48

Both barrels were subjected to tests by firing.

The object of the tests with the steel-bronze barrel No. 1 was to ascertain to what extent the theoretical ideas above enunciated would apply to this kind of gun-barrel.

These tests were made on the "Simminger Haide," from 40 to 50 shots being fired daily, two shots with the diminished charge of 1 kilogram (2.2 pounds) and 238 shots with the normal charge of 1.5 kilograms, (3.3 pounds.) The hollow and double walled projecticles, $2\frac{1}{2}$ diameters in length, had four copper packing-rings, and the powder used for the charge was large-grained powder from the factory at Stein, the size of the grains being from 6 millimeters to 10 millimeters, (.24 inch to .4 inch;) the density was 1.605.

The truth of the theory enunciated by General Von Uchatius as to the construction of gun-barrels was demonstrated by the fact that the barrel showed no signs of either a widening of the bore or any other flaw after these tests.

The test-barrel No. 2 was tried on the "Steinfelder Haide." The object of these tests was to determine the decrease in precision of firing consequent upon the firing a great number of shots with the charge of 1.5 kilograms, (3.3 pounds,) and with double-walled projectiles $2\frac{1}{2}$ diameters in length, weighing $6\frac{1}{2}$ kilograms, (14 pounds.) The velocity attained with this charge was measured as 1,480 feet. On the whole, 2,130 solid shot were fired and twenty shells were thrown.

The subsequent examination of the barrel showed the chamber to be altogether unchanged. The widening which was perceptible—about 0.1 millimeter (0.004 inch)—was due to burning out and to mechanical wear. The lands and grooves of the barrel were worn considerably, after this great number of discharges, by mechanical wear and by burning out, but from the mouth to the vicinity of the trunnions the lands were left quite sharp, and consequently were capable of seizing the projectile with perfect accuracy, giving its axis the necessary stability in the barrel.

After 2,100 discharges, a well-adjusted, double-walled projectile was purposely made to burst in the gun, in order to determine the amount of damage thus produced and its effect upon the accuracy of fit of the

Digitized by Google

shot. The following series of 25 shots did not show any loss of accuracy, although the grooves and lands were badly damaged, for the latter appeared to be crushed down and the metal squeezed into the grooves. Yet 100 per cent. successful shots were made on a range of 1,500 meters, or 2,000 paces, the target being 3.6 meters (10 feet) in height, and the mean breadth being only 62 centimeters, (24 inches.) A more satisfactory result could not be desired.

It should also be stated that the wedge closing of the breech, and made of forged bronze, as well as the copper packing-ring, gave perfect satisfaction, and did not seem nearly as liable to burning out as steel packing.

308. It remained only to determine whether the same quality of bronze can be made for a great number of barrels. This being the case, we would expect that steel-bronze barrels would come into general use, in place of cast-steel barrels with rings shrunk upon them.

The pecuniary advantages attending the adoption of steel-bronze barrels would be considerable. A cast-steel barrel, with built-up rings, costs, after deducting the value of the waste metal, 1,500 florins, ($750.) A steel-bronze barrel, under the same conditions, costs, 350 florins, ($175.)

The workshops of the Royal Imperial Arsenal could furnish annually steel barrels, built up with rings, 150; steel-bronze barrels, 1,000.

309. Experiment indicates how the properties of the tough metals may be improved by stretching beyond their elastic limit, either by loading-rods, or by forcing conical plungers through the cast cylinders while cold. The density, and, to a great extent, the elasticity, are increased considerably by such treatment.

The metals are generally weakest when cast, stronger when hammered or rolled, but strongest when drawn.

It will be seen that this method of working castings applies advantageously to the production of steel gun-barrels. Steel, having at once an elastic limit of 2,000 kilograms per square centimeter, (28,400 pounds per square inch,) and a ductility of 20 per cent., cannot be produced by any hardening process or method of manufacture, but only by stretching in the cold state.

The barrel of a heavy field-piece treated similarly to the tube of very soft Neuberg steel would be even better than a ringed steel barrel, and just as good as a steel-bronze barrel. The cross-section of such a barrel shows the same constitution as one of steel-bronze.

The quality of the material in the concentric layers changes continually in such a manner that its density, elasticity, and hardness increase continually as the surface of the bore is approached in exactly the manner required to resist the shock of discharge. At Creûsot it has been tried, in vain, to produce this result by hardening the barrels from within outward, the propriety of the above constitution being recognized. This result may be attained approximately with guns by shrinking

Digitized by Google

softer rings upon the hard center. Sudden changes take place in this case, and the separation of the core from the hoops must be allowed for.

With larger barrels, where rings must necessarily be employed, these need only be stretched, when cold, by conical plungers driven through them, which will give them such a degree of elasticity that they may be shrunk on with a pressure of 2,400 atmospheres, 36,000 pounds, without passing their limit of elasticity.

310. The steel bronze barrels will, according to General Uchatius, always be better than those of steel, for the following reasons:

1. On account of the quadruple price of the steel, and because old steel-bronze barrels can always be remelted.

2. On account of the time required in manufacturing, which with steel is six or seven times as long as that needed with steel-bronze. In order to produce a cast-steel barrel fitted with rings, the inner tube is first cast. It is then heated and worked under the steam-hammer; it is then bored, and finally the rings are shrunk upon it. For this purpose are needed, not only very costly plant, but also skilful, experienced, and very reliable workmen. The steel-bronze barrels are simply cast, then bored and pressed, and finally drawn; all of which manipulations are very simple.

3. On account of the greater rapidity of destruction of the steel by atmospheric influences. The destructive effect of oxidation rapidly penetrates to the interior with steel, while steel-bronze merely receives a superficial layer of verdigris, which does not penetrate.

4. Because steel barrels are not as safe for the gun's crew as steel-bronze barrels, of which the exterior layers are so tough that they must be stretched 50 per cent. before fracture.

Captain Volkmar, of the Austrian army, who has studied the process and experimented with the material under the direction of General Von Uchatius, is very enthusiastic in his statement of its value.

These new modifications of the most generally useful metals, iron and bronze, are well worthy of extended experimental examination.

311. There is no apparent reason why the same process should not similarly benefit the "low steels" which are coming into such general use.

These peculiar products are of interest, not only as valuable commercially, but as exhibiting a singular, and as yet a mysterious, molecular change which results from simple compression.

312. UNDERHILL'S ANGULAR BELT, seen in the engraving of the Pickering engine; MASON'S FRICTION-CLUTCH PULLEYS, which are now well known in the United States, where the writer has known their value by experience and by an acquaintance of ten or fifteen years; and several other important exhibits, attracted deserved attention and secured recognition by the jury of Group XIII.

313. In the Austrian section, the HYDRAULIC FORGINGS OF Mr. J.

Digitized by Google

HASWELL were exhibited by the K. K. Priv. Staats-Eisenbahn-Gesellschaft of Vienna, of whose workshops Mr. Haswell is manager.

These forgings are produced in properly-shaped molds or dies, by the pressure of powerful hydraulic presses upon the iron, which is first raised to a welding-heat. The metal is quite easily worked by this method if the heating is well done, and fills the molds as perfectly as if molten. The method is said to be comparatively inexpensive, and the forgings shown at Vienna as the product were of excellent character. Some were quite intricate in form.

The press used for this work had a power of between 800 and 1,000 tons. The water-pressure was stated at about three tons per square inch.

A new press then in course of construction was to have a "ram" two feet in diameter, and to work with the same water-pressure, giving a total pressure of about 1,500 tons.

The cylinder was to be of cast iron lined with steel. In this press a neat device causes the water discharged from the chamber of the press to enter a storage-reservoir, whence it is again taken to fill the chamber before the pressure is put upon the die, and while the ram is settling down to its work. A draw-back cylinder is mounted above the main cylinder, for the purpose of raising the ram from the mold. Mr. Haswell thus makes eccentrics for his locomotives, and frequently both forward and backing eccentrics are made in a single piece. He makes also pistons, axle-boxes, and cranks in the same way; and it will probably be found the best method of construction of many details which have usually been made in cast metal.

Hydraulic forging was not invented by Mr. Haswell, but he seems to have been the first to make this method a practical success. He not only uses his press in doing work usually made by ordinary forging or by the drop-press, but also such as is usually accomplished by the steam-hammer, as in "cogging" steel ingots.

314. Wheel-centers made under this press were among the heaviest pieces shown, and were fine pieces of work. In Austria, and throughout Europe, cast-iron wheels are never seen.

The finest wheels for locomotives, forged in the ordinary way, were shown by Déflassieux, Frères & Peillon, of Rive-de-Gier, in the French section.

315. Three STEAM-CRANES were supplied to the British department by the Messrs. APPLEBY BROS., which did excellent work during the installation of the exhibits, and they are worthy of mention for their compact, neat, and mechanical design and their excellent workmanship. These cranes (Fig. 208) were like those used by the British commissions in Paris and London. They were of three, five, and seven tons capacity, respectively. They differed only in their proportions. The bed-piece is in one piece. The main column is made of wrought iron. The top carries a spur-wheel, which is so attached that it may be made fast or

Digitized by Google

loosened, as required, while operating the crane. The truck carries a light iron floor, in the middle of which is an opening large enough to take in this gear. On the border of this circular opening is a track on which run the friction-wheels, carrying the frame of the crane and its appurtenances. The central column steadies the whole and keeps these rollers on the track as they revolve about it. These rollers, or friction-wheels, are three in number—two under the heel of the jib and one under the steam boiler, which is on the opposite side of the central post. The boiler has a cylindrical shell, with fire-box and flat upper head, and stands vertically. It contains a set of small flues, the makers considering it better to use a form which is not especially liable to give trouble where bad water is used than to adopt the tubular boiler, although the latter is superior in economy. The engines are carried on a pair of vertical A-frames, mounted between the crane-jib and the boiler. They are two in number, and drive one crank-shaft, each being attached to a crank-pin at its own end of the shaft, and these cranks being at right angles. Thus the whole apparatus is pretty nearly counterbalanced when the crane is moderately loaded. Between the frames are properly-arranged trains of gearing by which the jib can be raised or depressed, to give it less or greater reach, and by means of which the tackle is overhauled in raising the load, and by the use of still another of which sets of gearing the truck may be driven on the track, carrying the crane and its load.

The first motion is secured by means of a fast-and-loose bevel-gear on the crank-shaft, which acts, through a worm-shaft and its gears, upon the barrel carrying the chain attached to links leading to the head of the jib. The second motion is obtained in the usual way, the engines driving the chain-barrel through the ordinary arrangement of intermediate transmitting gearing. A change of speeds is provided for light and for heavy loads.

The traversing-motion by which the crane is turned about the wrought iron column as a center is similarly attached, acting upon the large spur-gear first mentioned. In this motion the connection is made by friction-clutches, to prevent injury by suddenly stopping.

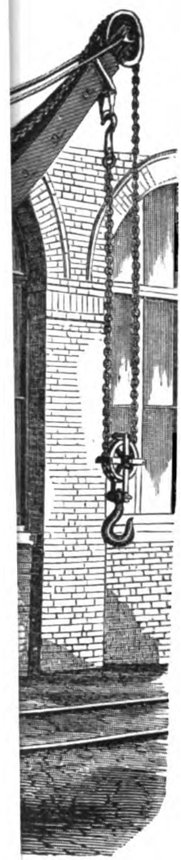
The traversing and hoisting gearing can be made to work together, the load rising or falling while the crane is rotating on the truck.

The exhibitors stated that, with light loads and high speeds, they can transfer and hoist one load per minute. They state that one of these cranes was employed to transfer from the cars to their place in machinery-hall a load of machinery which comprised all of the parts of the large oscillating marine paddle-wheel engine exhibited by the *Société Cockerill* in the Belgian section, and that this was done in six hours' work, including also the drawing of the loaded cars into position by the crane itself, and carrying them away as fast as unloaded.

The great blowing-engine shown by the same firm was similarly erected in five hours.

Digitized by Google

Digitized by Google



Digitized by Google

These cranes were thus found very useful at the installation and the removal of the machinery and of heavy exhibits in other departments.

These were among the best of the miscellaneous class of machinery exhibited in the British section. They were well planned in general and in detail. They were excellently proportioned, well made, and were destitute of every attempt at useless finish or ornament. They were as light as was consistent with their necessarily substantial character. The combination of motions just indicated was extremely useful, and neither element of the combination seemed to interfere with the operation of the others. The jib was swiveled, in its vertical motion, about a pair of pins at the feet of its two legs, and this arrangement permitted a broad base of support laterally, rendering the jib stiff against surges toward either side in swinging the load or in traversing.

Messrs. J. H. WILSON & Co., of Liverpool, also exhibited a design, differing in detail, but very similar, as a whole, to that of Messrs. Appleby. The same motions were all secured, and in the same general way. The boiler was even simpler in form, but the framing and the arrangement of the gearing was perhaps somewhat less well-considered. The machine did excellent work.

316. The following engravings exhibit a neat little device shown in the United States section, which may properly be described here. This is the HORTON LATHE-CHUCK AND JAW.

Fig. 209 gives a view of the chuck complete and in parts. The main feature is that of inclosing the circular wrought-iron rack in a deep groove or recess in the back-plate, and then turning the center-faces of back and front plates true. When bolted together this makes a perfectly-tight casing for the gearing, so that no dirt or chips can possibly get into them to clog or injure the chuck. When the rack is taken out, this makes an excellent independent jaw-chuck. It thus virtually makes two chucks combined in one. The jaws are solid, forged of one piece of the best wrought iron, and case-hardened with animal charcoal.

Fig. 210 represents the "inside chuck." This chuck is quite well known as the one used on the Brown & Sharpe universal milling-machine.

Fig. 211 gives a view of the form of all chucks over 12 inches in diameter. These are made in one casting, with the exception of a circular ring-cap, which incloses the rack in the same manner as in the smaller sizes. This allows slots to be made entirely through the body of the chuck, and thus makes it very convenient to bolt work upon, if required, or to use it as a face-plate with the lathe-dog.

The center hub is simply a straight piece planed off on three sides and fitted into the center of the chuck. If a larger hole is wanted in the chuck, this hub can be quickly taken out.

Fig. 212 presents the new jaw for the lathe-chuck. The object of this improvement is to make the jaws of a chuck so that they may be

Digitized by Google

ground perfectly true both on face and bite, and thus be made more reliable in holding the work.

It is a common experience in case-hardening jaws that the form changes more or less, so that it is almost impossible, without grinding, to hold work perfectly true. To overcome this difficulty, a raised seat A A, is introduced on the face of the jaw, on which the work rests while turning. There is a groove, or recess, formed in the corner of the bite and face of the jaw. This groove admits of the use of the emery-wheel for grinding off the raised parts A A, so that work coming to a sharp corner will rest upon the ground seat A and the bite of the

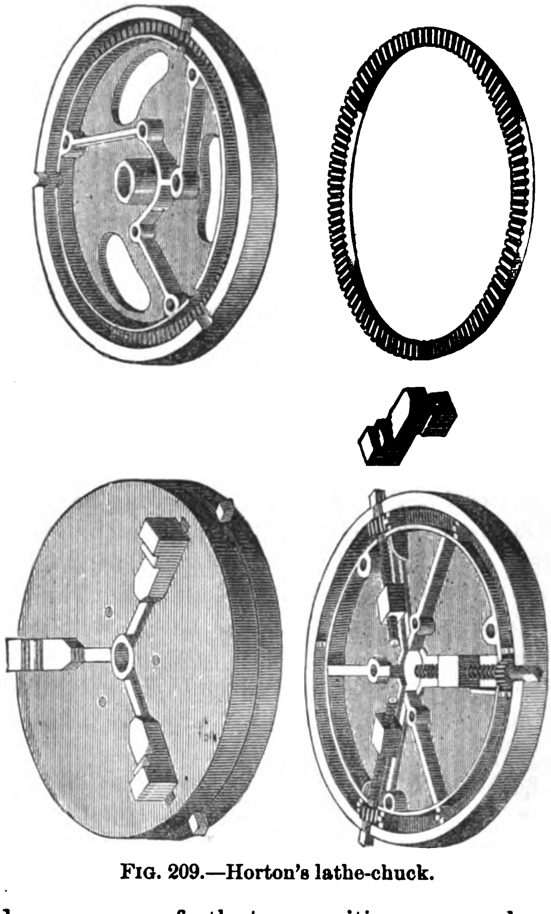


Fig. 209.—Horton's lathe-chuck.

jaw only, and assume a perfectly true position, an equal pressure being then exerted.

Another advantage of the groove is that a grinding wheel without a perfect corner will do its work accurately, as the wheel projects beyond the raised part in the recess formed by the groove, and thus grinds the seat perfectly true.

317. German opinion of American tools.—Dr. E. Hartig, a mem-

Digitized by Google

ber of the jury, and professor at the Royal Saxon "*Polytechnikum*," at Dresden, in his report, published since the above section of this report was written, remarks: "If we accept the expression 'machine-tools,' according to modern usage, as including not only machines for dressing and

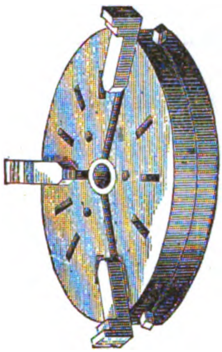


FIG. 210.—Horton's lathe-chuck.

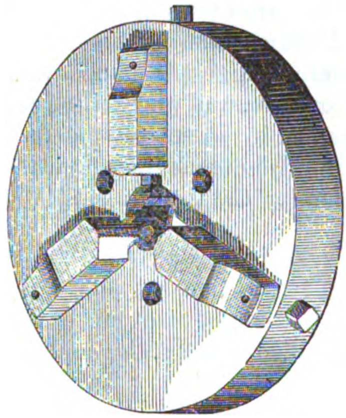


FIG. 211.—Horton's lathe-chuck.

working metals, but also the machines for dressing and working wood, which have of late become very numerous and have come into extended use, and if to these we add the machines for dressing stone, we will then include that group of machines whose representation at the Vienna Exhibition was the most successful in every respect. None of the

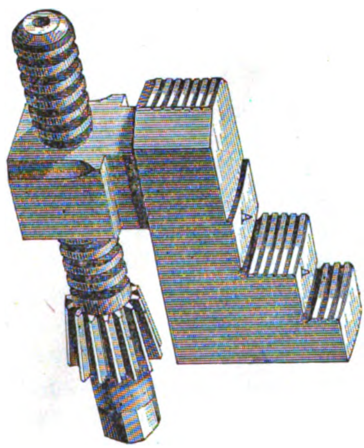


FIG. 212.—Horton's lathe-chuck jaw.

numerous divisions of this class was wholly without representation; no one of the countries that manufacture them was unrepresented. It is surprising that the machine-tool manufacturers of the United States were represented in a much greater number than upon any former universal exhibition, their exhibits being of unquestionable originality, and their value being made evident to every attentive visitor by the absence among

Digitized by Google

them of objects of inferior value. A true *élite* of reliable inventors and manufacturers: William Sellers, the originator of many unsurpassed designs; and Thomas Hall, the inventor of the handiest vise; B. C. Tilghman, the sand-etcher; and the Mowry Axle and Machine Company, who fastened the iron tires upon the wooden wagon-wheels without the use of heat! In considering this variety of triumphs of invention, the question naturally suggested itself anew, what influence is to be ascribed to the conception of the 'inventors' property,' when greatly refined and sharpened by an effective protection by patent-laws? A question which has found deliberate consideration and answer, in the course of the Exposition, by the International Patent Congress."

Digitized by Google

CHAPTER XII.

GENERAL REVIEW.

SCOPE OF THE REPORT; UNDESCRIBED EXHIBITS; TECHNICAL EDUCATIONAL EXHIBITS; NECESSITY OF STUDYING THE MANUFACTORIES OF EUROPE; BRITISH WORKINGMEN AS VISITORS TO VIENNA; AMERICAN MECHANICS AT VIENNA.

318. It has been the general intention of the writer in this report to review briefly only such machines and exhibits as came directly under notice while acting officially as a member of the International Jury, and such special exhibits as experience may have particularly qualified him to criticise.

There were a large number of exhibits at Vienna which were of great interest, not only to every mechanic, but to every intelligent person who recognizes the extent to which all progress in civilization, including intellectual and even moral advancement, is dependent upon the improvement of the materials and processes of the industrial arts.

The magnificent collections of Krupp, the proprietor of the immense iron-works at Essen, Prussia, the beautifully-graded steels and the splendidly-finished machinery shown by the Messrs. Schneider, of Creûsot, France, the noble show of heavy machinery exhibited in the Belgian section by the "*Société Cockerill*," of Seraing, the immense display of brass bronze and of other alloys and metals of Lavissiere, were each worthy of long and careful study.

319. TECHNICAL EDUCATIONAL EXHIBITS.—The writer, as an educator by position, although a "practical" man and an engineer by profession, was naturally much interested in the educational department of the *Austellung*, which may be looked upon as the illustration of the system of machinery by which we are to-day endeavoring to aid the advance of the more purely intellectual part of the work of civilization. The collections in this department were not as extensive as they should have been or as they were expected to be. The ordinary and standard apparatus which are everywhere used in higher schools and colleges, text-books in every branch of study for all grades and in every language, maps and charts, the familiar forms of physical and chemical apparatus, were all illustrated with some few novelties, but with rare examples of strikingly interesting innovations or improvements. The school apparatus and furniture from the United States, our American text-books, the French illustrative apparatus for very young pupils, the apparatus exhibited by London and Paris makers of philosophical instruments, were all attractive and exceedingly interesting to all who appreciate the public as well as

Digitized by Google

private benefits which follow the adoption of effective and truly practical methods of education. The German exhibits of apparatus for technical instruction were exceptionally interesting, both as constructions and as illustrations of German methods. Models exhibiting cinematic combinations, the various kinds of gearing, elements of machines, modes of transmission of power, models of typical forms of important machines, and other models illustrating processes of metallurgy and engineering were shown in great variety. Supplied with such apparatus, our American technical schools would, with their advantages of excellence of material in their classes, probably excel any schools, even of Germany, in the efficiency of the education which they would confer upon their students. A few of our professedly technical schools are already nearly as well provided with this kind of *material* as are the German, and one or two are even superior to all of the continental schools, with perhaps one or two exceptions, in this particular. It will probably not be long before we may expect to find ourselves in a position to offer to our young men all the advantages at home which they now seek abroad, and, in addition, some which can only be had in a country like our own and among a people like ours.

320. The engineer who attends the *Welt-Austellung* soon finds that, to learn thoroughly the lesson which he has come to study, he must pursue his investigations at a distance from, as well as within, the Exhibition limits. He finds there a splendid exhibit of machinery and of manufactured products; but to see the processes and the methods by which these products are created, he must visit the establishments which have contributed them. The writer, therefore, at the earliest possible moment, after the most important work was done, left Vienna to spend the remaining portion of available time in visiting some of the most successful or most interesting of those establishments in various parts of Europe, and also, where possible, to see something of that system of technical schools which has done so much for Germany.

321. While still at Vienna, a party of thirty-four English workingmen arrived to inspect the Exhibition, and to report to the British "Society for the Promotion of Scientific Industry" the results of their examination of the several departments with which they were familiar. These reporters were selected by competition from among 320 applicants. They were working-men actually engaged earning their living by working at the trades which they were severally chosen to represent. These men were very intelligent and evidently well capable of doing the work assigned them in a creditable manner, and their reports will probably prove most valuable.

While laboring under the disadvantage of a lack of opportunity for obtaining the superior education of the Germans, and while having no such inducement to exercise that native inventive talent which he undoubtedly possesses in hardly a less degree than the American, and while involved in those sad quarrels which are a natural consequence

Digitized by Google

of a misapprehension, by both masters and men, of those laws of political economy which control the relations between capital and labor, the English mechanic holds a position which commands the highest respect; and it may well be a cause of pride that we, who are closely competing with him, are his nearest relatives.

322. Other nations have, like the United States and Great Britain, sent corps of observation to Vienna, in which are included some of their most skilful artisans, and it may be fully expected that this enlightened policy will produce most valuable results. No nation, however, has as many representatives from among the class of "practical artisans" as the United States. Large numbers of our most intelligent and most experienced mechanics visited Vienna* to see for themselves what Europe is producing that is worthy of imitation. All were, probably, in some degree disappointed in their expectations of finding a large proportion of novelties, yet probably none came home feeling that the time and money which they had expended were lost.

From the Germans they learned the value of a practical mental and scientific training, and saw what it has done for a nation that cannot be termed a nation of mechanics. They learned also how well the Teutonic nations have developed this kind of education, and how much we, and still more the British, have been left behind in that great field of culture. They learned from the French that we do not excel in the combination of the useful with the ornamental, or in the exhibition of good taste in general work, or in the manufacture of those delicate kinds of apparatus and those marvellously perfect constructions which have become the ordinary tools of scientific work. From the British they learned to admire that simplicity of form and that substantial construction which distinguish the mechanical works of that nation to a degree that we may well hope at some future time to imitate, though perhaps hardly to excel. They learned, finally, that, while we may feel proud of the position already attained, we have still ample opportunity to improve in many ways.

* See Scientific American, 1873; correspondence.

Digitized by Google

Digitized by Google

REPORT

ON

MACHINERY AND MANUFACTURES.

PART II.

THE MANUFACTURING DISTRICTS OF EUROPE.

Digitized by Google

Digitized by Google

Digitized by Google

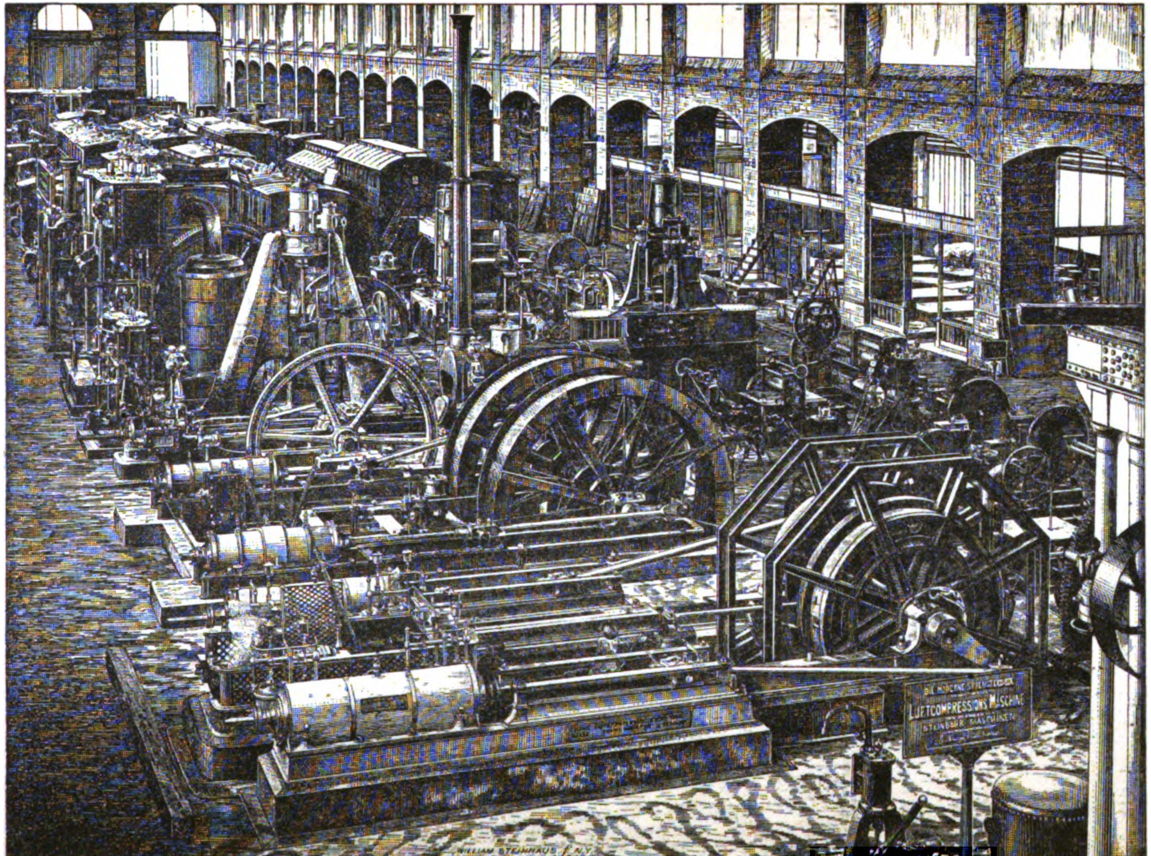


Fig. 213.

Digitized by Google

EUROPEAN MANUFACTURING DISTRICTS.

CHAPTER I.

SWITZERLAND AND HER MANUFACTURES.

INFLUENCES AFFECTING SWISS INDUSTRIES; COTTON-MANUFACTURES—THEIR DISTRIBUTION AND EXTENT; POWER-LOOM WEAVING; DYEING AND PRINTING; EMBROIDERY; SILK-MANUFACTURES—THEIR DISTRIBUTION; WATCH AND CLOCK MANUFACTURING; WOOLEN MANUFACTURES; LINEN-INDUSTRY; STRAW-BRAIDING; MANUFACTURES OF MACHINERY; IRON AND OTHER MANUFACTURES.

323. Immediately after the conclusion of the work of the International Jury, the writer left Vienna to visit the more important European manufacturing establishments and technical schools. Several weeks were devoted to that work.

It had been a part of the original programme to visit the South-European manufacturing countries, and it seemed particularly desirable to explore the more interesting manufacturing districts of Switzerland, and to learn something of the extent and the peculiar characteristics of method of those industries in which they are recognized as leading all Europe; but time did not permit the carrying out of this portion of the plan. But, although unable to visit Switzerland to correct the impressions formed at Vienna by a personal inspection of the manufacturing districts, the writer is indebted to the kindness of a colleague on the International Jury for valuable published statistics and general information.

In consequence of the scarcity of products of the soil, it is necessary, to compensate for this scarcity, for a large portion of the population of Switzerland to follow manufacturing industrial pursuits.

Swiss industry is impeded by a deficiency of raw material, especially of coal and iron, by its continental position and its elevation above the sea, and also by the fact that it is surrounded on all sides by countries having protective tariffs. It is favored by the abundance of water-power at its command, which will be still further increased when the manufacturing interests become capable of taking possession of the cold, higher regions of the Alps. It is also favored by a complete liberty of trade and by a restless tendency to open new roads, which inclination overcomes local impediments, and enables Swiss productions to be brought into all the markets of the world. Numerous establishments have now adopted steam-power together with water-power, and there are already manufactories employing steam-power only.

Digitized by Google

324. COTTON-MANUFACTURES.—Among all branches of industry the most important are:

(*a*.) The cotton-manufactures, the seat of which was originally the eastern portion of Switzerland and in the cantons of Zurich, Aargau, Glarus, St. Gall, and Appenzell, and which gradually spread throughout the cantons of Zug, Thurgau, Schaffhausen, Schwytz, Soleure, Bern, and several others. It consists principally of cotton-spinning, and, according to the census statistics of 1870, the following are approximate figures for the number of spindles:

	Spindles.		Spindles
Zurich	684, 566	Appenzell	4, 314
Bern	83, 412	St. Gall	218, 512
Lucerne	18, 636	Grisons	33, 122
Uri	....	Aargau	410, 434
Schwytz	75, 060	Thurgau	50, 146
Unterwalden	2, 400	Ticino	13, 028
Glarus	254, 468	Vaud	1, 397
Zug	111, 012	Valais	......
Freyburg	60	Neufchâtel	......
Soleure	28, 526	Geneva	......
Basel	44, 148		
Schaffhausen	26, 110	Total	2, 059, 351

In 1860 the total number was 1,602,109 spindles; or an increase of about 457,242 spindles has taken place from 1860 to 1870.

Assuming the annual consumption per spindle to be 28 German pounds, (31 pounds English,) and the yarn produced to amount to 25½ pounds, (28 pounds English,) on the assumption that No. 45 is the average number for textile fabrics produced in Switzerland, then, from the above, we have an annual consumption of raw cotton amounting to 52,000,000 pounds, (63,200,000 pounds English,) and an annual production of about 52,500,000 pounds of yarn, (57,700,000 pounds English.) A portion of this is exported into Germany, Austria, France, and Italy, while another portion is woven in the country, principally in the cantons of Zurich, Aargau, Glarus, St. Gall, Appenzell, and Zug.

325. Another branch of industry, that of power-loom weaving, which has of late years assumed considerable importance, also absorbs no inconsiderable quantity of yarn of all numbers, for the manufacture of embroideries, of machine-thread, combed-wool yarn, &c.

The fabrics thus produced support the dyeing and printing industries, of which the most important seats are the cantons of Glarus, Zurich, Aargau, and Thurgau. The principal seat of the business of weaving of colored goods is in the cantons of St. Gall, Thurgau, Zurich and Aargau, and Appenzell; and large weaving establishments exist in Wald, in the canton of Zurich, manufacturing fine muslins, the greater part of which are subsequently worked up in the extensive embroidering establishments of the two first-named cantons.

326. EMBROIDERY.—Embroidery, one of the most important branches

Digitized by Google

of the Swiss cotton-manufactures, is divided into (1) hand-embroidery, (2) broad embroidery, by means of looms, and (3) into power-loom chain-stitch, or crochet-embroidery.

Appenzell, Inner Rhodes, is the headquarters of hand-work, and some is produced in the valley of the Rhine and beyond the Swiss frontier. Swabia and the Bregenz forest also produce hand-embroidery.

More than 4,000 machines are in use in the manufacture of the second kind of embroidery, principally in the cantons of St. Gall and Appenzell, and lately in Thurgau, while crochet-embroidery forms a later branch of industry, in which small machines with one needle and larger ones with from 12 to 44 needles are used.

327. (*b.*) THE SILK-INDUSTRY stands at the head of the manufacturing pursuits of Switzerland in the magnitude of the trade, showing an annual exportation of 215,000,000 of francs, ($43,000,000.) Zurich is the most important center of manufactures of silk goods, but Bern, Basel, Schaffhausen, Aargau, Glarus, Thurgau, and Grisons share in this industry. Zug, Schwytz, and Unterwalden work for Zurich. Almost a monopoly of the manufacture of silk ribbons is held by Basel, from whence it has been introduced to a slight extent into the Bernese Jura and into the canton of Soleure. Some silk-spinning is also done at Lake Zurich and at Aargau, and the floss silk spinning of Basel, Zurich, Schwytz, Aargau, and Bern is a somewhat important business.

328. (*c.*) THE WATCH AND CLOCK MANUFACTURE, of which the principal seat is in the Neufchâtel, Jura and in Geneva, has recently spread into the neighboring cantons of Bern, Soleure, and Vaud. More than 200,000 watches are annually produced, and the export is considerably more than 100,000,000 francs ($20,000,000) in value. The import of raw material and tools amounts to more than 8,000,000 francs, ($1,600,000.) In this business a thorough classification and division of labor is carried into the smallest details. Connected with it is the manufacture of music-boxes, principally in Geneva and in the district of St. Croix, in Vaud, which latter alone produces about 100,000 of these pleasing toys per annum. In Geneva the manufacture of jewelry is also carried on extensively.

329. (*d.*) WOOLEN MANUFACTURES are carried on in Zurich, Bern, and Glarus, not, however, to a sufficient extent to supply domestic demands. It is, however, promising to assume considerable dimensions, and extensive establishments for the manufacture of worsted and of twine are being built in the cantons of Thurgau and Soleure.

330. The linen-industry in the Emmenthal of Bern, and at Burgdorf and Langenthal, does not produce sufficient to supply the consumption of the country.

331. (*e.*) STRAW-BRAIDING gives employment to the population in several districts of Switzerland. The production is not very considerable. The work of Aargau, from the village of Wohlen, has a wide reputation for its elegance as well as for its artistic designs.

Digitized by Google

332. (*f*.) THE MANUFACTURE OF MACHINERY, for which the other branches of industry create a demand, has not been confined to supplying this immediate demand.

Although compelled to contend with great difficulties in consequence of the necessity of importing nearly all raw material under high rates of duty, Switzerland has been able to secure a good reputation both in its own and in foreign countries, and to export successfully. The Swiss furnish steam-engines, steam boilers, heaters, and gas-fixtures, locomotives, steamships, all kinds of motors, machinery of transmission, cotton and woolen machinery, embroidering-machines, paper-machines, hand-tools and machine-tools of all kinds, iron bridges, rolling-stock for railroads, and agricultural machinery. These establishments are usually provided with founderies. This industry is represented in almost all the cantons of Switzerland; the main centers are, however, in the cantons of Zurich, Schaffhausen, St. Gall, Soleure, Aargau, Basel, Bern, Freyburg, Vaud, and Geneva. Small machine-shops are found wherever any branch of industry creates a demand.

333. Switzerland possesses several blast-furnaces in the Jura, which are said to produce a very superior iron from the ore mined in the neighborhood. The total production of the Swiss Jura is about 7,500 to 8,000 tons of pig-iron and plate and bar iron per annum. This is but a small part of the consumption of the Swiss iron-manufactures. Switzerland annually imports and works up at least 50,000 tons of pig-iron, bar and plate iron, castings and steel, inclusive of railroad materials.

334. Among industries of less note are the following: The manufacture of mathematical and philosophical instruments in Aargau, Zurich, Geneva, and Bern; of pianos, in Zurich and Basel; that of parquetry, in Valais, Freyburg, Bern, and Lucerne; of carved work in the highlands of Bern; the manufacture of a superior kind of paper in Basel, Zurich, Aargau, Soleure, Vaud, Geneva, Neufchâtel, and in other localities, and the manufacture of earthenware in the cantons of Bern, Schaffhausen, and Ticino. There are about 500 tanneries, of which the greater number are situated on the boundary-line between the Alps and that part of the country devoted to agriculture.

Digitized by Google

CHAPTER II.

MANUFACTURES IN GERMANY.

MANUFACTURES OF MACHINERY—THEIR DISTRIBUTION AND GROWTH; MANUFACTURES OF METAL GOODS; TEXTILE MANUFACTURES; WOOD AND PAPER MANUFACTURES; HISTORY OF THE MANUFACTURE OF MACHINERY; PRIME MOVERS; TEXTILE MACHINERY; LIGHT MECHANISM; MACHINE-SHOPS AND THEIR PRODUCTION; PROGRESS OF INVENTION; COTTON-MACHINERY; SEWING-MACHINES; STOCKING-FRAMES; LOOMS; PAPER MACHINERY; FLY-PRESSES; MACHINERY OF THE TOOL INDUSTRIES; MACHINE-TOOLS; PUMPS AND BLOWING-APPARATUS; METROLOGICAL APPARATUS; RAILROAD-PLANT—LOCOMOTIVE-BUILDING—CAR-BUILDING—USE OF STEEL—IMPROVEMENT OF ROLLING-STOCK.

335. MACHINERY—EXTENT OF MANUFACTURES.—The German Empire is now the grandest manufacturing nation of continental Europe. Its intimate connection with the United States, in which latter country so many citizens have had political and social relations with both governments, makes the industrial standing of Germany a matter of especial interest. The early and unintermitted development of technical education, in which this nation leads all others, is another circumstance which lends especial interest to the study of these economic conditions.

The distribution and extent of the German productive industries are stated to have been largely determined by her originally more peculiarly exclusively mining-industry. In intimate connection with the extension of mining and smelting in this country have arisen the manufactures of machinery and important improvements in the means of transportation. The former industry and the fabrication of textile goods have developed the latter within the last half century in Rhineland and Westphalia, in the kingdom of Saxony and in Alsace.

Thirty-two years ago (1841) there were no locomotive or car manufactories in Germany. Now Germany produces yearly about 1,000 locomotives and 30,000 cars, valued at from 17,000,000 to 30,000,000 thalers. Berlin, Carlsruhe, Esslingen, Graffenstaden, Chemnitz, Hanover, and Cassel form, with other cities, the principal seats of this manufacture. By increasing the tractive power of the locomotives and the capacity of the cars, it has been possible to more than counterbalance the rise in price of labor and of coal. Three establishments in Chemnitz alone have produced during the last thirty years over 30,000 power-looms, carding-engines, spinning-machines, and similar machines, containing more than 1,500,000 spindles. Chemnitz also leads the German machine-tool industry. The domestic sewing-machine industry is even stated to be competing with the foreign; manufactories in Berlin and Dresden are

Digitized by Google

stated to be capable of furnishing from 50,000 to 100,000 machines annually. The manufacture and introduction of agricultural machinery is slowly gaining a position in the market. The manufacture of printing-presses has always been a prominent business here, where the invention of the art of printing was made. Large numbers of printing-presses are furnished for exportation, especially to Russia.

The magnitude assumed by the business of manufacturing machinery within a short time may be seen in the fact that there were imported 217,225 cwt. of machines in the year 1868; at the same time there were exported 280,960 cwt., while the corresponding figures for 1872 were 663,720 cwt. imported, and 771,209 cwt. exported.

336. METAL GOODS.—The metal-ware industry has retained its original leading position. Formerly it had its seat in South Germany, but lately it has been moving northward into the mountainous countries bounding Rhineland and Westphalia. The manufacture of cutlery, tools, and weapons of war has been largely developed in parts of Westphalia, as Hagen, Altena, Iserlohn, and in parts of Rhineland, as Solingen and Remscheid. The manufacture of sewing-needles, founded three hundred years ago by laborers from the Spanish Netherlands, and the manufacture of iron and steel ware in Thuringia—in Suhl, Sömmerda—as well as in several cities of Würtemberg and Bavaria—Heilbronn, Nuremberg—have assumed an important place in the market. Berlin is famous for its weapons, cast-iron railings, forged and locksmith's ware. Articles of lead, tin, zinc, brass, and bronze are principally manufactured in Berlin, Nuremberg, Fürth, Munich, Cologne, and Hanover. The weight exported of these articles in 1872 was 307,998 cwt., while only 104,523 cwt. were imported.

The following figures are given for iron and steel products for the last five years:

	Imports		Exports.	
	1868.	1872.	1868.	1872.
	Cwt.	*Cwt.*	*Cwt.*	*Cwt.*
Sewing-needles, steel springs, &c	2, 591	4, 231	30, 835	20, 165
Fine iron ware	7, 041	11, 626	27, 915	43, 144
Rough-forged and cast-iron ware	245, 628	2, 155, 967	799, 384	2, 312, 697

337. TEXTILE FABRICS.—The industry of textile fabrics equals in importance that of metals. In the year 1861, 800,000 persons were employed; an equal number of looms and about 4,000,000 finishing-spindles were in use. In the mean time the number of inhabitants of the towns principally engaged in this business has increased 50 per cent. The industries of spinning and weaving are carried on principally on the banks of the Lower Rhine. This is probably owing to the influence exerted by the cities of Flanders and Brabant in the middle ages.

At the same time, the spinning of flax and the manufacture of linen

Digitized by Google

have acquired a greater importance in Westphalia, Silesia, and Saxony. They had been in a critical condition for many years, in consequence of the discouragements incident to passing from hand-spinning to machine-spinning, and they had partially lost the market.

The districts of Aix-la-Chapelle and Dusseldorf, the province of Brandenburg, the Saxon district Zwickau, and the countries of Upper Franconia, the Palatinate, Würtemberg, Alsace, and Lorraine are distinguished for their woolen fabrics. Of shawls and carpets, Berlin is the principal producer. The exports of woolen fabrics exceed the imports by about 200,000 cwt.

	Imports.		Exports.	
	1868.	1872.	1868.	1872.
	Cwt.	Cwt.	Cwt.	Cwt.
a. Woolen yarn	271,507	344,256	73,933	144,923
b. Woolen articles	74,979	166,590	292,347	360,302
c. Carpets	2,541	7,657	4,032	10,620

The value of exports has been estimated at 10,000,000 thalers.

The growth of the cotton-industry can be traced back to the beginning of the last century. As the official statement runs: "It attached its first threads to the woolen industry, at the side of which it now stands as an equally strong competitor." When the continental system of the first French empire stopped the importation of English twists, numerous spinning-mills were founded on German territory, and these have risen to great importance, though only after passing through several dangerous crises. In Chemnitz cotton-spinning machinery has been manufactured and used to a considerable extent since 1826.

The total production of cotton fabrics amounted to 1,650,000 cwt. in 1871, having been 1,000,000 cwt. in 1860, this covering not only the domestic, but also a part of the foreign demand. In the year 1872, 221,512 cwt. of cotton fabrics were exported; at the same time, only 49,059 cwt. were imported. On the other hand, the importation of cotton yarn in 1872 amounting to 456,863 cwt., exceeded the amount of exportation in a similar manner, the latter being only 98,800 cwt.

The manufacture of silk and mixed goods has its centers at Crefeld, in Elberfeld-Barmen, and at Berlin. It consumed in the year 1871–'72, 980,000 kilograms of silk and silk thread, valued at 27,500,000 thalers, while it used in the year 1843–'44 only 350,000 kilograms, valued at nearly nine million thalers. The value of these fabrics may be estimated at 50,000,000 thalers. In the year 1872, 14,041 cwt. of silks were imported, while the export amounted to 39,708 cwt.

338. WOOD AND PAPER.—The industry in wooden ware, especially in the manufacture of furniture, is of great economic importance. German furniture in very early times was of great value, and still has a high reputation. Subsequently this branch of trade failed with the decadence of

Digitized by Google

national architecture, and it has not fully recovered. The trade has only re-assumed importance within the last two decades, and then only in the larger cities of Berlin, Munich, Stuttgart, Dresden, Cologne, and Mayence. Omitting the statistics of rough-turned work and of wood cut into veneers, exports of furniture exceed the imports in value. In the year 1872, the exportations amounted to 310,220 cwt., and the imports were 58,270 cwt., while in the year 1868 the figures were 207,510 cwt. and 29,970 cwt., respectively.

The manufacture of paper and paper articles is now extensively carried on throughout the whole country. About one thousand paper-mills and factories are employed, generally merely manufacturing the cheap and common goods, in preference to the more expensive qualities. They have, however, already arrived at an annual production of machine-paper valued at 50,000,000 thalers; and in the year 1872 they were able to supply foreign markets with 20,000,000 kilograms more than their importations, after having satisfied domestic demands. The treatment of wood for the purpose of manufacturing paper-pulp is largely practiced. Paper-hangings are manufactured in great perfection in Hessen, Rhineland, Franconia, Thuringia; paste-board and card-work in Frankfort-on-the-Main, Dresden, and Leipsic. Articles of *papier-maché* are made in Thuringia and the mining districts.

339. MACHINERY, AND HISTORY OF ITS MANUFACTURE.—The official statement made to the International Jury relative to the manufacture in Germany of machinery and means of transportation was quite full, and the following account is undoubtedly accurate.

Germany seems to have taken an active part in the development of this industry during the last century. The spinning-wheel and the watch and clock, the steam-engine, the invention of which Otto Von Guericke took part, and one form of which was invented at the German University, Marbourg, the water-pressure engine which is claimed to have been first developed in Germany, and the fly-press and its applications, had all been extensively introduced at a very early date. In entering upon the manufacture of these machines, Germany has been behind her neighbors. The business took shape very gradually, and the exact date cannot be given, but it occurred at about the time when Germany began to rally from the effects of those great wars which occurred at the beginning of the present century, which changed its political relations so completely. About 1820, Germany, stimulated by the influence of England and Belgium, began to manufacture machinery for the general market.

340. PRIME MOVERS.—At about that time the manufacture of steam-engines was taken up in Prussian Rhineland. At first the production was limited to supplying the demands of the mining and smelting industries, which were then the most important in the country. The steam-engine manufacture of Rhineland and Westphalia still has there its largest market. Recently the manufacture of gas-engines has been

Digitized by Google

taken up with that of steam-engines in the above district. This business arose upon the demand of the smaller industries for prime movers of moderate power. Several machine-tool manufactures have also been added to the above on the Lower Rhine, among which the principal are the machines used in mining and smelting. They were not, however, well represented in the Exhibition.

On the Upper Rhine, and in the southwest of Germany, the manufacture of water-wheels, especially of turbine water-wheels, is developing rapidly, water-power being there largely available. This is also the case in Alsace.

341. TEXTILE MACHINERY.—The business of manufacturing machinery for cotton-spinning, weaving, and finishing has its main centers at Mülhausen and Thann, and has been greatly developed in Alsace by the progress of the manufacture of textile fabrics. At the same places and in Graffenstaden the manufacture of machines for working metals and wood is also growing. On account of the extensive production of textile fabrics, machinery adapted to that use was produced at an early date in Saxony, both for cotton and for wool, and to a less extent for linen goods. The London Exhibition of 1851 induced the capitalists of Saxony to enter upon machine-tool manufacture. This is at present one of the most extensive branches there carried on, furnishing machines for working metal and wood which are of excellent quality.

342. LIGHT MECHANISM.—The Prussian province of Saxony and the neighboring districts have developed the manufacture of sugar-making machinery also. The manufacture of manometers, or pressure-gauges, and other attachments to steam-boilers, is actively carried on upon a grand scale in the establishment of Schäffer & Budenberg, in Magdeburg. Their spring-gauges are sold all over the world. These and other establishments have also begun to build parts of machines, and this branch of their business is rapidly growing and promises to prosper. The articles now manufactured there are principally valves, cocks, and small brass goods. The manufacture of parts of machinery of transmission, such as coupling, wheels and pulleys, has not yet been fully organized, and they are still only made to order and are not given standard forms.

343. MACHINE-SHOPS.—At Berlin, the manufacture of machinery was commenced by the iron foundries, which gradually developed, and were transformed into machine-shops. These at first produced all kinds of machinery, but they gradually each assumed a special character.

The manufacture of locomotives is the most important of these industries. The building of machine-tools, steam-engines, hot-air engines, printing-machinery, machines for brewing, sugar-making machinery, agricultural implements, and large numbers of sewing-machines, and those manufactures lately developed, are all extensively carried on in Berlin. This city has become one of the most important centers of the German machine-industry.

Digitized by Google

Machine-shops are, however, distributed over all Germany. The following figures exhibit the weight of imports and exports of machinery from 1866 to 1871:

Year.	Import.	Export.
	Centners.	*Centners.*
1866	226, 023	144, 157
1867	226, 914	209, 129
1868	217, 225	280, 960
1869	292, 566	411, 088
1870	287, 221	432, 367
1871	315, 424	482, 917
1872	663, 720	771, 209

An increased consumption of machinery of foreign make is indicated, and also a continual increase in the export of machinery. Germany did not fully meet its own demand for machinery at the time of the Paris Exposition of 1867, but it now assists in supplying the markets of the world.

344. PROGRESS OF INVENTION.—The earliest manufacture of machinery occurred in the year 1801. The first extensive production of hand-looms was by Hanbold, at Chemnitz, 1826. Pickers and lappers were first built in 1842. From that time this manufacture gradually developed by the invention of important improvements at home, such as the construction of Hartmann's fine carding-engine for short wool, (Saxon Patent, v. 13, December, 1842,) and by the independent development of the power-loom by Schönherr, in Chemnitz, 1836; of the cloth-finishing machine and the shearing-machine by Thomas, of Berlin, 1845; Gessner, in Aue, 1853; and by Pressprich, at Grossenheim, of his fulling-mill, in 1854. The self-acting carding-engines by Schimmel, Pfaff, Wiede, and others; the calico-printing machines and dyeing and finishing machines by Hummel, of Berlin, 1840, and by Riesler, at Zittern, and the knitting-machines made by Voight, at Kappel, 1860, are also noteworthy. Eight hundred and seventy-eight patents have been issued in Saxony during the last forty years (1833–'72) on inventions connected with the manufacture of textile fabrics, and of these 574, 65.4 per cent., were taken out by Saxons and 304 by foreign inventors.

345. *The manufacture of sewing-machines, from American designs,* dates as far back as the year 1854. Moore, of Berlin; Hofmann, of Hesse; Huber, of Leipsic, build sewing-machines, and the workmen come from among the best classes of mechanics. The most important seats of this manufacture are Dresden, Hamburg, Berlin, Limbach, Chemnitz, Mannheim, Frankfort-on-the-Main, and Carlsruhe. The total production up to the end of 1872 has been estimated at 300,000 machines. The factory of Clemens Müller, in Dresden, was founded in 1856, and furnishes 18,000 machines annually. Its capacity has been increased up to 60,000 or 80,000. The sewing-machine factory (formerly that of Frister & Rossmann) in Berlin furnished 16,971 machines in 1872, and

Digitized by Google

has already built 3,610 in the first two months of 1873. It has a capacity for the production of 42,000 machines annually.

346. The development of stocking-frame manufactures occurred independently of that of other machines used in textile industry. The introduction of the machine, with a peculiar construction in wood, may be traced back to the middle of the seventeenth century in the Saxon Erzgebirge. A reliable estimate gives the number of looms built from 1784 to 1863 at 58,300. In 1770, the iron frame was introduced by Aurich at Grüna, Esche at Limbach, and by Ganzange in Zeulenroda. In 1853, Heinig, of Neukirchen, invented his machine, replacing the former arrangement, which allows the hand-loom some chance of competition with the power-loom in manufacturing. In 1842, the first English circular loom was set up at Stollberg, but the building and manufacture of these looms only began about the year 1850 in Limbach, Stollberg, Mitweida, near Schwarzenberg, and in Chemnitz. Circular looms have also been manufactured at Stuttgart, by Stückler & Perrot, since 1862. The ribbon-loom, a sort of power-loom upon which narrow ribbons are manufactured, has a history going still farther back. They were introduced from Holland at the beginning of the seventeenth century. Their use was forbidden in 1685 by an imperial decree, and they were again introduced in 1718, at Charlottenburg, and were finally, in 1765, allowed by a special decree of the elector. The manufacture of these and of other machines for lace-work, as braiding-machines, is carried on in small shops, especially in Berlin. They are also built in and about Annaberg, in Saxony.

347. Other countries have competed more effectively in Germany in the sale of machines for paper-manufacture than of those used in textile industry. Switzerland has been most prominent in this competition. The manufacture of rag-engines had been undertaken by many machine-shops, but the building of paper-machines for endless web was for a long time only attempted occasionally. This branch of manufacture is even now the specialty of a single firm, Golzern, in Grimma, Saxony. Machines for making paper-pulp from wood were invented and developed by Henry Völters, at Heidenheim, on the Brenz. Their manufacture is now carried on by Decker Brothers & Co., of Cannstadt. Up to the end of 1872, there had been built in Europe 212 of these machines, and in America, as stated, 150, a total of 362 such machines requiring about 22,000 horse-power, capable of manufacturing about 6,000 cwt. of pulp. In Germany there are about 77 real Völter machines in use, and numerous imitations.

348. The inventor of the fly-press, Fr. König, who built the first printing-machines in London for the Times, in 1817, started a factory which was devoted to the manufacture of these machines, in the Oberzell convent, near Würzburg. This factory supplied all Europe. It had built and sold 1,898 fly-presses up to the beginning of 1873, being distributed, by date, as follows:

Digitized by Google

1817 to 1830	52
1830 to 1840	54
1840 to 1850	186
1850 to 1860	314
1860 to 1872	1,292
Total	1,898

Of these about 60 per cent. were sold in Germany and 40 per cent. were sent to other countries. Russia has taken about 350 presses. The number of workmen employed exceeds 400. A second factory has recently been built near Würzburg.

Dingler, of Zweibrücken, has been engaged in the manufacture of iron hand-printing presses since 1841. The total production was 1,512 machines up to the end of 1872, of which Germany took 246, Switzerland 108, and Russia 148. Printing-machinery is also manufactured in Berlin, by G. Sigl, Fred. Jänecke, and others, and in Leipsic. Machines for lithographing, copper-plate printing, and book-binding have been made extensively at Offenbach, on the Main, by Heim Bros.

349. The manufacture of machines for the production of articles of food and luxury is less localized. Magdeburg produces machines and apparatus used in the manufacture of sugar; Dresden supplies the market for chocolate-machinery; Chemnitz furnishes brewers' machinery; Brunswick builds ice-machines; Stuttgart, Leipzic, and Dresden make machines used in the manufacture of cigars. The manufacture of grain-husking machines has been actively carried on, since about 1866, at Frankfort-on-the-Main, by the firm of Seck & Co. At the end of 1872, 515 machines of this kind were sold, of which 241 were for Germany, the annual production being about 100.

350. The development of the German machine-tool business was greatly retarded by the general custom of each machine-shop building its own machinery. It is true that Reichenbach, in Munich, (1804,) constructed several original and ingenious machine-tools. He built the first file-machine. The first impulse toward a general use of machine-tools was given by the British, and through the exertions of Beuth, of Berlin, who imported the best English models into Germany at the expense of the Prussian government, and who had them copied, and then made them familiar to the German manufacturers by *advertisement.* A. Hamann, of Berlin; Mannhardt, of Munich, and Henschel, of Cassel, first attained a reputation in this work.

The second period of development was that in which the simple copying of foreign designs was to some extent given up, and building on original plans was commenced. This policy was inaugurated about 1852, when several manufacturers of Chemnitz commenced the manufacture of machine-tools as a specialty. Since that time, Chemnitz has sent machine-tools to all the countries of Europe, to South America, and to Egypt. Although the manufacture of machine-tools originated

Digitized by Google

in the demands of the manufactories of machines required in the textile industries and of steam-engines, it owes its greatest development principally to the recent development of methods and means of transport, and especially to the demands of railroads for rolling-stock. Machinery for the manufacture of fire-arms has become important; and of these tools Chemnitz furnished a large number to the great gun-factories of Westphalia, to the royal Prussian manufactory of fire-arms, to the imperial Russian arsenals and naval stations, and to Italy and Servia. The total production of the "Chemnitzer Werkzeugmaschinenfabrik," (I. Zimmermann,) amounted, at the end of the year 1872, to 10,600 machines, and that of the "Sächsische Maschinenfabrik," (Rich. Hartmann,) to 2,645 machine-tools of all kinds.

After Chemnitz come Graffenstaden and Mülhausen and Berlin; Offenbach, on the Main, Stuttgart, Carlsruhe, Hamm, in Westphalia; Aue, near Schneeberg, all towns of importance in the machine-tool business. I. Banning, of Hamm, furnished to date 350 steam-hammers, with a weight of "tup," or drop, varying from 2 cwt. to 120 cwt. Kirchei's, of Aue, since 1863, has made a specialty of tinsmith's tools. He built 642 machines in the year 1870.

A peculiarly German specialty is the manufacture, by Uhlhorn, at Grevenbroich, of coining-presses fitted with a lever combination. The first machine of this kind was furnished by Dietrich Uhlhorn to the mint of Dusseldorf in 1818, to replace a screw-press, of French make, which had been broken. Now twenty-three states of Europe and several foreign states are said to employ 175 of these machines in their coinage. It is recognized as a most efficient machine.

Recently the marked influence of the manufactures of the United States is perceivable in the production of machine-tools in Germany, especially in wood-working machinery.

351. The manufacture of pumps, blowing-machinery, and ventilating-apparatus has not yet been completely separated from that of steam-engines and machine-tools. Independent and extensive manufactories have, however, been established for the manufacture of steam fire-engines at Dresden, Heidelberg, Aix-la-Chapelle, Stuttgart, and Berlin. The production of steam fire-engines has continued an independent industry in Chemnitz and Berlin.

352. Instruments required in the observation and measurements of steam-pressures, the measurement of speeds, and of the amount of motive-power demanded by machine-shops, were originally of foreign make, or were occasionally made in the shop where employed. They may well be separately manufactured on a large scale, as the delicacy of the work is exceptional. Manufactories have been erected in Berlin and Magdeburg within the last twenty years for the manufacture of spring pressure-gauges, the largest of which establishments, that of Budenberg & Schäffer, in Buchan-Magdeburg, furnished, up to the end of 1872, 235,000 gauges. The German laws regulating the erection of steam-

Digitized by Google

boilers, which direct that each boiler must have at least one pressure gauge, have been peculiarly favorable to the development of this branch of industry. The manufacture of gas and of water meters is of equal importance, and is a prominent branch of business in Berlin, Dresden, and other places. The single establishment of Siemens & Halske, in Berlin, had furnished 11,060 water-meters up to the end of 1872, all of which were of original design. On the other hand, the production of velocimeters and of dynamometers has only occupied a single establishment.

353. RAILROAD-PLANT.—In the early days of railways, about 1840, there were no facilities for supplying rolling-stock. There was a complete absence of establishments for building locomotives, and these were necessarily imported both from England and America. Soon, however, men were found capable of undertaking this work. Among them, the name of August Borsig is best known. His eminently practical good sense assisted effectively in the development of this branch of industry in Germany. Borsig recognized the fact that it was of primary importance to obtain a reputation for good work, and he therefore spared no pains to make his locomotives superior both in material and workmanship. A large iron mill, which existed many years at the gates of Berlin, was erected by this "man of iron will," who, not feeling satisfied with the guarantee offered by distant manufacturers, desired to have his boiler-plate, axles, and other details in iron manufactured under his own eye. Such energy was naturally crowned with full success. This had a very beneficial effect upon the German manufacture of locomotives.

The superiority of Borsig's work, which soon became generally acknowledged, crushed out all competition, even that of native manufacturers, until they determined to attempt to produce the same quality of work. It is for this reason that this branch of industry has succeeded so well in Germany, and it is claimed that it has not only been able to meet domestic demands, but it has also been able to compete successfully with England and other foreign countries. Large locomotive-works now exist in Königsberg, Elbing, Stettin, Berlin, Hanover, Chemnitz, Cassel, Munich, Carlsruhe, Esslingen, and in Graffenstaden and Mülhausen, all together being capable of building more than 1,000 locomotives annually, valued at 50,000,000 marks, ($12,000,000). As an indication of the number exported, it may be stated that Borsig's establishment built 1,031 locomotives from April 1, 1867, to April 1, 1873, and of these 300 went to Russia and 30 to Austria, Holland, and Java.

354. Equally encouraging progress has taken place in the manufacture of cars. With exception of the axles, wheels, and springs, cars were first made of wood put together with bolts and angle-irons. Gradually iron has taken the place of wood, and now the floor-frames are built wholly of iron on many roads, their wear and stability being, it is said, thus considerably increased.

The extended employment of cast-steel instead of cast-iron is an im-

Digitized by Google

provement which Germany claims as peculiarly its own. It was at first an attempt to displace iron by a material which then cost about six times its price, and which had until then only been manufactured on a small scale. Werner, at Carlswerk, near Neustadt-Eberswalde, was the first to make cast-steel axles of good quality for railroad rolling-stock; Krupp, of Essen, invented an ingenious method of making weldless cast-steel tires, and Meier, of Bochum, cast excellent steel disk-wheels in one piece. These three inventions have found extensive application. Iron is almost displaced on some roads, with great advancement in safety and durability and in the working capacity of the cars. Even the comfort of traveling has been thus greatly increased. A great improvement has been made in passenger-cars. Instead of the open or half-open third-class cars used formerly, the practice is now becoming usual of providing even the fourth-class cars with heating-apparatus in winter and of lighting them up at night.

Car-building establishments are distributed throughout Germany in larger numbers than locomotive-works, and not only in the towns mentioned as the sites of locomotive-works, Chemintz excepted, but at Greifswalde, Görlitz, Breslau, Dusseldorf, Hagen, Cologne, Deutz, Frankfort-on-the-Main, Mayence, Brunswick, Hamburg, and Ludwigshafen. These establishments also export extensively, turning out about 30,000 cars annually, valued at about 90,000,000 marks, ($22,000,000.)

355. By the employment of higher steam-pressures, and by a more complete utilization of the adhesion of the locomotive, its tractive power has been increased threefold over the earlier practice. The capacity of the freight-cars, as compared with their weights, has been increased considerably. While formerly the tare-weight amounted to about one-half the gross-weight, it has now fallen to about one-third or one-fourth.

In consequence of these improvements, rates of freight have been reduced without decreasing the income of the roads, and in spite of the higher prices of materials and labor. The official report to the International Jury, from which these facts were principally obtained, may therefore truly consider these branches of industry as the great levers in national economic advancement.

Digitized by Google

CHAPTER III.

GERMAN MANUFACTURING ESTABLISHMENTS AND TECHNICAL SCHOOLS

DRESDEN—THE POLYTECHNIC SCHOOL; FREIBERG—THE BERG-ACADEMIE; BERLIN—THE BORSIG LOCOMOTIVE WORKS—THE BAU ACADEMIE—THE GEWERBE SCHULE; ESSEN—KRUPP'S WORKS—KRUPP'S MINES AND SMELTING-WORKS—PRODUCTS OF HIS ESTABLISHMENT—KRUPP'S ORDNANCE—COMPARISON OF KRUPP'S WITH BRITISH AND AMERICAN DETAILS.

356. *Dresden.*—The first stopping-place after leaving Vienna was Dresden, the seat of a fine technical school and a favorite place of residence of Americans visiting Europe. There are no manufactures here that demand report.

The technical school is not well provided with apparatus, and its collection of models is not remarkable either for its extent or its interest. There are some excellent collections illustrating the processes of textile manufacture which are used in the course of instruction given by Prof. Dr. E. Hartig, a colleague on the International Jury, to whom the writer has been greatly indebted for valuable information. Among the models of machinery is a fine locomotive presented to the school by the builder, Richard Hartman, of Chemnitz. A model of a "Jonval" water-wheel was a reminder that it is here claimed that Henschel, of Cassel, invented this turbine, and that Jonval had seen it here some years before he brought it out as the Jonval wheel. The work done here by the students is unusually fine. They spend a large amount of time upon the preparation of elaborate theses. One student had made a very complete set of excellent drawings representing a windlass with its gearing; another had designed a neat-looking Fairbairn crane; still another had made designs for a cotton-mill, including buildings and the placing of machinery; another student had produced, as an original design, a Meyer valve-gearing, to which the Porter governor had been applied for regulation.

One of the best pieces of work exhibited by Prof. Weiss, who kindly acted as guide in the absence of other professors, was a set of drawings and specifications for the water-supply of a large city, and all necessary calculations to determine cost and relative efficiency of methods. The students give a considerable amount of time to such work, as is evidenced by the quantity of work accomplished. Sixteen hours a week are usually devoted to such problems in the drawing-rooms, and, in addition to this, the student attends lectures in the several auxiliary academic departments. Such designs as we were able to inspect were usually well

Digitized by Google

made, and in some cases they exhibited a remarkable amount of inventive genius—a rare quality in Europe—and were invariably well proportioned. It is in such schools as this that the German youth are acquiring a knowledge of the science of engineering, and that skill in the work of the drawing-room which has done so much for their own country during the last quarter or half century, and which has enabled them to find their way into the best manufacturing establishments in the United States, and to monopolize so considerably some special departments of work. At home, where the shops and the professions are alike overcrowded, they find few opportunities for advancement. In the United States opportunities are vastly more frequent, and these graduates of German schools are taking advantage of them.

On the river at Dresden we noticed *Schiffmühle*, (floating tide-mills,) which were evidently finding plenty of work. A *Kette-dampf*, or steamer driven by the now well-understood system of chain-towage, was plying between the city and the smaller villages up the stream. Several long barges on the river were fitted with rude "balanced rudders," such as are generally supposed to have been original in the United States. Visiting the famous picture-gallery, we saw an old painting in which was shown a peculiar form of saw, upon which several patents have been issued in this country, and which is claimed to be one of the most valuable of new inventions; the picture was numbered 1748, and painted by Croch three hundred years ago.

357. FREIBERG.—While at Dresden, a day was taken for a visit to the celebrated mining-school of Freiberg, which is situated not far distant, in the midst of a hilly mining-country which resembles somewhat some of the pleasantest portions of New England. This old Saxon city contains the *Berg-Academie* to which so many American students are indebted for their knowledge of the theory and methods of mining. The surrounding country is rich in ores and minerals, and is interesting both to the metallurgist and the mineralogist. The town itself is quaint and interesting from the evident antiquity of the buildings which line its principal streets, but it contains nothing especially interesting to an engineer.

The school is in the city, and consists of a number of departments directly or indirectly connected with the work of instruction in mining-engineering. The high character of its work and the distinction obtained by its faculty have been long well and widely known, and, together with its exceptional advantages of location, these inducements have made it quite a successful institution.

The collection of models is an excellent one. Many of them have been made here, and a large number of duplicates have been made also for foreign schools. We found a considerable number, wholly or partially finished, for schools of mines in the United States. Among these models was one representing a mine with its shafts and its galleries, its hoisting and pumping machinery, and all accessory apparatus. It was

Digitized by Google

worked by clock-work, and gave the visitor a very perfect idea of the general management of a large mine and of the method of working. A large number of models of pumps, water-wheels, and steam-engines, such as are commonly used in mines, gave one an excellent opportunity to study the forms and applications of such details. A model of a pair of direct-acting steam-engines, in section, was unusually well made; another represented the Cornish pumping-engine, and was made in metal. This could be driven either by steam or air. The price asked for it was 1,550 thalers. It was of about 8 inches diameter of steam-cylinder and 18 inches stroke of piston, constructed to a scale of 1½ inches to the foot from an original of 80 horse-power. A fine set of boring-tools, for mines or for artesian wells, was on exhibition; a good model of a blowing-wheel, a double blowing-engine, with one cylinder in section, several smelting-furnace models, filled with hot blast, and with cone and hopper charging-apparatus, models of puddling furnaces, and other equally useful models for mining schools were among the collections, and duplicates were to be had by purchase. These models were usually constructed in pear-wood, and were well made and nicely finished. The prices were moderate, but it requires a very long time to fill an order. Five men were employed in making these models, and the profit obtained from their work on material sold was sufficient to supply a considerable amount of valuable material to the school. Although this is an excellent and well-appointed school, it is a matter of congratulation that we now have equally good schools of mines in the United States, in which our young men may find equally good opportunities to acquire a knowledge of the subject, both by lecture-room instruction and by practical acquaintance with under-ground work. The importance of such knowledge in the development of the immense mineral resources of our country is well understood, and such schools are now frequently founded and are often well endowed. The profession of mining-engineering is an attractive one, and there are many young men in the United States whose tastes and mental powers are peculiarly well adapted to such work. We are, therefore, not at all dependent upon Europe, either for such material or for its education, and the working of our mines may be expected to be intelligently and profitably conducted, and our mining regions will be as rapidly developed as the growth of the nation and its agriculture and manufacturing industries may require.

358. BERLIN.—Returning to Dresden, we next took the train for Berlin, and rode through a pleasant but somewhat monotonous country. The planting of trees along all roads and along the borders of the fields was a feature which reminded an American of the fact that in the United States the importance, the vital necessity, of such compensation for the loss of the forests is not at all appreciated, and that the danger of serious results from the rapid changes of climate, such as invariably accompany the deforesting of a country, is becoming imminent. Public attention is slowly becoming attracted to this subject, and it is to be

Digitized by Google

hoped that prompt and intelligent legislative action may avert those consequences.

The country about Berlin is smooth and perfectly level, as it is through all that part of Europe, and the whole country is dotted with such windmills as were familiar to all in the United States a few years ago. The improved forms, now so common in this country, with self-adjusting sails and self-directing apparatus and regulation, are not seen in Prussia.

The *Borsig Locomotive-Works* are at Berlin. This establishment is one of the largest and most important of its class in Europe. It is stated to have supplied more than one-third of all the engines supplied to German railroads. The Borsig property consists of the locomotive-works, which are located in the city of Berlin, the boiler and forge shops, which are at Moabit, in the suburbs, and the iron and steel works, which are at the mines. Of these works but little can be learned, that is important to the engineer, in reference to their production. It was stated that up to 1870 the German roads had purchased 5,455 engines, of which 1,900 were constructed at the "Borsigsche Austalt," in Berlin where 158 were made in that year alone, and that the capacity of that establishment is sufficient for the production of about 175 per annum. The "Gesellschaft für Fabrication von Eisenbahnbedarf" built in that year over 2,500 railroad-cars, for which the receipts amounted to 3,500,000 thaler, and the Moabit establishment produced over a thousand tons of apparatus. The number of workmen employed in the city is not far from 1,500, and their capacity is sufficient to work 2,000 men. They work eleven hours per day, and are paid from ten to fifteen thaler per week. The buildings are quite well planned and well arranged, and the new structures in course of erection were well disposed and well lighted. Of the tools many were old, but some new tools had been imported from England, which were of the best recent design.

In the locomotive-works the methods of work are quite similar to those observed in the majority of other establishments in Europe. Engine-frames are made from rolled plates and trimmed up by a machine of peculiar design, constructed for this work. It is fitted with four independent tool-posts, which can be moved in all directions by independent feeds; the direction of the cutting-edge is adjustable, to suit the direction of motion of the tool. The thickness of metal usually adopted is 30 millimeters, (1.2 inches,) but the tender-frames are of lighter plate, usually but ten millimeters thick. Wheels are invariably of forged iron. The boilers are usually of iron, rarely of steel. Fire-boxes are made of copper in nearly all cases; steel is experimentally adopted in a few instances. The tubes are often made of iron, with a portion added at the fire-box end which is composed of copper—a peculiarity of locomotive practice which we had not observed elsewhere.

At the boiler-works the riveting was all done by hand, so far as observed. The heads of rivets were usually made by the use of a former driven by a heavy hammer or light sledge, and the shape was

Digitized by Google

usually that of the snap or hemispherical head. The practice, which is not uncommon in Great Britain, but which is rarely seen in the United States, of punching the holes somewhat smaller than it is proposed to finish them, and of enlarging by drilling to size, was quite generally adopted here. It makes good work, looks well, and is very strong. It is superior to the conical-headed riveting commonly seen in the United States, and some of our builders are adopting it even where the work is done by hand. In steam-riveting the snap-head is universally used.

The first locomotive built at the Borsig Works was completed July 21, 1841, by the founder, who has but recently died. He was greatly respected and beloved by his work-people, over whom he watched with paternal care. One of the evidences of this care is the large dining-hall and refectory, in which workmen are, when they desire, supplied with meals between 8 o'clock and 8.30 a. m., 12 and 1 at noon, and from 4 to 4.30 p. m. The married workmen usually go to their own homes, or bring their meals and eat here with the unmarried men, who usually obtain their food at this restaurant.

These works are supplied with iron and steel from branch establishments in Upper Silesia.

The Borsig Iron-Works were established in 1863. There are four blast furnaces, which yield about 30,000 tons per annum of manganiferous iron of excellent quality. There are also extensive puddling and steel works with three Siemens-Martin furnaces.

About 3,500 men are employed, and the 45 engines in the establishment are collectively of 4,400 horse-power. These works make excellent boiler-plates from pig from brown Silesian hematite ores, mixed with Styrian and Hungarian spathic ores. The following are averages of a series of tests recently made with samples of boiler-plates by Mr. David Kirkaldy. The length of the samples used in the experiments for tensile strains was in each case 18 inches, the ends for a length of 4 inches being made wider than the body of the sample. In the tests for bulging stress, discs 12 inches in diameter were cut out of the plates and pressed into an aperture 10 inches in diameter.

TABLE I.—*Tensile stress.*

	Thickness, inches.	Stress.		Ratio of elastic to ultimate strength.	Contraction of area at fracture.	Stress per square inch of fractured area.	Extension, per cent.	
		Elastic per square inch.	Ultimate per square inch.				At 40,000 pounds per square inch.	Ultimate.
Lengthway—								
Unannealed	.64	29,125	53,405	54.5	27.4	73.492	4.97	23.8
Annealed	.64	28,523	50,466	56.5	27.3	70,097	5.93	42.7

Digitized by Google

TABLE II.—*Bulging stress.*

	Thickness.	Stress in pounds; bulged, inches.				Ultimate.	
		50,000.	100,000.	150,000.	200,000.	Bulge.	Stress.
						Inches.	*Pounds.*
Unannealed	.640	.95	1.57	2.07	2.60	3.26	233,410
Annealed	.640	.90	1.49	1.95	2.39	2.69	223,375

TABLE III.—*Bending test.*

	Description.	Angle.	Effects.
		°	
Hot	Lengthway	180	Uncracked.
Do	Crossway	180	Do.
Cold	Lengthway	180	Slightly cracked.
Do	Crossway	57	Do.

Of the four samples submitted to bulging stress, one of the annealed and both the unannealed ones burst on arriving at the maximum strains recorded.

359. The *Bau-Academie*, of Berlin, is a technical school of high-standing, which is educating 650 students—its full complement. Its course of instruction is almost purely scientific. The establishment has some very fine models in its extensive collections, the best of which are bridge-models. Some of these are very large and are perfect reproductions in all but size of the structures from which they are modeled. A very large and complete collection of architectural models in plaster is a very valuable feature. Every well-known form of structure and of detail is shown here, with occasionally the finer work exquisitely reduced to scale. The buildings are not of modern form, and the rooms are not as well arranged as are those of many other schools.

The *Gewerbe Schule* is also a technical school of admittedly high standing, and is probably one of the best in the *personnel* of the establishment, in its buildings, and in collections to be found in Europe. The director is Dr. Reuleaux, a well-known writer on subjects connected with mechanics and engineering, and a member of the International Jury, Vienna. The faculty is moderately large, and comprises among its members some of the best known among the younger scientific men of Germany. The buildings are not remarkable for either arrangement or construction, but some of the lecture-rooms are well fitted up, and especial care is taken in ventilation of those which are artificially lighted. This school has a remarkably fine collection of models of geometrical and mechanical apparatus. Several workmen are kept constantly employed in the little machine-shop of the establish-

Digitized by Google

ment, and are continually enriching the already large and well-selected collections. The models are of a lighter and neater pattern than those usually seen in the cases of our own and of European schools, but as none are made for sale, they are likely to remain uncopied. The students do not work in the shop except when found unusually expert in the use of tools, and when they make special application for that privilege.

The course of instruction is largely by lecture, with such illustration as is possible by drawings and by the use of models. The work of the students is very creditable, and the institution is evidently prosperous, and it is doing a vast amount of good.

360. ESSEN; KRUPP'S WORKS.—At Essen, Prussia, are the works of Friedrich Krupp, the largest manufacturing establishment in the world. The proprietor gave to the International Jury an account of the growth and present condition of these enormous works, which was as interesting as it was instructive.

The cast-steel manufactory near Essen was established in the year 1810. It was conducted by Alfred Krupp from the year 1826, and was taken by him on his own account in 1848. The works have been very gradually but steadily developed. In January, 1873, the works covered an area of more than 4,784,000 square yards, of which about 900,000 square yards were roofed over. More than 12,000 workmen are employed, independently of about 2,000 who are supplied by contractors.

In the mines and smelting-works belonging to the firm there are employed about 5,000 workmen. The total number is about 17,000 men in all departments. The number of officers and salaried employés is 739.

The quantity of cast steel produced in the year 1872 exceeded 125,000 tons.

There are in operation 250 smelting-furnaces, 390 annealing-furnaces, 161 heating-furnaces, 115 welding and puddling furnaces, 14 cupola and reverberatory furnaces, 160 furnaces of other kinds, 275 coke-ovens, 264 smiths' forges, 240 steam-boilers, and 70 more in course of construction.

The total number of steam-hammers was 71, viz: 2 of 2 cwt. each, 1 of 3 cwt., 2 of 4 cwt. each, 1 of 7 cwt, 5 of 8 cwt. each, 3 of 10 cwt. each, 1 of 12 cwt., 7 of 15 cwt. each, 8 of 20 cwt. each, 18 of 30 cwt. each, 2 of 60 cwt. each, 1 of 65 cwt., 6 of 70 cwt. each, 2 of 75 cwt. each, 3 of 100 cwt. each, 4 of 110 cwt. each, 1 of 140 cwt., 1 of 150 cwt., 1 of 200 cwt. 1 of 400 cwt., 1 of 1,000 cwt.

Of steam-engines there were 286, viz: 3 of 2 horse-power each, 57 of 4 horse-power each, 46 of 6 horse-power each, 16 of 8 horse-power each, 17 of 10 horse-power each, 6 of 12 horse-power each, 1 of 13 horse-power, 4 of 14 horse-power each, 38 of 16 horse-power each, 4 of 18 horse-power each, 21 of 20 horse-power each, 16 of 23 horse-power each, 3 of 25 horse-power each, 22 of 30 horse-power each, 5 of 35 horse-power each, 2 of 40 horse-power each, 4 of 45 horse-power each, 4 of 60 horse-

Digitized by Google

FIGS. 214 and 215.—Krupp's Cast-Steel Works, Essen, Prussia.

Digitized by Google

power each, 2 of 80 horse-power each, 3 of 100 horse-power each, 1 of 120 horse-power, 5 of 150 horse-power each, 1 of 200 horse-power, 1 of 500 horse-power, 3 of 800 horse-power each, 1 of 1,000 horse-power, representing, altogether, nearly 10,000 horse-power.

Of machine-tools there were 1,056, viz: 362 turning-lathes, 82 shaping-machines, 195 boring-machines, 107 planing-machines, 42 punching and grooving machines, 32 presses, 63 grinding-machines, 31 burnishing and polishing machines, 142 other machines of different kinds.

In the year 1872 there were consumed 500,000 tons of coal, 125,000 tons of coke, 113,000,000 cubic feet of water, which was supplied from several water-works, 155,000,000 cubic feet of gas, supplied from the gas-works of the establishment to 16,500 burners. The works are connected with the "Cologne-Minden," "Bergisch-Märkesch," and the "Rhenish" lines of railroad.

To facilitate the traffic about the works there are:

(*a*) About twenty-four miles of railroad, with 180 sidings and 39 turn-tables, on which run 12 tank-locomotives, each of about 16 inches diameter of cylinder, and 530 cars. Six more locomotives are in course of construction.

(*b*) About ten miles of railway of 30 inches gauge, with 147 sidings and 65 turn-tables. The traffic on these railways is carried on by means of horses, and by 3 locomotives of 6 inches diameter of cylinder, and 270 cars. Four other locomotives are in course of construction.

The carriage department comprises 272 cars and 191 horses, of which 60 or 80 are supplied by contractors.

To facilitate communication between the several workshops, there are 30 telegraph-stations.

A permanent fire-brigade, consisting of 70 men, has been instituted, who perform at the same time police-duty. There are also 166 watchmen.

The general supply-stores, under control of the firm, supply to voluntary purchasers, *i. e.* to those belonging to the works, for cash, provisions, clothing, drapery, boots, &c., at cost-price. The receipts at the different stores amount to about £11,000 ($65,000) monthly, and are continually increasing.

Under this head are also to be enumerated: 1 hotel, 3 beer-houses, 1 seltzer-water manufactory, 1 flour-mill, and 1 bakery, with 2 steam-engines, producing at an average 85 tons of bread monthly.

Of the dwellings for the officers and workmen, there are for the former 206, for the latter 2,948, either occupied or in course of construction. There are now living in these houses, the number of which is being rapidly increased, more than 8,000 individuals. The existing boarding-houses offer board and lodging to 2,500 unmarried workmen, and other houses of the same description are now in course of construction for the accommodation of 1,600 more.

The arrangements for the accommodation of the sick consist of one hos-

Digitized by Google

pital containing 100 beds, and one epidemic-hospital with 120 beds, all under the supervision of physicians especially engaged for the purpose.

A sick, burial, and pension fund has been instituted for all those who receive wages. The firm contributes to this fund half the amount of the contributions paid in by workmen, and is also at the expense of providing pensions and support for those who have been rendered unfit for work in their service, and for the widows of workmen. The total receipts in the year 1872 amounted to £16,000, ($80,000,) the expenditure to £12,500, ($62,500,) and the capital in hand at the beginning of the year 1873 to £19,348, ($96,740.)

From another fund, members receive for their families free medical treatment on an annual payment of 3 shillings, (25 cents.)

The firm has a chemical laboratory, a photographic, a lithographic, and a printing and book-binding establishment. In the printing-office there are two steam and four hand presses in operation.

361. Besides the cast-steel works, near Essen, Friedrich Krupp possesses large mining and smelting establishments, which render the works independent of fluctuations in prices, and secure a regular and uniform supply of the best raw material. This comprises:

1. The administration of the Krupp mines:

(*a*) Coal-pits:

(1.) Pit "Graf Buest;"

(2.) Pit "Ernestine;"

(3.) Pit "Friedrich Ernestine;"

(4.) Pit "Hannover;"

and one-third of the "Humboldt and Diergardt concessions," on the left bank of the Rhine.

(*b*) The iron-ore mines:

(1.) In the mining-districts "Kirchen," "Daaden," "Siegburg," "Hamm," and "Neuwied," 64 mines, (Nos. 1 to 64.)

(2.) In the mining-districts "Wetzlar," "Weilburg," "Dietz," "Oberhessen," "Rheinhessen," and "Dillenburg," 294 mines, (Nos. 65 to 358.)

(3.) In the mining-districts "Hamm on the Sieg," "Wied," "Unkel," "Coblenz," and "Runderoth," 56 mines, (Nos. 359 to 414.)

Total number of mines 414, underlying an area of more than 239,200,000 square yards.

The firm possesses important grants of excellent iron-ore beds in North Spain, whence it is intended to import annually 300,000 tons of ore for the production of cast steel. To facilitate importation, a railway in Spain, nearly eight miles long, and several steamers are already in course of construction.

2. The Administration of Krupp's Smelting-Works controls:

(*a*) The Sayner and Oberhammer Smelting-Works, containing two blast-furnaces, one of them using charcoal as fuel. Together they produce daily about 20 tons of "spiegeleisen" and "char-

Digitized by Google

coal spiegeleisen." An iron-foundry and a machine-manufactory are connected with the "Sayner" Works.

(*b*) The Mulhofer Smelting-Works, on the Rhine, connected by a branch line with the Rhenish Railway, terminating at the Engers Station. They contain four blast-furnaces (three of them of the latest Scotch style of construction) with pneumatic lifts. Each of them produces daily about 45 tons of spiegel, bessemer, and refined iron.

(*c*.) The Hermann's Smelting-Works, on the Rhine near Neuwied, also connected by a branch-line with the Rhenish Railway, has at present only one blast-furnace in operation; two others are, however, in course of construction.

(*d*.) The Bendorf Smelting-Works, with one blast-furnace of an older style, are not in operation.

(*e*.) The Johannes Smelting-Works, formerly the property of the German-Dutch Joint Stock Company for Smelting and Mining, near Duisburg, on the Rhine, produce daily, in four blast-furnaces, from 140 to 160 tons. The construction of six more furnaces has been commenced, and these works are connected with the Railway "Rhenish" and the "Bergisch-Markisch."

These works have also 140 coke-ovens in operation, and 120 more in course of construction.

Krupp's Smelting-Works produce, from 11 blast furnaces, nearly 10,000 tons of pig-iron per month.

362. An idea of the character of the work which is done at Essen is best shown by the following classified and condensed, but still quite complete, description of the objects exhibited at Vienna:

(1.) A crucible cast-steel block, (1,800 crucibles were used, each containing about 60 pounds,) 54 inches diameter of octagonal section, weighing 52,500 kilograms, (52½ tons.)

This casting, originally cylindrical, was reduced to the octagonal form by forging under a 50-ton hammer, to illustrate the malleability of the material. Cuts were made in four different places, while red-hot, to show, when broken off afterward, the density and soundness of the cast-steel. This block, of gun-metal quality, was intended for the body of a gun of 37 centimeters (14 inches) caliber, and was to be given the required form by additional forging.

All articles produced in the establishment, with exception of disk-wheels and frogs, which are cast in molds, are forged and wrought from similar castings of circular cross-section.

(2.) A straight locomotive-axle of crucible cast-steel in the forged state, (pattern of the Northeastern Railway of Switzerland.)

(3.) A forged tender-axle of crucible cast steel, (pattern of the same railway.) The body of this axle was forged complete under the hammer, and required no further working.

(4.) Six carriage-axles of crucible cast steel, forged to the dimensions agreed upon by the German railways.

Digitized by Google

Production in 1872 of unmounted axles, in the forged and finished state, 16,450.

The first extensive trials with Krupp's cast-steel axles were made in the year 1850, at Borsig's Works, Berlin, by a commission appointed at a meeting of German railway engineers, (pamphlet by Landbaumeister Dihm, Berlin, 1850, printed by J. Petsch.) Although the trials were very favorable, Krupp's cast-steel axles were not generally adopted until the years 1861 and 1862. The production increased rapidly, however, so that the firm supplied in 1865 more than 11,000, while the supply during 1872 exceeded 16,000 axles.

(5.) Two unwelded rings of crucible cast steel, forged from solid blocks by punching a hole in the middle and then driving them out under a hammer.

Railway-tires are given the required dimensions and sections by rolling such rings.

(6.) Two samples of tires, rolled and complete ready for turning; also, one tire ready-turned. Production of 1872, more than 45,000 tires.

Up to the year 1853, only forged-iron and homogeneous-iron tires were manufactured. Krupp's establishment is claimed to have been the first to introduce the unwelded cast-steel tires for use on railroads, and to have caused them to be generally adopted. Since the expiration of their patent of 1853, this method of manufacture has, in principle, been imitated by all works manufacturing cast-steel tires.

(7.) Two unwelded angle-rings of crucible cast steel for steam-boilers, made in the same manner as the tires.

(8.) Two coupling-rods and two connecting-rods forged from crucible cast steel. Pieces of machinery of this description are supplied by the works in the forged state only.

(9.) Four piston-rods forged from crucible cast steel, (pattern of the Central Railway in Switzerland.)

(10.) Two slide-bars of crucible cast steel, in the forged state.

(11.) Two pistons, forged from crucible cast steel, (pattern of the Niederschlesisch-Märkisch Railway.)

(12.) Two locomotive crank-axles of crucible cast steel, one with single and one with double bearings. Both axles are in the finished state. Those crank-axles which were supplied to the French-Orleans Railway during 1857, 1853, and 1859, had, up to 1873, run over 500,000 kilometers, (312,000 miles,) and were still in good working order.

(13.) A locomotive eccentric crank, and one driving-wheel crank, both of crucible cast steel, in the finished state. These pieces are supplied by the works in a rough, or turned, or in a finished state.

(14.) A set of locomotive and tender axles, (pattern for engines CIV of the Northeastern Railway in Switzerland,) consisting of—

(*a*) One driving-axle of crucible cast steel, fitted with tires, cranks of same material, spoke-wheels of wrought iron, and cast-iron counterweights. Weight, 2,160 kilograms, (about 43 cwt., or two tons.)

Digitized by Google

(*b*) Two coupling-axles of crucible cast-steel, fitted with tires and crank-pins of the same material, spoke-wheels of wrought iron, and cast-iron counterweights. Weight of each, 1,900 kilograms, (about 38 cwt.)

(*c*) Two tender-axles of crucible cast steel, body forged, fitted with tires of same material, and spoke-wheels of wrought iron. Weight of each, 1,200 kilograms, (about 24 cwt.)

Production in 1872 of complete sets of locomotive and tender axles, 475.

(15.) Two carriage-axles of crucible cast steel, body forged, fitted with tires of same material, and spoke-wheels of wrought iron. Weight of each, 950 kilograms, (about 19 cwt.) Axles and tires of the dimensions approved by the German railways.

Production in 1872, 4,650 sets.

(16.) Two carriage-axles of crucible cast steel, fitted with disk-wheels, cast in molds of same material. Weight of each, 1,000 kilograms, (about 20 cwt.)

Production in 1872, 4,340 sets.

(17.) A collection of spring-steel fractures, and cross-sections of spring-steel. This steel is supplied in bars of any section, not less than 10 millimeters thick and 65 millimeters wide.

Production in 1872, 3,000,000 kilograms, (about 3,000 tons.)

See fractures and cross-section under No. 26.

(18.) A collection of cast-steel springs for locomotives, tenders, and carriages.

(*a*) Two locomotive-springs, with 10 flat leaves, welded links, and bored bolt-holes; two with 14 flat leaves and welded, bored, and reamed bolt-holes.

(*b*) Several car-springs, with flat leaves and rolled eyes.

Production in 1872, 38,600 springs.

(19.) A reversible double crossing, or frog, of crucible cast-steel, cast in a mold, and ready to be laid down. (Pattern of the "Cologne-Minden" Railway.) These "frogs" have been introduced on many German and transatlantic railways.

(20.) Bessemer steel-rails. The manufacture of these rails was illustrated by a Bessemer casting, from which octagonal blocks were forged, as shown by exhibited samples. These blocks are given, by rolling, the required form for rails, are cut off according to weight, and rolled to the prescribed section. Two rails rolled in this manner, the ends of which were not cut off, were exhibited. Several rails were ready cut and punched according to the "Cologne-Minden," Section V.

The annual production of steel rails increased from 100 tons, in the first year, to 50,000 tons in 1872. This increase is, no doubt, one of the best proofs of the favorable results obtained from the use of steel rails on railroads, and these rails are now very largely introduced.

Besides the manufacture of steel rails for ordinary railroads, the man-

Digitized by Google

ufacture of smaller sections, from 11 to 22 pounds per yard, for mining-purposes, has also considerably increased.

Production in 1872, 2,000 tons.

A collection of rail-fractures of different kinds was also shown.

(21.) Two switches of Bessemer steel, (section of the "Oberschlesisch and Niederschlesisch-Märkisch" Railroad,) planed as supplied by the works in the finished state.

(22.) A double crank-shaft, of crucible cast steel, forged from a solid block, and finished for a transatlantic steamer—weight, 9,000 kilograms; length, 7,650 meters; diameter, 0.38 meters.

(23.) A trunnion-hoop, unwelded, of crucible cast steel, in the forged state.

(24.) Two pressed sides for field-gun carriages, of cast steel, 6 millimeters and 10 millimeters thick.

(25.) Rolling-mill machinery. The rolls exhibited illustrate the most usual forms and dimensions used in this, which is one of their oldest branches of manufacturing.

(26.) A collection of fractures of hardened tool-steel, as well as various other fractures of manufactured articles, such as axles, tires, and frogs, and disk-wheels, and mint-dies with polished surface.

(27.) A series of exhibits of various classes of ore, pig-iron, and pig "steel-iron," from the mines and smelting-works of the firm, used in the manufacture of steel.

363. The ORDNANCE made by Krupp is all manufactured from crucible cast steel of a quality especially adapted to this purpose.

All these guns are breech-loading, and have Krupp's breech-piece.

The naval and coast gun carriages are generally manufactured from wrought-iron; only special parts, such as the axles, cylinders, and piston-rods of the hydraulic buffer and the slide-rollers of the coast-gun carriages being made of cast steel. Cast iron is only used for small truck-wheels. There were exhibited—

(28.) A 30½-cm. (30½ centimeters diameter) gun on coast-carriage.

Caliber 305 millimeters, (12 inches.)

Length of gun, 6.7 meters.

Length of bore, 5.77 meters.

Weight of gun with wedge, 36,600 kilograms,* (80,500 pounds.)

The gun has 72 parallel grooves, with 4.5 millimeters width of lands, and a uniform twist of 21.79 meters in pitch.

Weight of charged steel shell, 296 kilograms.

Weight of charge, (prism-powder,) 60 kilograms.

Initial velocity, 465 meters.

Weight of charged common shell, 257 kilograms.

Weight of charge, (prism-powder) 50 kilograms.

Initial velocity, 460 meters.

* The kilogram = 2.2 pounds; the meter = 3.28 feet, = 39.33 inches; the centimeter = 0.0328 foot, = .3928 inch; the millimeter = 0.00328 foot, = 0.03928 inch.

Digitized by Google

The carriage is intended for earth parapets of 1.9 meters height, and has a height of 2.380 meters. To check the recoil, a hydraulic buffer is used.

The projectile is lifted by means of a movable crane with windlass, which is arranged on the right-hand side of the slide.

The elevation (+17°—7°) is taken by means of a toothed arc on the upper part of the carriage. For training, the end of the slide is provided with a chain-gear.

By this apparatus the gun can be very easily and quickly handled.

To run in the gun, a rope windlass may be placed, if necessary, on each side of the slide at the rear.

	Kilograms.
Weight of carriage	5,650
Weight of slide	15,350
Total weight	21,000

This gun, and all of those exhibited, in fact, was a magnificent mass of metal, beautifully finished, conveniently arranged, and in every respect a splendid piece of work.

(29.) A 28-centimeter howitzer on coast-carriage. The gun is constructed to be placed in coast-batteries.

Caliber, 280 millimeters.

Length of gun, 3.200 meters.

Length of bore, 2.520 meters.

Weight, with wedge, 10,000 kilograms.

Preponderance, 0.

This gun has 72 parallel grooves, with 4.5 millimeters width of lands, and a uniform twist of 11.2 meters.

Weight of charged common shell, 199 kilograms.

Maximum weight of charge, 20 kilograms.

The carriage of the gun admits of an elevation of 75°.

The carriage differs from the coast-gun carriages principally in that the whole of the under face of the slide lies in the platform on firing, so as to extend the impact of recoil over a larger surface. For training, the slide is placed upon rollers, for which reason the rear slide-trucks are put on eccentric axles.

The projectile-crane, training-gear, hydraulic buffer, and self-acting running-out apparatus are the same as in the other coast-gun carriages. The elevating-gear is also similarly constructed.

Weight of the whole carriage, 9,220 kilograms.

Height, 1.675 meters.

(30.) A short 26-centimeter ship-gun on battery-carriage.

Caliber, 260 millimeters.

Length, 5.2 meters.

Length of bore, 4.420 meters.

Weight of gun, with wedge, 18,000 kilograms.

Preponderance, 0.

Digitized by Google

This gun has 64 parallel grooves, with 4.25 millimeters width of lands, and a uniform twist of 18.2 meters.

Weight of charged steel shell, 184 kilograms.

Weight of charge, (prism-powder,) 37.5 kilograms.

Initial velocity, 450 meters.

Weight of charged common shell, 159 kilograms.

Weight of charge, (prism-powder,) 30 kilograms.

This gun has a carriage for use in a broadside-battery of iron-clads. The carriage differs from former ship-carriages for similar purposes principally in that the hydraulic buffer and apparatus for self-acting running out are similar to those of coast-gun carriages. The hydraulic buffer is so arranged that the gun, with the upper part of the carriage, can be held on any part of the slide.

The training is effected by a toothed wheel, which works into a toothed racer in the deck, and is moved by a worm-wheel so as to dispense with brakes to retain the gun in the required direction. For elevation, there is arranged on both sides of the gun a toothed elevating-arc; both are, however, moved simultaneously from the left side of the carriage by a hand-wheel. In order to relieve the ship's side in firing, the recoil is partially received by ribs on the upper face of the deck-racers and by a strong hook which ties down the fore part of the slide.

Total weight of carriage is 8,756 kilograms.

Height, 1.220 meters.

(31.) A long 24-centimeter gun on battery-carriage for casemate ships.

Caliber, 235.4 millimeters.

Length of gun, 5.23 meters.

Length of bore, 4.54 meters.

Weight of gun, 15.500 kilograms.

Preponderance, 0.

This gun has 32 grooves, with a width of lands of 3.9 millimeters at breech and 7.85 millimeters at the muzzle. The twist is uniform, and of 16.48 meters pitch.

Weight of charged steel shell, 135 kilograms.

Weight of charge, (prism-powder,) 24 kilograms.

Initial velocity, 430 meters (2,296 feet) per second.

Weight of charged common shell, 118.5 kilograms.

Weight of charge, 20 kilograms.

Initial velocity, 424 meters per second.

The gun is mounted on a battery-carriage for casemate ships. Being situated in one of the obtuse angles of the casemate, so as to be capable of firing through a broadside and a bow or stern port, it was necessary to make arrangements for a change from the one to another port. This is done by means of a turn-table, on which the gun rests supported by the middle slides and the rear slide-rollers, after the fore slide-rollers have been lifted by an hydraulic lifting-jack which is fixed under the slide for this purpose. To facilitate the unshackling of the pivot-bar

Digitized by Google

when changing ports, it is divided, and at the joint an easily-removable bolt is put in.

To check the recoil, the carriage is provided with an adjustable plate-compressor. A running-in-and-out gear, of chain, is applied on both sides of the slide-end. For training, the pinion of the cog-racer is moved by the same cranks which are used for this chain-gear.

The elevation is taken by means of a cogged elevating-arc.

	Kilograms.
Weight of carriage	2, 344
Weight of slide	5, 466
Total weight	7, 810

Height, 1,195 meters.

(32.) A long 21-centimeter gun on coast-carriage.

Caliber, 209.3 millimeters.

Length of gun, 4.708 meters.

Length of bore, 4.106 meters.

Weight of gun, 10,000 kilograms.

Preponderance, 0.

This gun has 30 grooves, with 3.4 millimeters width of lands at breech and of 7.3 millimeters at the muzzle. The twist is uniform and of 14.23 meters pitch.

Weight of charged steel shell, 95 kilograms.

Weight of charge, (prism-powder,) 17 kilograms.

Initial velocity, 430 meters per second.

Weight of charged common shell, 79 kilograms.

Weight of charge, 14 kilograms.

Initial velocity, 430 meters per second.

The gun is mounted on a coast-carriage of a description similar to that of the 30½-centimeter gun. Height, 2.015 meters.

	Kilograms.
Weight of carriage	2,090
Weight of slide	5,110
Total weight	7,200

(33.) A 21-centimeter siege-gun, with slide-carriage.

Caliber, 209.3 millimeters.

Length of gun, 3.400 meters.

Length of bore, 2.910 meters.

Weight of gun, with wedge, 3,900 kilograms.

Preponderance, 0.

The gun has 30 grooves, with 3.7 millimeters width of lands at the breech and of 7.5 millimeters width at the muzzle. The pitch of rifling is 12.36 meters.

Weight of charged common shell, 79 kilograms.

Weight of charge, (prism-powder,) 6.5 kilograms.

Initial velocity, 300 meters per second.

Digitized by Google

The carriage for this gun is a short slide-carriage, in all essential points similar to the coast-carriages. The slide, when in battery, rests in front on the pivot-block, behind on two rollers which can be moved, for the purpose of training, by means of handspikes. The elevating-arc admits of 27° elevation and 6° inclination. The crane, hydraulic buffer, &c., are similar to those of the coast-carriages. This gun is properly arranged for transport. For this purpose, a strong axle, with large wheels, is placed in the axle-supports, after the gun and carriage have been run in on the slide; then the forward end of the slide is raised by means of a lifting-apparatus which is permanently fixed on the slide. This consists of a screw, with worm-wheel gearing. Finally the rear end of the platform is limbered up. The rear wheels have a diameter of 2.046 meters and a breadth of 0.180 meter in the rim. The distribution of the weight resting on hind and fore wheels is in the proportion of 4 to 1. To lighten the transport-wagon, the slide-rollers may be carried separately. For transport by rail, the limbered-up carriage can be easily placed on a 10-ton freight-car. The bed, made of oak beams, and provided with pivot-block and racer, can be carried on an ordinary freight-car. As soon as the gun has been carried to its proper place over the bed in the battery, it is unlimbered and the rear slide-rollers are then lowered down on the racer by means of a windlass. The slide is afterward let down in front upon the pivot-block and the transport axle and wheels are removed.

Height of battery, 1.9 meters.

	Kilograms.
Weight of carriage	922
Weight of slide	1,728
Total weight	2,650

The limbered-up gun has a total weight of 8,160 kilograms.

The bed complete weighs 2,080 kilograms.

(34.) A long 17-centimeter gun, on upper-deck carriage.

Caliber, 172.6 millimeters.

Length of gun, 4.250 meters.

Length of bore, 3.780 meters.

Weight of gun, with wedge, 5,600 kilograms.

Preponderance, 0.

The gun has 48 parallel grooves, with 3.5 millimeters width of lands, and a uniform twist of 11.2 meters.

Weight of charged steel shell, 55 kilograms.

Weight of charge, (prism-powder,) 10 kilograms.

Initial velocity, 460 meters per second.

Weight of charged common shell, 45 kilograms.

Weight of charge, (prism-powder,) 10 kilograms.

Initial velocity, 465 meters per second.

The upper-deck carriage for this gun is to be placed in the bow or stern of an iron-clad, and so arranged as to be moved easily and quickly

Digitized by Google

into a rear position. To check the recoil, a plate compressor is used. For training, the slide, which usually rests on the supports, is placed on the rollers, for which purpose the rear slide-rollers are mounted eccentrically.

Height, 1.020 meters.

	Kilograms.
Weight of carriage	1,255
Weight of slide	2,235
Total weight	3,490

(35.) A 15-centimeter siege-gun on wheel-carriage.

Caliber, 149.1 millimeters.

Length of gun, 3.44 meters.

Length of bore, 3.040 meters.

Weight of gun, with wedge, 3,000 kilograms.

Preponderance 1 meter from the trunnion, 25 kilograms.

This gun has 36 grooves, with 3 millimeters width of lands at the breech and 5.5 millimeters at the muzzle.

The pitch of the twist of the rifling is 9.7 meters.

Weight of charge, common shell, 28 kilograms.

Weight of charge, (prism-powder,) 6 kilograms.

Initial velocity, 470 meters.

The carriage of this gun is constructed as a wheel-carriage. The brackets are made of plates and angle-iron. The elevating-screw admits of 35° elevation and of 5° inclination. The hydraulic buffer is a peculiarity in this carriage. At the discharge this reduces the recoil to 1 meter or less. The buffer-cylinder can be moved vertically, being fastened to the brackets at one-third of their length from behind. The piston-rod can be moved vertically and horizontally by means of a pivot-bolt connected with an anchor which is partly imbedded in the parapet. Height, 1.830 meters; weight of carriage, 1,845 kilograms.

(36.) A long 15-centimeter gun on ship carriage.

Caliber, 149.1 millimeters.

Length of gun, 3.85 meters.

Length of bore, 3.43 meters.

Weight of gun, 4,000 kilograms.

Preponderance at the commencement of the rounding of the wedge, 75 kilograms.

The gun has 48 parallel grooves, with 3 millimeters width of lands and 9.7 meters pitch of rifling.

Weight of charged steel shell, 35 kilograms.

Weight of charge, (prism-powder,) 8 kilograms.

Initial velocity, 460 meters per second.

Weight of charged common shell, 28 kilograms.

Weight of charge, 6.5 kilograms.

Initial velocity, 465 meters per second.

The carriage of this gun is made for broadside use. It is a slide-car

Digitized by Google

riage. To check the recoil a plate-compressor is used, and a breeching is attached as reserve. The elevation is effected by a toothed elevating-arc, and the training by means of tackles, for which side-eyes are provided on the rear end of the slide. The slide usually rests upon supports on the racers; for training, it is lifted upon the rollers.

Height, 0.960 meter.

	Kilograms.
Weight of carriage	1,505
Weight of slide	935
Total weight	2,440

(37.) A 12-centimeter gun on ship-carriage.

Caliber, 120.3 millimeters.

Length of gun, 2.925 meters.

Length of bore, 2.602 meters.

Weight of gun, with wedge, 1,400 kilograms.

Preponderance, 100 kilograms.

The gun has 18 grooves, their breadth increasing toward the breech, with 2.5 millimeters width of lands at the breech and 6.5 millimeters at the muzzle. The pitch of twist is 842 meters.

Weight of charged steel shell, 15.5 kilograms.

Weight of charge, (large-grained powder,) 3.5 kilograms.

Initial velocity, 450 meters per second.

Weight of charged common shell, 15.5 kilograms.

Weight of charge, (large-grained powder,) 3 kilograms.

Initial velocity, 450 meters per second.

The carriage for this gun is a wheel-carriage, constructed for the main or upper deck of small vessels. To check the recoil, a hydraulic buffer-cylinder, movable vertically and horizontally, hangs on the pivot-bolts. The piston-rod is fastened to the carriage. A strong breeching is provided as a reserve. The carriage rests usually on four rollers. For training, the rear rollers, which are mounted eccentrically, are lifted, and the weight is thus transferred to a training-roller.

The elevation is taken by means of a toothed elevating-arc, which admits of a motion of 15° and 10° in elevation and depression, respectively.

Height, 0.900 meters.

Weight of carriage, 895 kilograms.

(38.) A 9-centimeter field-gun, with carriage.

Caliber, 91.5 millimeters.

Length of gun, 2.040 meters.

Length of bore, 1.819 meters.

Weight of gun, with wedge, 425 kilograms.

Preponderance, 50 kilograms.

The gun has 16 grooves, with 2.5 millimeters width of lands at the breech and 6.5 millimeters at the muzzle. The rifling has 4.53 meters pitch.

Digitized by Google

Weight of charged shell, 6.9 kilograms.

Weight of charge, (cannon-powder,) 0.6 kilograms.

Initial velocity, 322 meters per second.

The gun-carriage has riveted wrought-iron brackets. Weight of carriage, (without accessories,) 546 kilograms. The elevating-screw admits of an elevation of 15° and of a depression of 8°.

(39.) An 8-centimeter field-gun, with carriage.

Caliber, 78.5 millimeters.

Length of gun, 1.935 meters.

Length of bore, 1.728 meters.

Weight of gun, 295 kilograms.

Preponderance, 70 kilograms.

This gun has 12 grooves, with 2.5 millimeters width of lands at breech and 6.5 millimeters at the muzzle. The rifling has 3.62 meters pitch.

Weight of charged shell, 4.3 kilograms.

Weight of charge, (cannon-powder,) 0.5 kilogram.

Initial velocity, 357 meters per second.

Weight of carriage, (without accessories,) 460 kilograms. The elevating-screw admits of $13\frac{5}{6}^{\circ}$ elevation and 8° inclination.

(46.) A 6-centimeter mountain-gun, on carriage.

Caliber, 60 millimeters.

Length of gun, 1.250 meters.

Length of bore, 1.130 meters.

Weight of gun, with wedge, 107 kilograms.

Preponderance, 14 kilograms.

This gun has 18 parallel grooves, with 3 millimeters width of lands and 2.10 meters of pitch of rifling.

Weight of charged shell, 2.3 kilograms.

Weight of charge, 0.2 kilogram.

Initial velocity, 300 meters per second.

The carriage has wrought-iron brackets, cast-steel axles, and wooden wheels. On the naves of the axles there are conical friction-brakes.

Weight of carriage, 109 kilograms; height, 0.660 meter.

The elevating-screw admits of 21° elevation and of 10° depression.

(41.) Ammunition:

- (*a*) Shells, forged of crucible cast steel, for each of the exhibited guns, both whole and cut to exhibit the cross-section.
- (*b*) Common cast-iron shells for all exhibited guns, some cut to show cross-sections, and all with complete percussion-fuses.
- (*c*) Models of cartridges and of prismatic powder.

The specific gravity of the prismatic powder is, for the 26-centimeter, 28-centimeter, and 30½-centimeter guns, from 1.72 to 1.76; for those of smaller calibers, it ranges from 1.62 to 1.66.

364. The variety as well as the magnitude of the work done at Essen is well shown by the preceding description.

It should be remarked that the general construction of these guns

Digitized by Google

is similar to that of the British Woolwich gun, except that the Prussian gun is breech-loading.

The description just given of this remarkable class of productions of the Krupp establishment is particularly valuable as exhibiting the peculiarities of a practice in the construction of artillery which is very largely introduced in Europe, especially in Prussia and the other German states and in Russia, and which is competing with those other characteristic forms adopted in Great Britain and in the United States.

The compressing-apparatus and friction-gear are in many instances similar to those introduced by Capt. John Ericsson, and used on nearly all the heavy ordnance of the United States Navy and of the navy of Spain. It has also been closely imitated in the Scott gun-carriages used in the British navy.

Digitized by Google

Digitized by Google

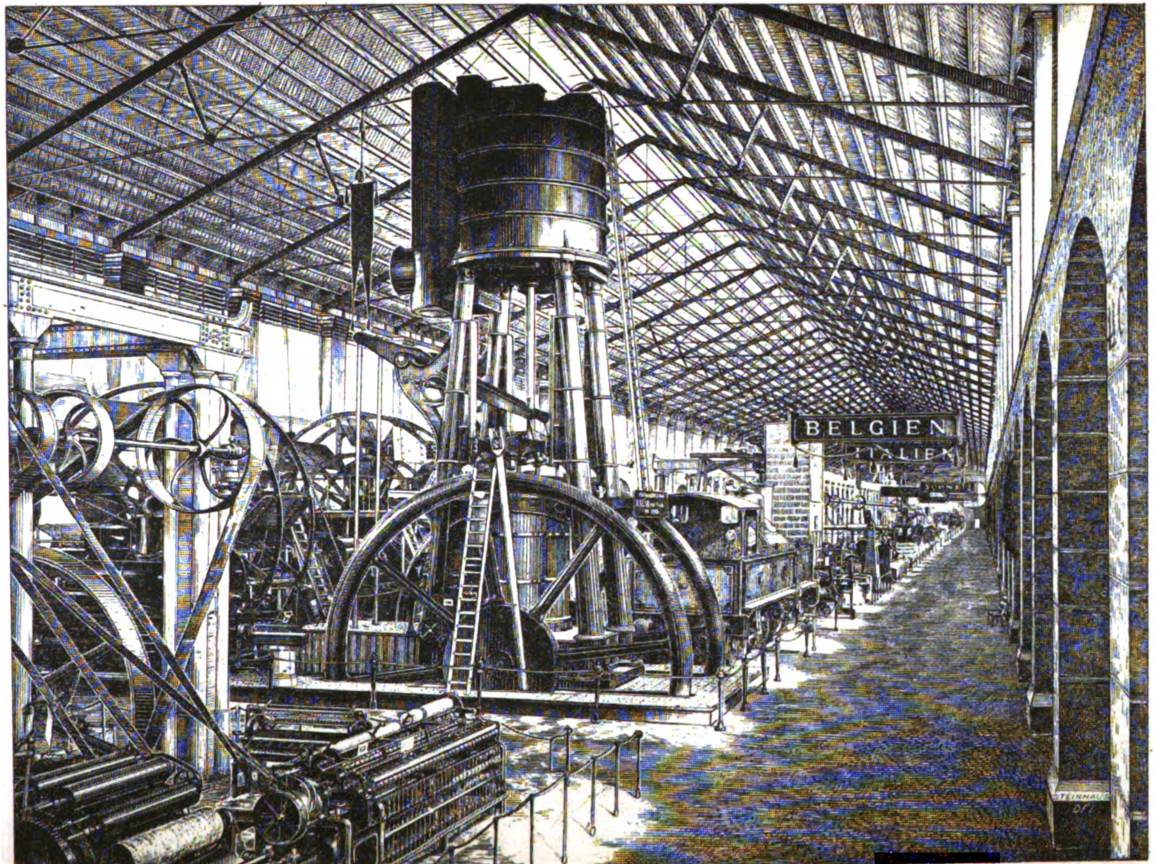


Fig. 216

Digitized by Google

CHAPTER IV.

BELGIAN AND FRENCH MANUFACTURING ESTABLISHMENTS AND TECHNICAL SCHOOLS.

BELGIUM.—THE SERAING WORKS OF THE SOCIÉTÉ COCKERILL; HISTORY OF THE COCKERILL WORKS—EXTENT—PRODUCTION; THE COCKERILL EXHIBIT AT VIENNA; BELGIAN MANUFACTURES—HISTORY—PRODUCTION; CONDITION OF WORKING-PEOPLE.

FRANCE.—PARIS; CONSERVATOIRE DES ARTS ET METIERS—ITS HISTORY; WORKS OF MM. SCHNEIDER & CO., AT LE CREUSOT—THEIR HISTORY—EXTENT OF THE WORKS AND PRODUCTION; LYONS; THE PERMANENT INDUSTRIAL EXHIBITION; CAIL & CO.'S WORKS, AT PARIS.

365. BELGIUM.—Seraing is situated near the city of Liege, a city of over 100,000 inhabitants, which has long been celebrated for the extent of its manufacturing industries, and has been frequently called the "Birmingham of Belgium." This has prospered as a manufacturing district for centuries, and at an early date the bishops of Liege were sufficiently powerful to raise a considerable force and to maintain themselves against the attacks of all enemies, whether nobles or citizens.

The town of Seraing and the great manufacturing establishment of the "*Société Cockerill*" now occupies the site of the residence and landed property of the bishops. These works are the only very extensive works of the kind in this district, and are the largest in Belgium, and, with but few exceptions, have no equals in size in the world.

The first blast-furnace erected here was put up by the English founders, the Brothers Cockerill, in 1826. The establishment now produces annually 350,000 tons of coal, from four collieries; its thirty iron-mines yield a hundred and fifty thousand tons of ore annually; there are nine blast-furnaces—four of which were at the time of our visit unfinished—and large Bessemer works and founderies. The furnaces in blast yield, as an average product, about 60,000 tons of foundery and forge iron, and those in course of erection are intended to supply dark iron to the Bessemer works. The founderies produce 5,000 tons of iron and brass castings, and the rolling-mills turn out between 40,000 and 50,000 tons of rails and large quantities of other rolled metal per year.

The ten converters in the steel-works were stated to yield 17,000 tons of steel per year; the forges can make nearly 2,000 tons of forgings, and the plate-iron-working shops 6,000 tons of bridges and steam-boilers per annum.

The establishment has a ship-building yard at Antwerp.

At Seraing the works cover two hundred acres of land, on the prop-

Digitized by Google

erty formerly belonging to the bishops of Liege; the number of workmen employed is between nine and ten thousand, who receive about $2,000,000 annually as wages. The two hundred and fifty steam-engines and the numerous furnaces consume 350,000 tons of coal per year, and sales amount to between $5,000,000 and $6,000,000.

The coal raised from the mines directly at the works is of good quality, and its excellence and the convenience and cheapness of this deposit of fuel constitute the principal element of the success of the establishment. The coal cokes well, producing a coke of considerable strength and hardness, clean, free-burning, and unusually pure.

Several Appold kilns are used in coking, which were said to do good work, and a considerable amount of coal is also still coked in the common coke-oven. This coke is not much inferior to those which have made the English Yorkshire districts so successful.

The iron made here, in the blast-furnaces above referred to, is of good quality, and answers well for the Bessemer works. The ores are obtained both from this district and from Spain and Great Britain. The castings made from this iron are smooth, of good color and grain, and are remarkably clean and strong.

All of the refractory material used in the furnaces and founderies is obtained from the immediate neighborhood. There is no necessity of importing either molding-sand or fire-clay, and bricks of fine quality are made on the spot.

The machinery and plate-iron work is well made and usually well proportioned. The material is always excellent, the design generally good, and the fitting and the finish are almost invariably such as would receive commendation from any engineer.

The low cost to the works of Bessemer steel has led to the introduction of that material very extensively into the machinery made here, taking the place not only of iron forgings, but of cast iron in many places. The new Bessemer works now in process of erection will yield a product of low steel amounting to a hundred and fifty tons of metal per day, and its use in construction will then become still more extended.*

The pay of the workmen in the foundery is 75 or 80 cents a day; of puddlers, $1 to $1.50; pattern-makers are given about the same pay as the molders; riveters in the boiler-shops receive the same; machinists are paid about 25 cents more, and foremen in the several shops are paid about $2. The length of the working-day is nominally twelve hours.

366. The following account of the Seraing establishment is based upon the statements furnished to the writer and other members of the International Jury by the proprietors:

The principal establishments of the Cockerill Company are situated at Seraing, six miles from the town of Liege, in the valley of the Meuse,

* In these works, since completed, the cast iron is run into the converter from the blast-furnace, as at Creusot.

Digitized by Google

upon the carboniferous formation which runs through that territory. They occupy the estate which was used as a summer residence by the prince-bishops of Liege until the end of the last century.

The business of the Cockerill establishments comprises coal and iron mining, the reduction of the ores, the manufacture of cast and wrought iron and steel, the construction of engines, boilers, and machines, and the construction of iron bridges and of iron vessels.

The Cockerill Company is managed by a board composed of five members and a Director-General.

These establishments form eleven special divisions, managed by chief-engineers.

The foundation of the Seraing establishment was the work of John Cockerill, who was an Englishman, born at Haslington, Lancashire, England, August 3, 1790. His father, in 1799, introduced at Liege the construction of machines for wool-spinning, and, after having acquired a large fortune, in 1813 he left his factories to his two sons, James and John.

Coal and iron mining and the smelting of charcoal pig-iron had been practiced, and workshops manufacturing articles of wrought iron had been in existence in the Liege territory for centuries. Beside those engaged in husbandry, the working-class of the country was composed of coal-miners, smelters, blacksmiths, cutlers, nail-makers, and of lock and gun smiths.

In 1817 the Cockerill Brothers bought from the government of the Netherlands the palace of Seraing, and established works for the construction of steam-engines and of machinery for spinning flax, and they afterward erected a flax-spinning mill.

In 1822 John Cockerill came to reside at Seraing, and bought the grant of coal-mines upon which the works now stand, and took proper measures to introduce on the continent the smelting of cast-iron with coke and the fabrication of iron by the English processes.

The business of the factory was then chiefly sustained by the orders of the government. In 1824 steam-engines of 300 horse-power were constructed, under John Cockerill's supervision, for the men-of-war of the country, while the English navy had engines of only 150 horse-power.

In 1826 the first coke blast-furnace, and the furnaces, hammers, and blast-engines, and the engines for the iron-works were employed. The coal-pits, furnished with powerful ventilating and hoisting machinery, were set in operation upon a scale previously unknown.

The first continental railway was decreed by the Belgian government after the revolution of 1830, and the first locomotive was constructed for that railway, in 1834, by the Seraing Works, which soon after supplied all the engines for the beginning of the Belgian net-work of railways.

The Seraing establishment continued to increase rapidly until the

Digitized by Google

demise of John Cockerill, which happened in 1840. It comprised in 1842, at the time of the formation of the joint-stock company established to continue operations:

1st. The grant of coal-mining, with three collieries furnished with all needed ventilating and hoisting engines.

2d. Thirty-seven coke-kilns of large size.

3d. Two blast-furnaces, with "steam bellows" and grants of iron-mines.

4th. A vast iron-foundery and a copper-foundery.

5th. An iron-making establishment, with 35 reverberatory furnaces, 5 sets of rolls, with hammers, steam-engines, and all tools and apparatus required in such works.

6th. An engine and boiler works, containing 144 forge-furnaces, 280 lathes and boring-machines, 200 planing, grooving, tapping, and drilling machines, &c.

There were 2,200 employés and workmen. The driving-engine was of 920 horse-power.

The Seraing establishments had been placed by John Cockerill, in 1829, under the general superintendence of Gustave Pastor, his nephew, and the latter continued in service when the company was formed and until 1866, at which time M. Pastor withdrew, and he was succeeded by M. E. Sadoine, chief engineer of the government navy.

367. The works now comprise:

Coal-mines.—Four collieries, with eight shafts for raising the coal; 24 engines of 900 collective horse-power; 2,400 workmen, (since 1867 women have not worked in the collieries of the company;) annual production of fuel 350,000,000 kilograms, (350,000 tons.)

Coke-furnaces.—Four groups comprising 143 horizontal kilns; 12 groups comprising 216 Appold kilns; 3 crushers and 6 washers; 6 steam-engines, of 168 collective horse-power; 140 workmen. Annual production of coke, 140,000,000 kilograms, (140,000 tons.)

Iron-mines.—Thirty mines, in the Belgian provinces of Liege and Namur, in Luxemburg, and in Spain; 17 engines, 306 horse-power collectively; 800 workmen. Annual production of the mines, 150,000,000 kilograms, (150,000 tons.)

Blast-furnaces.—Five blast-furnaces, with hot-blast apparatus and casting-houses for ordinary casting, yielding 55,000,000 kilograms, (55,000 tons;) 4 blast-furnaces for Bessemer steel pig now building; 15 engines, of 480 collective horse-power; 300 workmen.

Founderies.—Two iron and one copper founderies; 2 workshops for molding; steam-cranes; 1,000,000 kilograms foundery-flasks; 6 engines, of 90 collective horse-power; 280 workmen. Annual production, 5,000,000 kilograms, (5,000 tons.)

Iron-works.—Seventy-five reverberatory furnaces; 12 sets of rolls; 7 hammers; 55 engines, of 1,900 collective horse-power; 1,240 workmen. Annual production in rails, girders, bar and sheet iron, 40,000,000 kilograms, (40,000 tons.)

Digitized by Google

Steel-works.—Ten Bessemer converters, of from 5 to 7 tons capacity, 6 of which are just erected; 16 reverberatory furnaces; 7 hammers; 4 sets of rolls; 46 engines, of 3,079 collective horse-power; 560 workmen. Annual production in steel, 17,000,000 kilograms, (17,000 tons.)

Forges.—Twelve reverberatory furnaces; 7 hammers; 70 forge-furnaces; 5 engines, of 283 collective horse-power; 200 workmen. Annual production of machinery, 1,500,000 kilograms, (1,500 tons.)

Engine-shops.—Three hundred and sixty-eight lathes, slotters, planers, drills, &c.; 5 machines to forge bolts and nuts; 2 hydraulic presses; traveling cranes, stationary steam-cranes, and others; 20 engines; 1 hammer; 1,400 workmen. Annual production of machines and mechanical apparatus, 7,000,000 kilograms, (7,000 tons.)

Bridge and boiler building.—Fifty-five drilling, planing, &c., machines; 3 hammers; 54 forge-furnaces; 11 engines, of 120 collective horse-power; 510 workmen. Annual production of boilers and of bridges of various kinds, 6,000,000 kilograms, (6,000 tons.)

The Antwerp ship-building yard contains a stock of tools appropriate to a ship-builder's yard, with covered ways, rafts, and boats; ways and slips for launching both sea and river steamers; carpentry and joinery shops, with steam-power; 2 engines, of 15 horse-power, and employs 680 workmen. Annual production, 2,500,000 kilograms (2,500 tons) of iron vessels.

The interior conveyance and forwarding department has in operation 15 locomotive-engines, employed on the junctions of the interior railways, with the north line; employs 420 workmen and 60 horses, 15 of which are in the collieries.

These works cover an area of 200 acres, intersected by 22 kilometers* of railroads of standard gauge, and 12 kilometers of smaller tracks. A basin communicating with the Meuse by a canal and 2 wharves belong to the establishment.

In 1872 there were 8,912 people employed in all the works.

There were 254 steam engines, of 7,834 collective horse-power.

The wages paid annually amount to 8,500,000 francs, ($1,700,000.)

The consumption of fuel amounts to 350,000,000 kilograms, (350,000 tons.)

The production of the divisions is from 25,000,000 to 30,000,090 francs, ($5,000,000 to $6,000,000.)

The establishment owns on the heights of Seraing, and in a very healthy situation, a large infirmary managed by nuns. It contains 85 beds. A special physician is attached to it, and an orphan-asylum, containing at present forty-one children of both sexes, adjoins it.

The establishment has also a dispensary, which delivers medicines gratuitously to persons attached to the works, and to their families.

In each division there is a refectory, furnishing meals to the workmen. Kitchens are added to several of these refectories; and baths are put up at the collieries for the miners.

* The kilometer is 3,280 feet, about three-fifths of a mile.

Digitized by Google

A society for relief and pensions has been instituted for the people of the works, and the establishment accords, out of its own funds, temporary relief and pensions to the workmen and employés not concerned in the society, membership in which is not compulsory.

The Seraing Works have constructed (to January 1, 1873,) 2,100 steam-engines, of from 4 up to 600 horse-power, for all known manufacturing purposes; 900 locomotive-engines; 31,540 sets of machinery and of mechanical apparatus, and various pieces of mechanism for manufactories; has done a large amount of repair-work, and has furnished manufactured material for mining, for the reduction of ores, the fabrication of metals, for buildings, sugar-works, plate-glass manufactories, paper-mills, spinning-mills, lattice and suspension bridges, turrets for iron-clads, &c.

The ship-yards at Antwerp and St. Petersburg have built 282 sea and river steamers, yachts, mail-steamships, steam-tugs, pilot-boats, light-ships, dredging-machines, transport-ships for passengers and freight, transatlantic steamers and floating-docks for iron-clads.

The Cockerill Company can supply annually 100 locomotives, 70 marine steam-engines from 4 to 1,000 horse-power, and above 1,500 sets of mechanical constructions. It erects complete works, makes special apparatus, does repairs, &c. It can build 6,000 tons of bridges and turn-tables per annum. Sea and river steamers of 5,000 tons burden, British measurement, can be built here.

It was at Liege that Cockerill, senior, established the first manufactory of cotton and woolen machinery on the continent, and at Seraing the first coke blast-furnace and the first puddling-furnace, and afterward the coke-kilns were erected and the making of iron by English methods was commenced.

The first steam-engine and the first locomotive-engine on the continent were constructed at Seraing.

Since 1824 the Cockerill establishments have constructed very powerful steam-engines for the drainage of the collieries of the Liege Valley, where they are still working.

368. At Vienna this great firm exhibited a marine engine of 220 nominal horse-power, built for the Belgian mail service between Ostend and Dover.

The steamers carrying the mail between Belgium and England are remarkable for their great and regular speed, their fine accommodations, and, above all, for their excellent sea-going qualities in bad weather. Their speed, in calm weather, reaches 17 knots (19¾ miles) an hour, and is not exceeded by that of any other channel-steamers. The time on the passage averaged for six months, between Ostend and Dover, 4 hours 4 minutes. This result, it is said, is not inferior to that of the steamers plying between Holyhead and Dublin, which latter are of 2,000 tons burden, and fitted with engines of 750 nominal horse-power.* This

* Actual horse-power not stated, but probably 3,500 to 4,000.

Digitized by Google

speed is due to the fine lines of these ships, to their great power, and to the excellent design and good construction of their engines. The latter have given at the official trials a power of nearly 1,600 horses.

The success of the first of these ships, the "Louise-Marie," which was supplied in 1866 to the Belgian government, induced the government to have seven of these steamers built, without the slightest alteration of design. Six are now running regularly. The engine intended for the seventh was that shown at the Exhibition. All of the principal forgings are of Bessemer steel, from the steel-works of the Cockerill Company.

These ships were built in the ship-yard of the company, at Antwerp; the engines were constructed in the works at Seraing.

The principal dimensions were as follows:

Length on water-line	200 feet
Breadth, extreme	20 feet.
Depth	13¼ feet.
Tonnage, (B. M.)	568 tons.
Tonnage, (net)	505 tons.
Draught	7 feet.

369. BELGIAN MANUFACTURES.—The interesting city of Liege and all the country about it is an exceedingly prosperous and industrious district. It probably is the most active manufacturing district in Continental Europe. All along the road between Liege and Brussels manufacturing villages are thickly distributed, and the whole country is one great manufactory of machinery and "Birmingham wares."

This is one of the earliest of European iron-making districts. It is now well known to have been a seat of manufactures in iron as early as at the time of the Roman occupation, nearly two thousand years ago. It is only two or three years ago that the ruins of several furnaces of the rude form then used were discovered at Lustin, with their charges of fuel and ore still in place.

In building machinery the Belgians are only second to the English, and they have even competed successfully with the latter in some instances in making pumping-machinery for British mines. The Belgian workman has hardly as much energy or tact or skill as the British, but he, nevertheless, does good work, and is persistent and steady.

Belgium has always been noted for its production of some kinds of textiles, of which the best known are the woolens of Ypres, the linens of Flanders, the cloth made at Verviers, the calicoes of Ghent, the carpets of Tourney and Brussels, and the lace of Mechlin and Brabant. The manufactures of porcelain, the Namur cutlery, and the Liege ironwares are scarcely less well known. Flanders and Antwerp almost monopolize the cotton-goods manufacture. Cotton-machinery is largely imported from England, and the higher grades of work-people are not infrequently also English. For hundreds of years these districts have also produced woolen goods, obtaining their woolen in earlier times

Digitized by Google

principally from England, Spain, and Germany, and returning the manufactured material to all the markets of Europe.

370. We were told that in 1872 Liege produced from about one hundred iron-works some 200,000 tons of pig-iron, 100,000 tons of finished iron, and that Chaleroi produced 400,000 tons of pig and 250,000 tons of worked iron. In this small country, which has an area of but eleven thousand square miles, and a population of less than six millions, there are nearly two hundred coal-mines, and the province of Hainaut alone produces over 2,000,000 tons of coal per year. Valuable zinc-mines exist between Liege and Aix-la-Chapelle, and all of the valuable building-stones are found in large quantities and of fine quality.

Flanders produces nearly $10,000,000 worth of flax per annum, and of an exceptionally fine quality. Verviers employs four thousand men in cloth-manufacture, and the cotton-manufactures of Belgium now employ a capital of £3,000,000 sterling.

371. The condition of the working-people of Belgium is not such as to make them well satisfied. They receive low wages, but the cost of living is also very low, and the difference to be observed between them and between all working-people in Europe and those of the United States is not due to small wages. The money-value of labor and of the necessaries and luxuries of life are fixed there, as in all parts of the world, by the uncontrolled laws of supply and demand. The people lack that enterprising spirit and active disposition which is so universally characteristic, not only of the American native-born citizen, but of the European imported into the United States. That wonderful abundance of all those smaller articles of comfort and luxury which is seen in the United States is entirely wanting there.

In some cases employers are taking upon themselves, to a certain extent, the care of their employés, and are endeavoring to make their condition more tolerable.

As was remarked by the writer immediately after visiting the district* in which the Messrs. D'Audrimont are engaged in such an enterprise, the employer never fails ultimately to receive a bountiful return for all capital expended in providing for the physical, the intellectual, or the moral welfare of his employés. Physical benefits conferred bring back a return in healthful energy; intellectual training gives intelligence which invariably finds application; moral advancement results in an increased sense of duty and of responsibility; and all together promote wonderfully that appreciation of the mutual obligations binding master and man which is the best of all preventives of strikes and of lock-outs and of all those unfortunate disagreements which divert the trades-unions from their legitimate work, of stimulating industry and preserving uninterrupted the prosperity of the working-man, and which bring embarrassment and distress upon all classes. The Messrs. D'Audrimont evidently understand this, and have erected at their collieries at Mich-

* See Scientific American, 1873; correspondence.

Digitized by Google

eraux, the Hotel Louise, a house of entertainment for their work-people. This house contains 200 beds. The rooms are fitted up plainly, but neatly, with all modern conveniences, and the prices charged for lodging and subsistence are as slight an advance upon cost as will secure the proprietors against absolute loss. Each man pays about a franc and a half (30 cents) per day for lodging, meals, washing, and necessary attendance. A miner, returning from work, goes to the lavatory, removes his begrimed suit of clothes, sends them down by a "dumb-waiter" to the laundry, takes his bath, receives a clean suit of his own clothes in return for those sent down, and makes his appearance ready for his meals, or for cleanly occupation during his "off watch," dressed very like a gentleman, and, with his neat suit and freshly-blacked boots, he experiences a feeling of self-respect rarely known under the ordinary *régime* of less well-administered coal-mines.

Here the maximum earnings of a miner are stated to be about 90 francs ($18) a month, one-half of which might be saved by a frugal single man.

In the cotton and woolen mills, as well as in many other branches of industry in Belgium, the work-people labor, generally, seventy-two hours per week, and no abatement of time is made for women or for children, in which classes 35 per cent. and 25 per cent., respectively, of the working-population is included. In some cases the working-hours have been reduced to ten, and that without decrease of production. The amount of work done by each hand probably averages less than with us, although the speeds of machinery are about up to our standard. Thus, cotton-looms run 125 to 180 picks per minute; woolen, 140 or 150, and sometimes at higher speed. Cotton-spindles are driven up to 6,000 revolutions on American, and to 5,000 on East Indian cotton. Wool spindles make 5,000 or 5,500, and flax-spindles 3,500 turns per minute. The number of operatives varies from seven to ten per thousand spindles, a number exceeding the figures of our own or English mills. Some of these mills contain 200,000 spindles; and the tendency is, as with us continually toward increasing the size of mills, and securing that increase of economy which is a usual consequence of enlarged production. That sound business policy which dictates the purchase of the best possible machinery is also well understood there, and the less-frequently acknowledged principle that prosperity always ultimately follows honest work and liberal dealing is, perhaps, more generally recognized than among many other manufacturing peoples.

372. **France** and Belgium are vastly more in sympathy with each other than is either with their common neighbor, Germany. The people of the north of France and the Belgians and the Dutch are much alike in their quiet, steady business ways, and of industrious habits. The former have always been celebrated for manufactures of the finer classes of textile fabrics, and for excellence in all the arts which demand exceptionally good taste and an appreciation of the beautiful.

Digitized by Google

The great silk-industry of France has been growing from the time of Francis I, and now consumes over 5,000,000 pounds of raw silk in addition to that raised in the country. About 50,000 tons of beet-root sugar are made annually; nearly 150,000,000 pounds of cotton are consumed, and in coal and iron the production and consumption are only second to Great Britain.

For many years the silk-manufacture, having its center at Lyons, and employing a large proportion of the population of St. Etienne, Tours, Avignon, and of many people in Paris. The cotton goods made at Rouen, Troyes, Lille, and the broadcloths of Abbeville, Louviers, Sedan, Amiens, and Rheims; the carpets of Aubusson and Paris; the laces and linens of Valenciennes; porcelain of Sevres and Limoges; the clock and watch making of Paris, and the great variety of fine jewelry and "fancy goods" made in the same city, have been among those acknowledged as the best in the markets of both continents.

The total number of spindles in France is stated at two and a half million in silk-mills and nearly five million in cotton-mills.

In 1872 France, with 228 blast-furnaces, produced more than a million tons of cast-iron, principally coke-iron; the amount of charcoal-iron was about 180,000 tons. A hundred and forty thousand tons of steel were made, one-third of which was made at Le Creusot.

Paris is not usually regarded as a manufacturing city, but it is the seat of a vast number of minor industries, and contains some establishments of large size, and interesting to the engineer as well as to the ordinary traveler. Several of the great technical schools of France are at Paris, and some of the auxiliary establishments of the French army and the headquarters of the several departments of government are in the city.

While in Paris we visited, among other places of interest, the Conservatoire des Arts et Métiers, the famous École Polytechnique, the École des Mines, and the École des Ponts et Chaussées.

373. The Conservatoiré des Arts et Métiérs is, to the engineer, one of the most interesting institutions of Paris. We were kindly entertained by the director, General Morin, and by the sub-director, M. Tresca, and were afforded an opportunity to examine the wonderful collection which has been gathered here from all directions, and which represents every department of industry.

The most interesting among the many specimens of early engineering was the steam-carriage of Cugnot, built in 1770, and which was probably the first locomotive-engine ever constructed. It was quite a large machine, probably weighing a ton or more. The boiler was carried behind the carriage and supplied steam to a pair of singularly-constructed engines, which turned one pair of wheels.

These engines were single-acting, and worked a ratchet which engaged with the teeth cut on the disks secured to the wheels. It was remarkably well made for so ancient a piece of work.

Digitized by Google

The original looms of Vaucanson and Jacquard are preserved here in the Salle des Filatures, and in other departments are almost equally interesting relics. The collections are well arranged and classified.

M. Tresca had a mechanical laboratory, in which are many of the larger objects belonging in the collections, but it is principally occupied with apparatus for testing the efficiency of machinery and with illustrative models driven by power.

Nothing like this collection exists in the world. In its extent and completeness it is unexampled.

374. The growth of this great school has been a gradual one, although liberally aided by a government which, although never itself stable, has been noted, through all its mutations, for the substantial aid which it has liberally accorded to its educational institutions.

Descartes, the distinguished philosopher, is claimed to have been the earliest to propose public instruction for working-people.* He proposed to built a large lecture-hall for each trade, annexing to each a cabinet containing the apparatus appropriate to that department, and to place each of these lecture-rooms in charge of a professor familiar with the subject there to be taught, who should present to the students the principles of his art in proper form, and who should be capable of answering the questions addressed him by his pupils in relation to all details of practice.

It was a century later, however, that this project of Descartes took shape, and the actual commencement of the work is attributed to the great mechanic, Vaucanson.

This distinguished man, previous to 1775, had gathered together, at *l'Hotel de Mortagne*, the first collection of machinery and apparatus which was ever devoted to public use in the manner proposed by Descartes. At his death, Vaucanson bequeathed this collection to the state, and it thus became the germ of this splendid institution which is now so famous.

M. de Vandermonde, the first director, added five hundred machines to the collection between 1785 and 1792.

In 1793 a "*commission temporaire des arts*" was formed, by decree of the *Convention Nationale*, consisting of MM. Vandermondè, J. P. Leroy, Conté, Beuvelot, Molard, l'Abbe Gregoire, and the celebrated physician, Charlés. This commission did a noble work in collecting valuable apparatus and models, and in preserving them from injury during the riots and the turmoil of that sad period in French history.

By a decree of the convention, it was soon after ordered that a "*conservatoire des arts et métiers, un dépôt public de machines modeles, outils, dessins,*" &c., should be established, and that three "*demonstrateurs*"

* The Marquis of Worcester, the distinguished inventor of one of the earlier forms of steam-engine, two hundred years ago, earnestly urged the establishment of a definitely-arranged system of technical education, which should combine instruction in science and in its useful application in the arts.

Digitized by Google

and a designer should be employed. After some delays, the new institution was established in the old priory of *Saint-Martin-des-Champs.*

The school has experienced the vicissitudes always to be anticipated in such cases; but its collections have never ceased growing, and its field has been extended by the addition of new departments and the establishment of new professorships, until it now has a faculty of fifteen members.

Many of the most noted French savants have been members of its councils or of its faculty. Thenard, Charles, Darcet, Dupin, Say, Clement, Berthollet, Chaptal, Gay-Lussac, Arago, Pouillet, Poncelet, Morin, Tresca, Ollivier, Bequerel, Payen, Peligot, Moll, Alcan, and others have all been, or are at present, in the lists.

The names of General Morin, the *directeur*, and of M. Tresca, the *sous-directeur*, are well known to every educated engineer and mechanic, and their works have assumed a permanent place among "engineering classics."

375. The works of Arbey, the builder of some of the excellent machinery noticed at Vienna, are at Paris; the great establishment of Cail & Cie. are also here. The arrangement of the former (Fig. 217) is somewhat like that noticed at several other establishments. The heavier tools are on the lower floor, and lighter tools are mounted in galleries on either side. Before visiting the latter, we made a journey to Le Creusot to visit the great establishment of Messrs. Schneider & Co., which produces a large fraction of all the iron and steel made in France.

376. CREUSOT.—This immense establishment has grown up from a very insignificant beginning during the past century. The first buildings were erected in 1782, and the mining of coal from the beds which underlay the present city and works, then called Charbonnières, has never since been intermitted. The elder M. Schneider, who still lived* at the time of our visit, an active, intelligent old gentleman, purchased the place

*EUGENE SCHNEIDER.—We regret that we are compelled to record the death of another of those distinguished engineers to whom the world is so much indebted for its material prosperity. In Great Britain, the Dowlais Works, in Prussia, the great establishment of Krupp, at Essen, and in France, the immense works of the Messrs. Schneider are illustrations of the success which may sometimes attend earnest application and the exercise of a talent in organization and in direction such as is essential to the prosperity of any large manufacturing community. In all these cases, the marvelous accumulation of capital and the creation of a great city by the industry of a single proprietor, and during a single life-time, has been the most remarkable fact.

Eugene Schneider and his brother Adolphe purchased the works at Le Creusot in 1836. The works had been established a half-century earlier by a company in which Louis XVI held an interest. It had never prospered, however, and the Messrs. Schneider bought it for about two and a half millions of francs, after thirty millions had been expended upon it. In 1838, the first locomotive was built here for a French railroad, and Le Creusot has supplied nearly all that have been made for them up to the present time. There were then employed at Le Creusot about 2,000 men. In 1842, M. Bourdon, the celebrated engineer and inventor, then in the employ of the Messrs. Schneider, invented and built for the works a steam-hammer, at about the same time that Nasmyth introduced his in Great Britain. In 1815, M. Adolphe Schneider was killed by a fall from his horse, and Eugene succeeded him in the Chamber of Deputies,

Digitized by Google

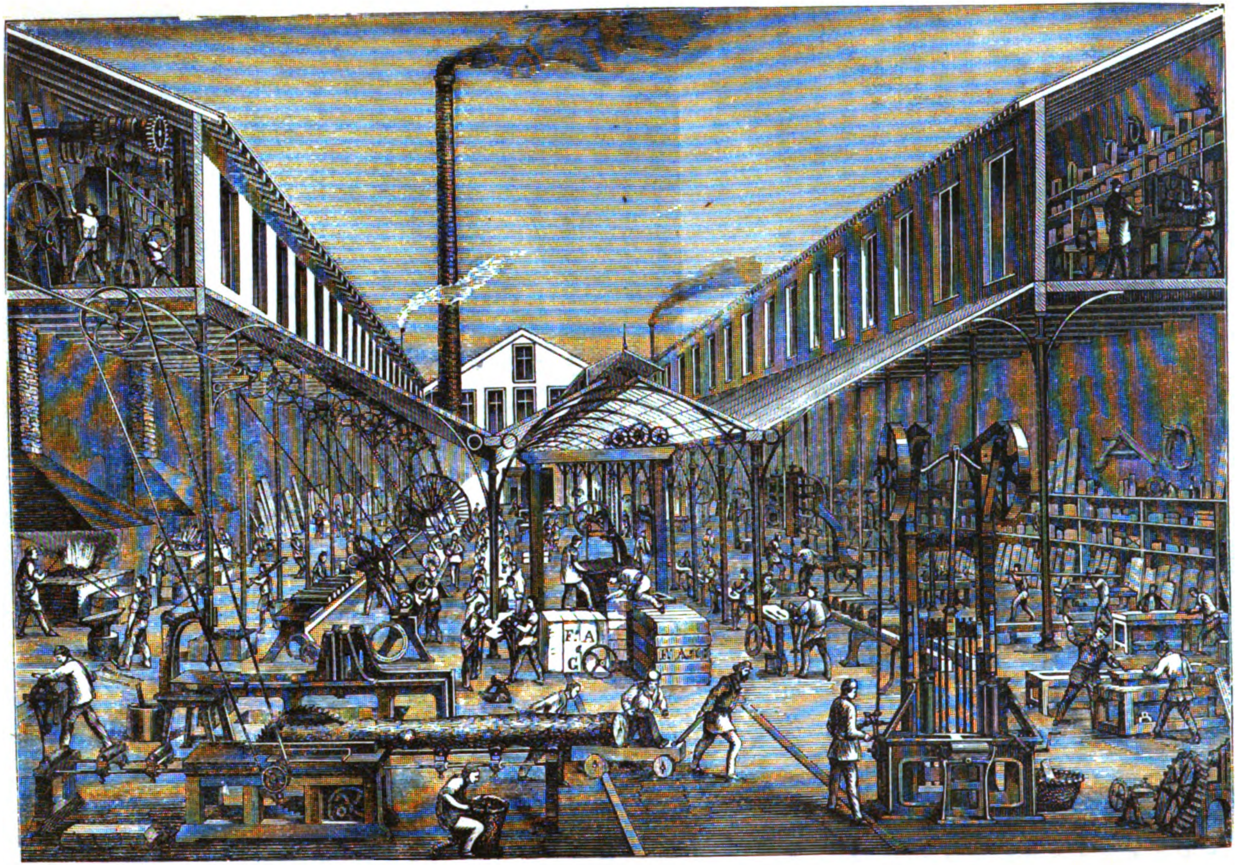


FIG. 217.—Works of Arbey & Co., Paris.

Digitized by Google

Digitized by Google

in 1837 for about a half million dollars, at which time its production was 40,000 tons of coal and 6,000 tons of iron per year, and the number of workmen employed was less than fifteen hundred. The town had a population of about three thousand.

377. The wonderful change which has occurred during this century of development was best realized by the visitor when he obtained a view of the great collection of mills as he approached them in train from the Paris and Lyons railroad. The description given by the writer at the time would not be out of place here.

Leaving Paris early in the morning, we reached Le Creusot late in the evening. Long before reaching the latter city we could see across the country great masses of smoke rising slowly from the valley and floating across the hills like heavy thunder-clouds, obscuring large tracts of the country, which was elsewhere beautifully illuminated by the bright light of the moon, then just past the full. As we finally skirted the town, nearing the station, a sight burst into view such as is seldom witnessed, and to which no verbal description can do justice. The vast clouds of smoke which we had been watching from miles away were issuing from the tops of hundreds of chimneys and from the midst of numbers of great blast furnaces, which rose far above the surrounding buildings. The long structures covering the rolling-mills and forges were plainly seen through the gloom, lighted up by a ruddy glow from great masses of hot metal passing through the rolls, or by the brighter glare of scores of forge-fires; and on the hill above and behind the works, barely revealed by the light of the partly-obscured moon, we could see the populous town which has grown up here, founded and supported by this marvelous example of recent industrial progress. A dull unintermitted roar of escaping steam, the loud clatter of gearing from the rolling-mills, and the rumble of the rolls, with the unceasing concussions of many steam-hammers, the sound of loud voices, now and then rising

and was again elected in 1846. Meantime, the works were carried on under the direction of his son, who, by his death, is left to assume nominally that entire responsibility which he has actually borne, although still a young man, for many years. Eugene Schneider was made minister of agriculture and commerce in 1851, and was at the same time decorated with the insignia of a commander in the Legion of Honor. A little later we find him a member and vice-president of the Corps Législatif, remaining by re-election in 1857 and 1863, and becoming its president in 1865.

During all this period his establishment at Le Creusot was rapidly increasing in magnitude and importance, and our readers will remember the description given of it by our correspondent, Professor Thurston, after his visit to M. Schneider in 1873, on his return from Vienna. The venerable founder was then at home, and was still exhibiting an earnest and intelligent interest in its affairs, although he had then surrendered all administrative control to his son.

M. Schneider has, throughout his life, taken an active part in all the public affairs of France which are concerned in her industrial progress. He was a member of the general council on manufactures, a member of the board of regents of the Bank of France, and was president of one or two societies formed for the encouragement of industry. He was decorated with the Grand Cross of the Legion of Honor in 1868.

At the time of his death the enlargement of the Creusot establishment, which had been commenced at the time of the visit of our correspondent, had been largely com-

Digitized by Google

above the noise of machinery, and the barking of the numerous dogs in the city beyond, mingled and produced almost as novel and exciting an impression upon the ear as did the strange and interesting scene upon the eye.

The works now furnish employment to nearly sixteen thousand people, of whom probably ten thousand work in the mines.

Twelve large blast-furnaces were in blast, which produce annually over a hundred thousand tons of iron, which is consumed in the Bessemer works and the iron-mills. Fifty thousand tons of steel and twenty thousand tons of iron rails are made, and the machine-shops turn out a hundred locomotives and an immense amount of other machinery.

The blast-furnaces recently built are twenty meters in height, and others, of earlier construction, are twenty-five meters high. They are supplied with blast heated to one thousand degrees in Whitwell and Cowper stoves, both of which are used.

Ores and fuel are obtained on the place, and are of good quality. For Bessemer metal, imported magnetite ores from Algeria are used, which are said to be as pure and rich as any in the world. The metal for the converters is brought directly from the blast-furnaces in large ladles, into which it is tapped from the furnace, and which are drawn on a line of rails to the converters by horses. This peculiarity of Creusot practice is probably one of the important elements of successful competition with other works.

It was at this place that the Siemens-Martin process was first made successful. It is still used in the production of the softest grades of steel. Both at the works and at Vienna, remarkably beautiful samples

---

pleted. The works are of such extent as to cover over 800 acres of ground, employing about 15,000 workmen, raising over 700,000 tons of coal from the underlying coal-beds, making nearly 200,000 tons of pig-iron, 100,000 tons of puddled iron, and 75,000 tons of steel per annum. They turn out 100 locomotives per year, immense quantities of machinery, bridge-work, steam-engines, and other manufactures in metal.

The coal-mines employ 1,200 men; there are thirteen blast-furnaces, three sets of Bessemer converters, six Siemens-Martin furnaces (which were first introduced here) rolling-mills and forges employing over 3,000 men, containing fifteen steam-engines and covering thirty acres of ground. The engine-shops are at Chalons-sur-Saone, and furnish employment to 2,500 men. At Le Petit Chalons, iron-ship-building is carried on and bridge-construction is a principal branch of industry. The whole establishment now has in use over 3,000 steam-engines, having an aggregate power of about 20,000 horses.

The town of Creusot has grown from a little village, as found by the Messrs. Schneider, containing, possibly, 3,500 people, to a city of 25,000 inhabitants. It is dependent entirely upon the works for its maintenance. The director, M. Henri Schneider, is also the mayor of the town; and this patriarchal form of government is not the least interesting feature of the place.

M. Schneider will not soon be forgotten. His skill as a mechanical engineer, his administrative ability, his splendid power of organization, his statesmanship, his patriotism, and, above all, those noble traits of character which endeared him to all with whom he became associated, have given him the fame which is accorded to the successful in every branch of life, and have secured for him that grateful remembrance which is the greater reward of a life full of good works. It is pleasant to be able to feel that his mantle has fallen upon one who is well worthy to wear it.—*Scientific American, Supplement.*

Digitized by Google

of this steel were shown. The great advantage possessed by this process in the production of low grades and fine qualities of steel arises from the fact that, when the steel is ready to be tapped off, it may be tested to determine its precise adaptation to the proposed use; if not of the required degree of carbonization it may be retained on the hearth under a reducing, or an oxidizing, or a neutral flame, as desired, and pig-metal, spiegel, or wrought iron, which may be needed, can be added, if necessary. The molten metal may be held in the furnace as long as may be wished, and finally, when precisely of the quality demanded, may be tapped off with a certainty that it is of the right composition.

Some of these steels contain as little as one-fourth of one per cent. carbon, and are wonderfully ductile. Nothing resembling some of the samples shown there had been met with by the writer. Since his return, a few specimens have been sent for test to the Mechanical Laboratory of the Stevens Institute of Technology, which are of similarly low grade in carbon and equally remarkable for ductility and resilience. The Midvale Steel-Works of Philadelphia furnished these specimens.

The Siemens regenerative furnace is in use at Le Creusot, and eight new furnaces were in course of construction at the mills. The rolling-mills were well built and well arranged for doing work efficiently and promptly. The buildings are very excellent in design, substantial in construction, and well adapted to such purposes. The rolls were strongly made and were driven at good speed, and the iron was well handled.

The machine-shops were of less interest. The forge contained some hammers of large size; the heaviest had a weight of 15 tons.

We admired particularly the arrangement of the drawing-rooms and offices. They were unusually well placed, neatly built, and well furnished, and were light, airy, and very pleasant. The office of the superintendent of each department was placed in telegraphic communication with his section of the works, and he gave orders to his subordinates and received their reports without leaving his chair. All offices were within convenient distance of the rooms of the proprietor. The organization and administration were simply admirable. The *personnel* of the establishment comprised a larger proportion of well-informed and well-educated officials than we had met in any similar establishment in Europe. The workmen seemed, as a class, very intelligent and industrious.

378. A visit to Lyons, the center of the silk-manufacturing industry of France, enabled us to see something of the manufacturing of South France. The manufacture of silk has constituted the principal industry of this district for many years. It was first commenced about three hundred and fifty years ago. Twenty-five years ago it employed over fifty thousand looms, consuming a million of pounds of the raw material, valued at $30,000,000, and producing goods worth nearly double that amount. The business now employs about seventy thousand looms and double that number of workmen, and the value of the product is estimated at $80,000,000. The work is not done in large manufactories,

Digitized by Google

but in the houses of the people or of the master-workmen. A very large quantity of the Lyonnese silk is sent to the United States.

The attempt was made some years ago to found a "Permanent Industrial Exhibition" at Lyons. We found the buildings, which covered a great area of ground, nearly empty; the enterprise was evidently a failure. We found a few exhibits still remaining. A horizontal stationary engine, by Duvergier, of Lyons, was, in some respects, worthy of study. Its regulator adjusted a single-ended link, and the main and cut-off valves were moved by the same eccentric. The link could be adjusted by hand when desired. The cylinder was overhung from the end of the frame, like the arrangement adopted sometimes by Corliss.

MM. Marvel Frères exhibited a chain-cable weighing 82 kilograms per link. The same firm exhibited an armor-plate, measuring 6.26×1.485×0.270 meters, and weighing 19,750 kilograms; a bridge-plate, 22.5×0.5×0.12 meters, and weighing 1,053 kilograms; several heavy crank-shafts, and an armor-plate 6 inches thick, doubled up, as was stated, *cold*.

The Société Anonyme, of Charente, had on exhibition some very fine castings of Siemens-Martin steel; they were remarkably good. MM. Chevalier & Grenier, of Lyons, presented a horizontal compound engine, with a boiler fitted with superheater, and with removable tubes and fire-box, like that exhibited at Vienna. The governor was of the parabolic class, with ball guide, and attached to the throttle-valve. The main steam-valves are plain and can only cut-off by the lap of the valve.

379. CAIL & CIE., at Paris, have a large establishment on the Quai de Grenelle, beyond the Champs de Mars, in which they employ nearly four thousand men. These works produce large numbers of locomotives, steam-engines, and machinery, and an immense quantity of sugar machinery. The buildings are low, usually of but one story, are well lighted and are crowded with machinery. Iron columns and girders support the roofs. They are not as conveniently arranged as those of some other establishments visited, but a railroad-track is carried through every building, and a number of small switching-engines are kept employed in the transportation of material from one to another.

The tools in use are not comparable in efficiency to those familiar to manufacturers in the United States. Some recent improvements and some modern tools are distributed throughout the works. The character of the work done was very good in all departments. We noticed that all scrap was kept apart and carefully assorted.

The locomotive-shops were said to turn out a hundred and twenty engines per year. The number of draughtsmen employed was given as *one hundred and ten;* either the number is incorrect or an immensely greater expense must be incurred in getting up new designs than is usual in such establishments, and must prove a heavy tax. The variety of work done here is greater than is usual in such places, and that fact may possibly account for such extraordinary development of this department.

Digitized by Google

CHAPTER V.

MANUFACTURING ESTABLISHMENTS OF GREAT BRITAIN.

NO IMPORTANT ADVANCE SINCE 1871; SHARPE, STEWART & CO.'S LOCOMOTIVE AND TOOL WORKS; CREWE, AND THE WORKS OF THE LONDON AND NORTHWESTERN RAILROAD COMPANY; BRITISH IRON-MAKING; THE CUMBERLAND HEMATITE DISTRICT; BARROW, AND ITS STEEL-WORKS; CUMBERLAND ORES; BARROW STEEL; TESTS MADE BY FAIRBAIRN, AND AT THE STEVENS INSTITUTE OF TECHNOLOGY BY THE AUTHOR; THE CLEVELAND IRON-DISTRICT; DIMENSIONS OF FURNACES; ORES; FUEL; FLUX; ENGINES; SOURCE OF ECONOMY IN WORKING; LANCASHIRE: JAMES WATT & CO.'S WORKS AT SOHO; LOW MOOR IRON-WORKS; SCOTCH IRON-MAKING PRACTICE; GLASGOW AND ITS INDUSTRIES; IRON SHIP-BUILDING; IRON VS. WOOD; ELDER & CO.'S FAIRFIELD WORKS; R. NAPIER & SONS; OTHER BRITISH FIRMS; EFFICIENCY OF STEAMERS; DIMENSIONS AND PERFORMANCE OF STEAM-VESSELS; THE BRITISH NAVY; HER BRITANNIC MAJESTY'S IRON-CLAD MONARCH; CLASSIFICATION OF WAR-VESSELS; HULL OF THE MONARCH; TURRETS AND ARMAMENT; ENGINES AND BOILERS; PERFORMANCE; BRITISH NAVAL POLICY; THE DEVASTATION; THE INFLEXIBLE; SIR JOSEPH WHITWORTH & CO.'S MACHINERY AND GAUGES; WHITWORTH ORDNANCE; COMPARISON WITH THE WOOLWICH SYSTEM; WHITWORTH'S COMPRESSED CAST STEEL; VALUE OF NEW AND RESILIENT METALS; SHEFFIELD; STEEL AND ARMOR PLATE; THOMAS FIRTH & SONS; SIR JOHN BROWN & CO.; CAMMELL & CO.; SOUTH WALES; THE DOWLAS'S WORKS; THE SIEMENS STEEL PROCESSES; J. PENN & SONS' TRUNK AND OSCILLATING ENGINES; SHIPBUILDING ON THE THAMES.

380. After leaving France we still had a short time to give, before the sailing of the steamer in which we had taken passage, to the exploration of some of those British manufacturing districts of which we had seen products at Vienna. At a visit made two years previously to the principal of these districts, partly on business and partly for the purpose of obtaining general professional information, the writer went over very nearly the same ground. There seems to have been but little change, either in general standard practice or in matters of detail during this interval.

A brief description of a few of these leading establishments in each of the principal of these districts will be quite sufficient to indicate the points of resemblance and of difference between them and similar establishments in the United States.

381. SHARPE, STEWART & CO.—Sharpe, Stewart & Co., of Manchester, are among the best-known and deservedly-distinguished of British locomotive and machine building firms. Their practice is probably as fairly representative of the best English methods as that of any other shop in the country. The firm has been long known, and, like those of nearly all old establishments, its works have grown into their present shape very gradually, and the buildings are neither well arranged nor

Digitized by Google

well adapted to modern methods of work. Both buildings and tools are too generally old and dilapidated, and are such as would not be retained in use by an American firm of equal wealth and standing. It is the fact, however, that in no part of Europe is the economy to be obtained by the substitution of modern automatic and rapidly-working tools for half worn-out machines of older design so well appreciated as in the United States, and a "rotation in tools," as some engineer expresses it, is not generally understood to be an essential to the greatest success in manufacturing.

Some of the older tools were here fitted with recent improvements in details, as, for example, the Whitworth tool-holder, which reverses the edge of the tool of the planing-machine at each movement of the table and places it in position to cut each way. The tool is carried in a cylindrical holder, with vertical axis, and with its edge in the axial line. Simultaneously with the reversal of motion of the table this tool-holder makes a half revolution and presents the cutting-edge of the tool in position for taking a cut in the new direction of travel. The tool is usually round-nosed, to avoid the difficulty which would be met with in securing the precise adjustment of the common side-tool. A slotter, fitted with two tools and used in dressing the cranks of locomotive-axles, was another illustration of a successful attempt to economize labor. All machine-tools were fitted with automatic feed-motions.

The firm are building large numbers of locomotives. Their practice is in some respects in advance of that of the majority of British builders, and some of their designs are very similar to those which have long been standard in the United States. In some points it resembles that subsequently seen at Crewe, in the shops of the London and Northwestern Railroad Company. The variety of styles of engine, both passenger and freight, was remarkably great, and special designs seemed to have been frequently made for foreign markets, to which a large number of engines have been supplied by the company. The use of outside cylinders is more usually adopted here than in the general practice of British firms. The simplicity of parts and the superior strength of the straight axle in this plan of engine have long ago made it the standard design in the United States. It is much less frequently seen in Great Britain, and the breakage of cranked axles is therefore not infrequent. The driving-wheels are all flanged, and even the intermediate wheels are not left, as in American engines, without flanges. The tires are made of Vicker's crucible-steel. The engine-frames are made of plate, and are *planed* on each side to bring them to size. This seems an operation for which some less expensive substitute should be found. The plan of grinding practiced at Crewe is probably far preferable. The fire-boxes of the boilers of the locomotives are made usually of copper. The tube-sheets are made an inch or more in thickness where they receive the tubes, and are worked down to the same thickness as the remaining part of the fire-box where clear of the tubes. This plan was entirely unfamiliar to

Digitized by Google

the writer, and is probably but little practiced, if known at all, in the United States. Where it can be done conveniently, the riveting is done by steam with a rather light steam-riveter, which sets up seven-eighths rivets with two blows. The edges of the sheets are planed instead of being left to be chipped after riveting up, with the serious risk of injuring the lower plate along the edge of the lap. The practice of planing the edges has been introduced into the United States, but is far less general than it should be. The shells of the boilers were made of ⅜ to ½ inch plate, butt-jointed, with the covering-strips on the outside except where the laps occurred. The work was all carefully laid out and well done. The seams looked well along the laps and at the corners, and the rivets were of good quality and well headed. The machine-work was all good, and some of it was exceptionally excellent. The firm make a great variety of small machinery and of attachments to engines and boilers. The effort seems to be made to make them cheaply and to give them efficiency without expending anything for finish. They are the licensees, in Great Britain, of the patents of Giffard on his injectors, and of the Messrs. Sellers for some of their finest tools. The firm have made, it is stated, over 25,000 Giffard injectors in one year. We found nothing to demand notice in the foundery. Scotch pig seemed to be largely used; we saw a considerable amount of Glengarnock and Gartsherrie in the stock-piles.

382. CREWE.—LONDON AND NORTHWESTERN RAILROAD REPAIR-SHOPS.—The works of the London and Northwestern Railroad, at Crewe, nearly midway between London and Liverpool, are exceedingly interesting to the engineer. These works employ about 6,000 men, and the city which has been built up around them contains nearly 25,000 people, who are all directly or indirectly dependent upon them for support. In this establishment a hundred and fifty locomotives are constructed each year, and all the locomotive-stock of the company, 1,700 or 1,800 in number, are kept in repair. The low steel, and much of the iron and other material used in the shops, are made on the grounds; even the bricks which are to be used in new buildings are made here, a large annular, perpetual kiln, of the Hoffman kind, furnishing them in sufficient numbers and at comparatively low cost. They are molded in a powerful machine, built at Rugby, which is capable of turning out 30,000 per day.

The works grew into their present shape under the superintendence of Mr. Ramsbottom, who had recently left Crewe, and had been succeeded by another distinguished engineer, to whom the writer is indebted for essential favors. Mr. Ramsbottom planned the works, and has made the establishment one of the finest of its kind in Europe. He is one of the most ingenious and boldest engineers living, and has introduced here some of the most radical departures from standard designs and practice and some of the most effective and original machinery to be seen in Great Britain.

The steel-works contain four 10-ton converters, which are kept quite

Digitized by Google

well employed; their product is converted into boiler-plate, rails, tires, and running-parts of engines. The accessory apparatus is well designed and well arranged. Our distinguished American designer, A. L. Holley, could not have done much better had he planned these steel-works.

The foundery is large, well built, finely lighted, and is furnished with a number of hydraulic cranes near the ends, and has a strong, quick-working, travelling crane, running from end to end. It is well fitted up for making large numbers of small castings, and the work seen finished and in progress was excellent.

The rolling-mill contains large plate-rolls driven by the Ramsbottom reversing-engine, of which the use is becoming quite common in Great Britain. This engine is attached directly to the train, and makes the same number of revolutions as the rolls. Instead of reversing the mill at each pass by cross-gearing and clutches, as is usual in old mills, the engine is here reversed by means of the Stephenson link commonly employed on marine engines. In order that reversing may be done promptly and with certainty, the engine has been made without a fly-wheel, and is given great strength. It has two steam-cylinders coupled to cranks, set at right angles with each other, and the valves are given very little of either lap or lead. This engine has not been introduced to any extent in the United States. The system of three-high rolls, with the rising and falling table introduced by Mr. Charles Hewitt, for iron, and afterward by Mr. Holley and Mr. Fritz in steel, mills, is usually thought quite as good, and by many engineers preferable.

The steel-works and the puddling-mill, which latter contains about a dozen furnaces, keep the rolls well employed.

The peculiar steam-hammer in use here is one of the striking innovations on ordinary practice with which Mr. Ramsbottom is to be accredited. It consists of two immense masses of iron forming the hammers, which are mounted on carriages sustained by small, strong, friction-wheels, and move toward or separate from each other by moving horizontally on rails. Between them is the anvil, which merely takes the weight of the piece to be worked, while it is struck simultaneously by the two hammers which approach it from either side. The hammers are driven by large steam-pistons, which are, in this case, set below the floor and under the anvil. This hammer requires no such foundation as is needed by the usual form of steam-hammer, and it possesses the apparently generally unrecognized, but nevertheless important, advantage, that none of the energy of the blow is wasted and misapplied to the shaking of the earth and the injury of the buildings; it is all usefully applied to the shaping of the work. For many kinds of work this hammer has such decided advantages over the standard forms that it seems surprising that it has not become more widely known and more generally introduced. There were three of these hammers in use at Crewe. One of the smaller ones was used in working out the cone-shaped steel castings which were made for tires. In making these

Digitized by Google

tires, the castings were taken for finishing to a singularly-constructed stretching-mill, in which they were forced, by a process of rolling and pulling, along an iron cone, by which they were, at a single operation, given the required size. The plan was exceedingly ingenious, and cannot be described without complete drawings. With good tough metal it works well. Engine-tires were all carefully turned, but the tires used for tenders were left as they came from the mill.

The puddling-furnaces at Crewe were of the ordinary form. The heating-furnaces were those of Siemens, and the amount of work done at these works may be well indicated by the fact that these furnaces consume 200 tons of fuel per day in the gas-producers.

The boiler-shop was as well planned and built as the foundery. Here they were using steel in the shells of their locomotive-boilers, and were trying it in fire-boxes where they had previously used copper exclusively; the results were reported to be satisfactory. The use of steel in locomotive-boilers has, so far as the writer has had knowledge, always been satisfactory in result where the metal has been obtained of uniform quality. If given just sufficient carbon to enable it to be melted in the crucible or on the hearth, and to be made so fluid as to become thoroughly homogeneous, steel is always found best; if it contain much above one-quarter of one per cent. carbon, it is likely to prove unsatisfactory, sometimes hardening, and frequently cracking, if used in fire-box plates.

In riveting, the work is done, where possible, by the steam-riveter, and usually the rivet is closed up by two blows. The older riveting-machines were too light to do good work at a single blow; and it may be doubted whether it is not better practice to use a light machine in the manner described than a heavy machine, striking a single blow, unless, like the machine of the Providence Steam-Engine Company, one die is used to hold the sheets together, while the rivet is headed up by a second die driven by an independent steam-piston. The seatings for man-hole plates, safety-valves, dome-tops, and such details, are of wrought iron, struck up in a single piece—an excellent practice, and one which should be adopted universally. The usual habit in the United tates of using castings for such parts is vastly less satisfactory and is anything but creditable.

The machine-shops were extensive, well lighted, and well arranged, and contained some excellent tools; the latter were principally of Whitworths manufacture.

Some peculiarities of practice in making details were observed here. Eccentric straps were usually bushed with a kind of Babbitt or white metal; connecting-rods were made solid at the ends, instead of being fitted with costly straps, with their gibs, keys, and set screws, and were simply bored out to receive bushings of white metal in place of the usual form of brass box. These bearings run well for a year or more; when they begin to shake, they are taken out, recast, and replaced, an

Digitized by Google

operation of little cost and requiring very little time. This method was reported to have proved perfectly satisfactory. Its cheapness and convenience are important recommendations.

The boiler-shells are usually 48 inches diameter and of ⅜-inch plate, and are subjected to working-pressures of 120 or 130 pounds per square inch.

Both feed-pumps and injectors are used. The latter are of a simple, cheap, and quite effective form, which resembles slightly some of the cheap styles used in the United States and elsewhere.

Here, as all over Europe, the frames of the locomotives are made of heavy iron plate 1⅛ inches thick, cut into shape and tool-dressed to fit; this is done by piling six or more upon the planer-table and working all together. When given the desired outline they are removed from the cutting-tools and placed in a tank, where they are flooded with water and are ground smooth by a horizontal grindstone; the method seems to satisfy the manager, and was said to be both effective and inexpensive.

The style of locomotive now usually built resembles the American type somewhat, but has driving-wheels of larger size. On passenger-engines these wheels are from 6½ to 8½ feet in diameter; the former size is the most common. Formerly, very large wheels were used on fast engines; they were not infrequently 8 and were sometimes 10 feet in diameter; the Cornwall, with drivers of the latter size, was, at the time of this visit, at work on the line. These large wheels are only in single pairs; they are said to shake too seriously at high speed; they are driven by outside cylinders. The smaller sizes are usually built for engines having inside cylinders and two pairs of coupled drivers; they are now used in nearly all new passenger-engines, as on railroads in the United States. Freight-engines, or "goods-engines," as they are called in Great Britain, are given smaller wheels.

In these engines the solid-bar link is adopted; it possesses some important advantages over the strap link; it is simple and strong and wears well.

Trucks, or "bogies," are not used by British engineers, who consider that the short wheel-base introduces a serious element of danger in its liability to swing across the track, and who think that the small leading-wheels, necessarily used under a locomotive truck, are also objectionable. They prefer a single pair of larger leading-wheels carried in a rigid frame without radius-bar.

The Ramsbottom packing-rings are used on pistons. These are single small rings sprung into grooves turned in the face of the piston. This dispenses with followers or "junk-rings," and is inexpensive. The same plan has been frequently tried in the United States with many variations of proportions and with varying success.

The wrought-iron wheel is almost exclusively used, but cast wheels are on trial. Quite recently the distinguished American engineer Mr.

Digitized by Google

W. W. Evans, of New York, has exported American wheels to foreign countries. No success has been met with abroad in making these wheels, and it does not seem probable that such wheels as our roads have used so long can be made in other countries, until such metal as we use can be obtained there.

A system of mechanical firing was in use at Crewe under shop-boilers, and was reported to be very successful.

This great manufactory should be visited by every one who desires to see the best of British practice and the most original inventions of this class to be found in the country.

383. BRITISH IRON-MAKING is seen in its most characteristic development in the newer iron-making districts of Cumberland and Cleveland. There has been, during past years, a continuous but not very rapid improvement in the methods and plant, which now seems to have reached its limit. Economy in the production of iron from the ore is promoted by increasing the size of furnace and elevating the temperature of blast. The limit in the first direction is practically determined by the strength of the fuel, in most cases. When the furnace is given a height at which the fuel is crushed under the superincumbent weight, further increase of altitude becomes impossible. As the maximum diameter is determined by the altitude, it also becomes impossible to exceed a certain capacity of furnace, which will vary with every variation in the hardness of the fuel. Where the limit is not thus fixed, it is found that the increase of economy becomes less and less as the magnitude of furnace increases, and it finally becomes so slight as to be balanced by higher proportional increase of direct and incidental expenses of building and working.

In the Cleveland district the strength of the coke used as fuel is such that the latter causes have determined the limit, and the furnace now apparently most generally approved is about 75 or 78 feet in height and 26 or 27 feet in diameter of bosh.

The increased economy which attends elevation of temperature of blast has similarly attained a limit in practice, which is somewhat above the highest temperature yet actually reached. Where iron hot-blast stoves are used, they limit the temperature of blast to about 1,200° as a maximum, as they are liable to crack seriously at a higher range. With the Whitwell, the Cowper, the Sellers, and other stoves in which more refractory materials than iron are used, the temperature has been carried several hundred degrees higher, but with very little if any advantage; on the whole, and practice seems to have settled down at about 1,200° F.

384. CUMBERLAND HEMATITE-DISTRICT.—In the northwest corner of England, near the celebrated "Lake District," and in the neighborhood of the well-known ruins of Furness Abbey, there has lately sprung up an immense business in the mining of ores and in the manufacture of iron and of steel. It is but a few years ago that the now

Digitized by Google

well-known Cumberland hematite-ore was found to be the only British ore well adapted for the Bessemer and Siemens process of steel-making. The section of country has, in consequence of this discovery, been rapidly settled, and manufactures of metal have been developed here with a rapidity only equaled in the neighboring Cleveland district and in the western portions of the United States.

As the present tendency of improvement in the applications of metal is evidently to the introduction of the low grades of steel and its substitution in nearly all directions for iron, a capacity for the production of steel in large quantities and for long periods at small expense, either in making or in transportation to the market, will probably ultimately determine the position to be held by any country in reference to the markets of the world. The standing of Great Britain, therefore, is not improbably dependent upon the extent of this one deposit of ore and upon the skill and economy with which it is worked. Our own country, with its vast deposits of rich and poor ores, seems far more likely than Great Britain to supply the world, in the near future, with its steel.

385. The works of the several firms producing steel and iron in the Cumberland district are situated in and near the city of Barrow. This city has grown up since the discovery of the value of this ore from a mere village to a town of nearly thirty thousand inhabitants. The whole of this section is owned by the Dukes of Devonshire and of Buccleugh, of whom the one holds the lands and the other all manorial rights. They, with a few other capitalists from other portions of England, have controlled the whole of the immense mining and manufacturing interests now concentrated here.

The first blast-furnace was erected in 1859 by Messrs. Schneider, Hanney & Co. The first steel-making plant was erected by Sir James Ramsden, in 1864. In 1866, these establishments passed into the possession of the Barrow Hematite Iron and Steel Company, which also acquired title to the mining-property, and thus secured control of all the industrial enterprises of the district.

At the time of our visit there were sixteen blast-furnaces at work. They varied in height from 56 to 61 feet, and in diameter from 16 to 19½ feet. The largest yields 400 tons of iron per week, and is thought to be quite as large as is advisable for this district. The temperature of blast was stated to be about 900° F.; an increased temperature had been found to give no advantage. The blast was furnished by nineteen blowing-engines which average about 100 horse-power each. The total production of cast iron was given at about 300,000 tons per year, which was principally of dark foundery-grades, well adapted to use in the Bessemer works. The ores are used without mixture, and seem to work well in the furnace.

The steel-works contain eighteen converters and produce about 100,000 tons of steel-rails, tires, and other material per annum. The whole establishment was unusually well arranged, and the buildings were well

Digitized by Google

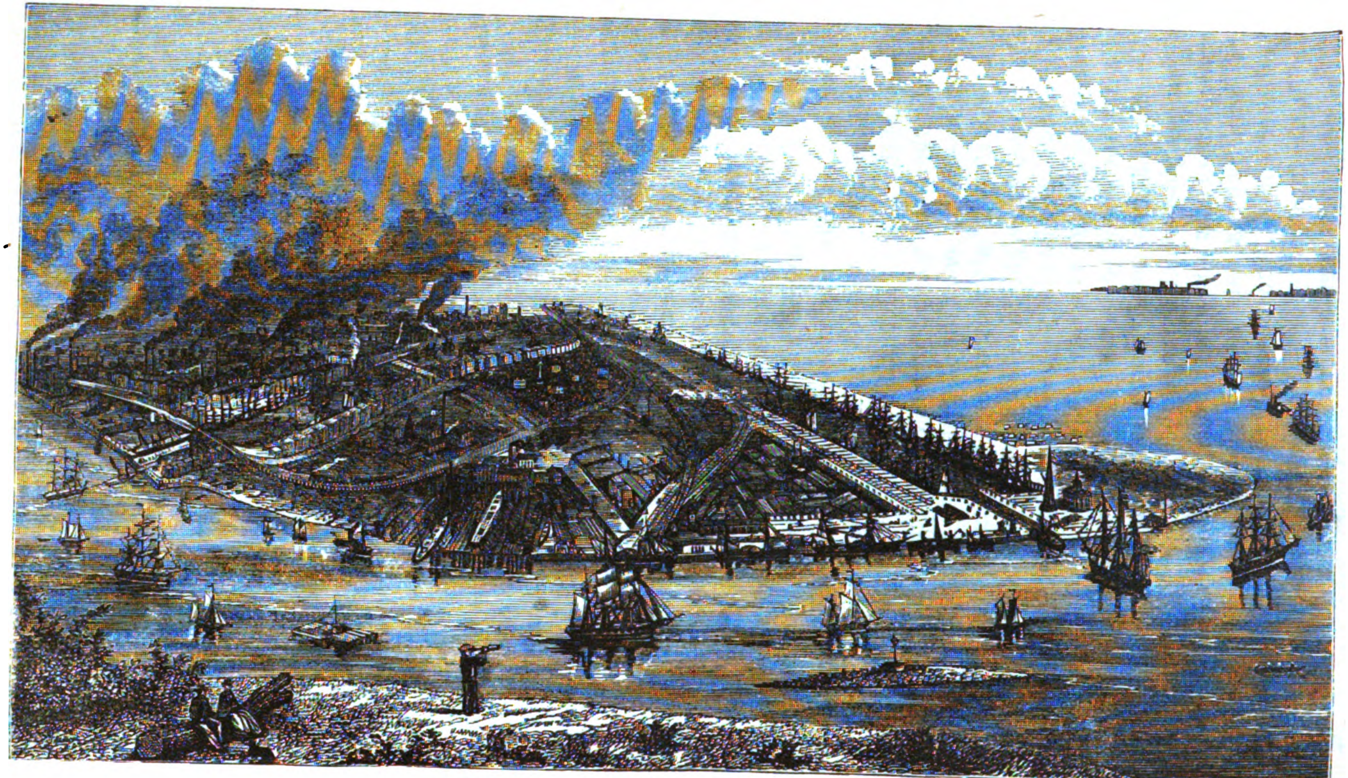


FIG. 218.—Barrow-in-Furness.—England.

Digitized by Google

Digitized by Google

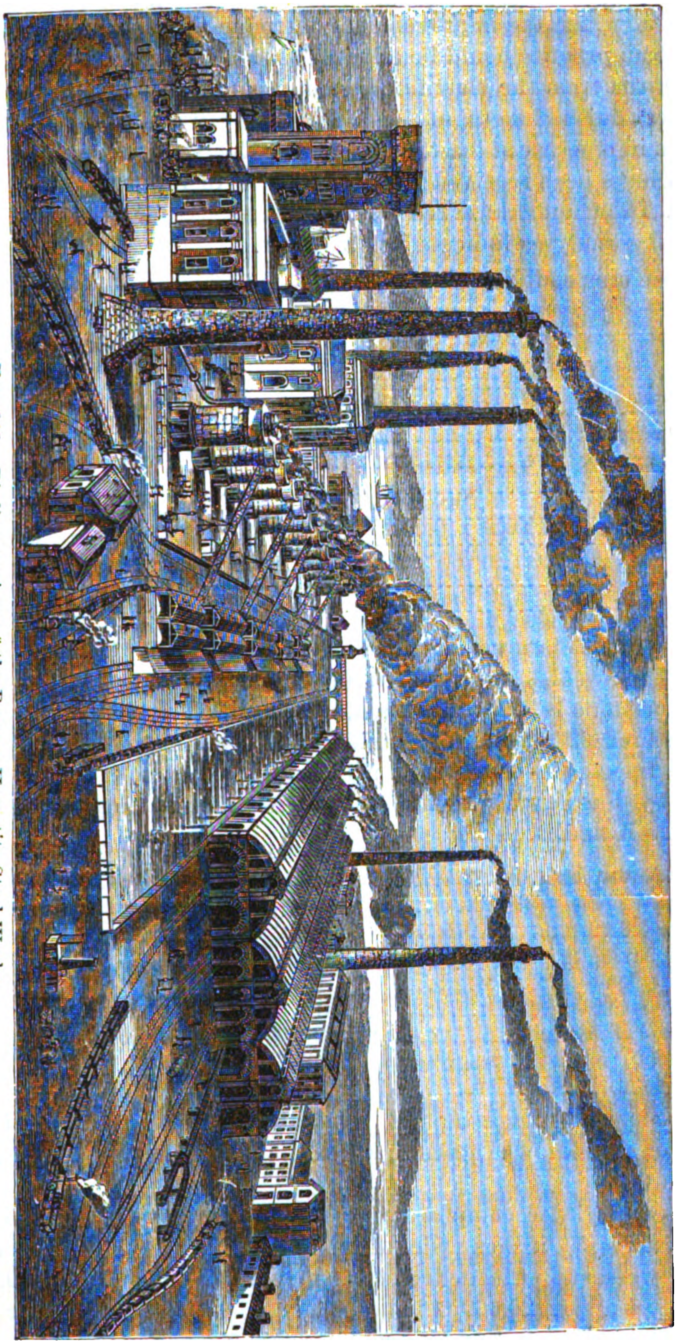


Fig. 219.—Bird's-eye view of the Barrow Hematite Steel-Works.

Digitized by Google

planned, light, airy, and convenient. The machinery is all well made, substantial, and of the most modern British designs. There were some places at which the improvements introduced by Mr. A. L. Holley into American practice could be adopted with advantage.

The iron from the blast-furnaces enters the steel-works at one end and leaves as finished metal at the other. The roll-trains are heavy, and are driven, in one case at least, by one of the Ramsbottom reversing engines, which have been received with so much favor in England.

386. The Cumberland red hematite is a very pure sesquioxide. The following analyses indicate its character.

These ores contain:

	Best.	Ordinary.	Lean.
Oxide	95.	78.61	61.30
Phosphorus	0.	.01	0.01
Sulphur	0.	.01	Traces
Silica	4.31	16.15	27.06
Alumina	0.07	1.67	2.76
Prot. manganese	0.04	.24	.24
Lime	0.34	.60	1.17
Magnesia	Traces.	.24	.65
Water	0.47	2.00	6.59
Total	100.23	99.53	99.72
Metallic iron	0.66	0.55	0.43

The Spiegeleisen used at Barrow is obtained from Germany and Sweden. The Swedish is considered fully equal if not superior to the German. The limestone is found in the neighborhood. The coke is Durham coke, and is brought across from Yorkshire at small expense.

387. Specimens of the steel made at Barrow were subjected to experiment by Fairbairn, who found it to have properties as recorded in columns A and B.

	A.	B.	C.
Specific gravity	7.754	7.795	7.785
Weight per square foot	483.70	486.40	485.50
Tenacity	80,905.00	72,195.00	89,504.00
Crushing strength	225,568.00	225,568.00	225,568.00
Tensile resilience	2,547.00	3,351.00	2,719.00
Crushing resilience	41,420.00	50,207.00	41,848.00
Modulus of elasticity	33,663,333.00	27,881,000.00	30,421,000.00
Co-efficient (tons) of transverse strength	4.50	3.90	5.35

The experimenter compares the Barrow steels with other Bessemer steels of well-known makers, which have the mean values given in column C.

A riveted girder, composed of a web 12 inches deep and ¼ inch thick, with flanges 5¼ inches wide, of angle iron 2½ × 2½ × ¼ inches and 13.9 feet between supports, deflected 0.1 inch under 5,000 pounds, 0.2 under 12,000, 0.4 under 26,000, 1 inch under 38,000, and broke after a deflection of 1.8 inches and under a weight of 49,544 pounds, yielding by tearing the lower flange. A similar girder gave way by lateral flexure under

Digitized by Google

Digitized by Google

AUTOGRAPHIC STRAIN DIAGRAMS OF METALS

PRODUCED BY THE BESSEMER & SIEMENS PROCESSES

as recorded by the Testing Machine of Professor Thurston.

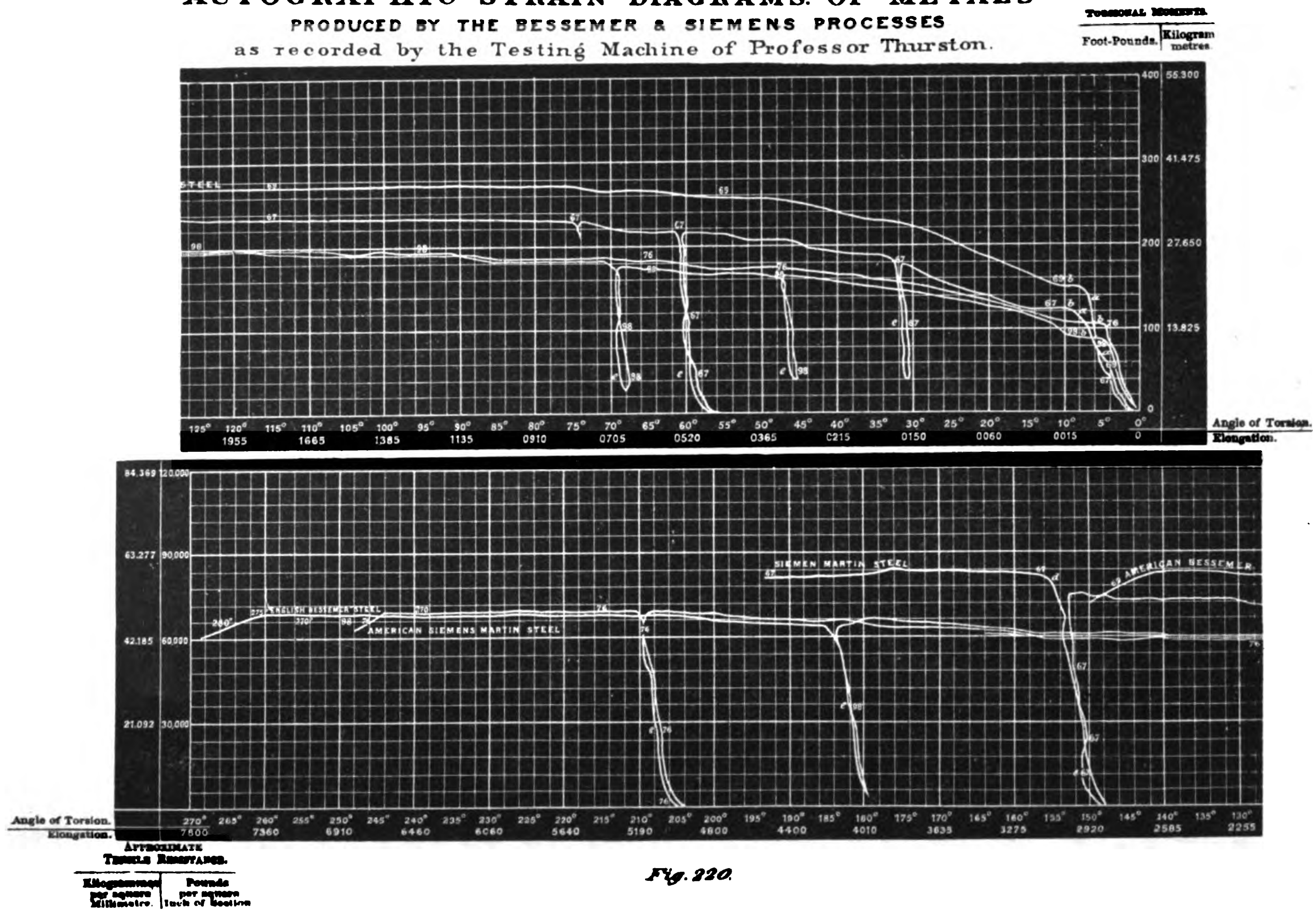


Fig. 220.

about 30,000 pounds. These steel beams were pronounced by Mr. Fairbairn one-third stronger in resistance to deflection than the best wrought iron, and much superior in their resistance to impact.

588. This low steel is the best known material for rolled beams, and for built girders intended to resist either, or both dead load and impact. In ultimate strength the ratio of this Bessemer metal to good iron is as 1 to 0.652.

A collection of specimens of these steels has since been presented to the Engineering-Department of the Stevens Institute of Technology. Specimens cut from the head of a steel rail were subjected to test in the autographic testing-machine, and the strain-diagrams (of one of which Fig. 220, No. 98, presents a *fac-simile*) automatically recorded by the machine corroborate general testimony regarding the quality of the softer Barrow steels.

This specimen was cut from the head of a Barrow rail which had been bent up cold to an angle of 120° without cracking.

The elastic limit is seen to be moderately high, 28,000, indicating a combination of elasticity and good wearing qualities. The ultimate strength is about 70,000 pounds per square inch; the elasticity is uniform and the resilience unusually high.

In homogeneousness of structure, the metal is not quite equal to the other metals of which the strain-diagrams are given for comparison, but it is freer from internal strain, and consequently from inherent deficiency of stiffness, than are the others.*

389. THE CLEVELAND DISTRICT.—This iron-making district of Yorkshire is situated in the Northeast section of England, and is generally known as the Cleveland district. The principal seat of this industry is in the neighborhood of Middlesborough-on-Tees, and the ore is obtained from the Yorkshire hills a few miles from the river. This district has had almost as rapid a development as the Cumberland region. Its principal city, Middlesborough, was, like Barrow, a mere hamlet a quarter of a century ago, and, like Barrow, has now grown into a city containing over 25,000 people; and where there was then only an extended and barren moor, desolate and seemingly valueless, there are now more than a hundred blast-furnaces, many of which are larger than any yet built in any other part of the world.

It is in this district that builders of furnaces have exhibited the greatest intelligence and enterprise in pushing improvements to their practical limits, and a maximum of economy in production has been attained by the use of large furnaces and of heated blast.

390. At a former visit, in 1871, the writer examined these furnaces very carefully. The largest furnaces then built were a pair built for Messrs Cochrane & Co., which were 30 feet in diameter and 95 feet high,

* See a paper by the author "On the strength, elasticity, ductility, and resilience of materials of machine-construction;" Transactions American Society of Civil Engineers; Van Nostrand's Engineering Magazine; Journal Franklin Institute, &c., 1874.

Digitized by Google

with a capacity of 30,000 cubic feet. These have since been lined and brought to a diameter of 27 feet, as it was found that they were too large to work satisfactorily. They were fitted with the Cowper hot-blast stove, heating the blast to a temperature of 1,400° F.

The furnaces of Messrs Gjers, Mills & Co., are 85 feet high and 25 feet in diameter of bosh. Their hearths are 8 feet in diameter and 8 feet high. The brickwork, the inner and outer stacks included, is made of Newcastle fire-brick, which is there less expensive than the ordinary building-brick generally used elsewhere. The body of the furnace is built up nearly in the form of a cylinder, tapering slightly as it rises, and is hooped with iron. In many cases furnaces are now incased with sheet-iron. At Middlesborough the foundations are made of concrete.

The temperature of blast usually carried is about 1,200° F., and the cast-iron stove with "pistol-pipes" is generally used.

The usual proportion of diameter to height of furnace is about 1 to 3, and of diameter of hearth to altitude about 1 to 11.

The blast is invariably heated, and a tall chimney is usually built to take away the products of combustion from the stoves and boilers. That at the above-described furnaces had a height of 110 feet. The area of heating-surface in the stoves was somewhat variable, but the best practice was claimed to give about 1,250 square feet per thousand cubic feet of blast per minute, reckoned by the capacity of the blowing-engines.

The furnaces of the Ferry Hill Company, which are a little way out of the city, are the highest in the district. They have a height of 102½ feet and a diameter of bosh of 27½ feet. They were claimed to have made iron more economically than any other furnaces in the shire, producing 550 tons per week with less than 500 tons of fuel.

At Spennymoor, near Ferry Hill, we found the furnaces of the Weardale Iron-Works—Messrs. Rogerson & Co.—and examined the plant with some care. The two blast-furnaces are each 85 feet high and 26½ feet in diameter of bosh, supplied with a blast of a temperature of 1100° F., and 3½ pounds pressure. The product was stated to be from 300 to 400 tons per week. The ore was a mixture of Cleveland, Weardale, and Spanish. The coke was very hard, resonant, and strong, and was used at the rate of 27½ cwt. per ton of iron made. The hoist was a water lift. The stoves were of iron. The iron made here contains both sulphur and phosphorus in small quantities, but is very uniform in quality, even-grained, and strong.

The pig was decarbonized in 64 puddling-furnaces and worked into iron of all standard merchant sizes of bar and plate. The round iron runs from $\frac{3}{16}$ inch diameter to 8 or 9 inches.

391. The cost of the furnaces, of medium height, say from 75 to 78 feet, is not far from £16,000, including all the accessories of hot-blast apparatus, hoists, and kilns.

The ore used is a lean argillaceous oxide, which is found in the green

Digitized by Google

lias of the Yorkshire range of hills. It is roasted at the furnaces, where it is dropped from the cars directly into the kilns, which are usually continuous in their operation. The fuel used in these kilns is frequently fine coal and "breeze," and the amount consumed in good work averages about a hundred pounds to the ton of ore. In calcination, the ore loses 25 per cent. of its weight, and then contains usually not much above 40 per cent. metallic iron. The composition of ore and of iron is as follows:

ORES.

Protoxide of iron	39.92	43.02
Sesquioxide of iron	3.60	2.86
Protoxide of manganese	0.95	0.40
Alumina	7.86	5.87
Lime	7.44	5.14
Magnesia	3.82	5.21
Potash	6.27	....
Silica	7.12	7.12
Carbonic acid	22.85	25.50
Phosphoric acid	1.86	1.81
Sulphuric acid	Trace	....
Bisulphide of iron	0.11	....
Water	2.97	3.48
Organic matter	Trace	0.15
Ignited insoluble residue	1.64	0.05
	100.41	100.61
Metallic iron	33.62	35.46
Authority	A. B. Dick.	A. B. Dick.

IRONS.

Carbon, (graphitic)	3.04	3.35
Silicon	2.73	1.57
Sulphur	0.04	0.04
Phosphorus	1.30	1.38
Manganese	0.38	0.07
Nickel, Cobalt	....	....
Authority	Percy.	Percy.

The fuel used in these furnaces is Durham coke. It is very remarkable for its strength and hardness, which enable it to carry the burden of the highest of these immense furnaces. It contains from 92 to 95 per cent. carbon and 1 per cent. or more of sulphur. This impurity and the rather heavy proportion of sulphur and phosphorus in the ore unfit the iron produced for use where either steel is to be made or great strength demanded. The attempt has been made at Middlesborough to make steel, but unsuccessfully. The coke is made at the coal-mines to avoid increased expense of transportation. The process requires from two and a half to three days, and the product equals frequently about two-thirds the weight of coal charged into the ovens.

The limestone used as a flux is also obtained largely from the Durham

Digitized by Google

district. It varies greatly in composition, the best containing 95 per cent. and upward of carbonate of lime, and the poorer containing less than 90 per cent., with a serious admixture of magnesia.

The common proportions of the charge are about 8 cwt. of ore, 2½ cwt. of limestone, and 3 cwt. of coke. The cinder produced is usually of a light greenish-gray color, strong, somewhat porous, and quite free from iron. An analysis given the writer at his previous visit gave 33 per cent. silica; 23 or 25 per cent. alumina; 30 to 35 per cent. lime; 2 per cent. or less sulphur; ½ per cent. oxide of iron, and the remainder consisted principally of magnesia.

392. The form of blowing-engine in general use is quite similar to that so frequently adopted in the United States. It has vertical cylinders, the steam and blowing cylinders in the same line and their pistons attached to the same rod. Those at Ferry Hill are of 10½ feet stroke, and the steam and blowing cylinders are respectively 67 and 130 inches in diameter. In some cases a peculiarity of general design or of valve-gear may be seen, but the usual practice and the best examples are not noticeably different from those of engineers in the United States.

393. The expense of making iron is less in the Cleveland district, notwithstanding the leanness of the ores, than in any other part of Great Britain or possibly of the world. The ore, as mined, contains, as a maximum, in selected specimens, but 45 per cent. of oxide, or about 30 per cent. metallic iron; the flux is usually somewhat refractory and is not exceptionally rich in lime. On the other hand the one great advantage possessed by iron-makers here is the very excellent character of a fuel which enables them to adopt the maximum size of furnace and temperature of blast which may be, on the whole, used with advantage. It is to these peculiarities, and to the boldness, skill, and experience of their blast-furnace engineers and managers, that their success is due.

The growth in size of furnaces may be seen by the following outline:

The first furnace built here, in 1851, by Messrs Bolckow & Vaughn, was but 42 feet high and of 4,500 cubic feet capacity.

The Clarence works, in 1853, built furnaces 48 feet high, and the largest, fifteen years ago, was but 58 feet high, and of 7,000 cubic feet capacity. Whitwell & Co. built a furnace, in 1861, 60 feet high; Bolckow & Vaughn, in 1862, constructed one 75 feet high and of 12,000 cubic feet contents, and Vaughn soon after ran up a furnace to a height of 78 feet; and the firm, in 1868, built a pair of furnaces of 96 feet height, and of a capacity, the one of 26,000 the other of 29,000 cubic feet. Mr. Cochrane subsequently built the Ormesby furnace of 41,000 cubic feet, and the Ferry Hill furnace of 103 feet height and 33,000 cubic feet capacity. No important increase of economy occurred with these larger sizes, although an increased yield is observable. In other districts furnaces which had been given great height, in imitation of the Cleveland furnaces, have been reduced to 55 and 60 feet height, as it was found that their contents could not sustain so great a burden.

Digitized by Google

At Cleveland the capacity now amounts to from 300 to 400 cubic feet per ton of yield per day. The conclusion of the most experienced iron-masters whom we met confirmed our own conclusion, that, although there is a certain height and proportional diameter of furnace which will be the practical limit as determined in each case by the character of the materials used, that limit is rarely approached until after an economical limit is reached, beyond which it does not pay to enlarge them.

Similarly, the benefit of increased temperature of blast reaches a working-limit within the temperature at which practical difficulties arise in elevating it. When all the escaping gases are thoroughly utilized in the hot-blast stoves and under the steam-boilers, a furnace will usually be found to work with satisfactory economy and without serious difficulty in keeping up, provided it has originally been well designed for its work and properly fitted up.

Cleveland metal sells in the markets at a price which ranges from 15 to 20 per cent. below the price of Scotch and Newcastle irons, but the profits to the iron-masters have always been satisfactory.

394. LANCASHIRE.—This coal-district contains a large number of collieries, of which no small proportion are worked out, and it is here that we are brought most strikingly into view of the possibility of a not distant time when Great Britain shall have exhausted her coal-fields, and with their loss have become a merely agricultural country. The depth to which these shafts are already sunk, even where the mines are still capable of yielding a large supply, is becoming a serious matter, both as affecting the cost of raising the fuel and of keeping the mines free from water, and as affecting the value of a day's work at depths at which the subterranean heat is sufficient to debilitate the workman and at which thorough ventilation becomes a matter of difficulty. The introduction of the pneumatic rock-drill may aid in this matter in a very important degree. By doing the work of several men, this machine permits the atmosphere of the mine to be kept wholesome with a less supply of air; its exhaust of pure air at every stroke at the very extremity of the working insures a certainty of a complete renewal of air, which cannot be attained by any other method; its exhaust of pure air is also rendered intensely cold by its great expansion, and it may be found, possibly, that mines may be worked at vastly greater depths than have previously been thought inhabitable. The great power of penetration—amounting to over 50 feet in ten hours, in some cases, in the hardest granite*—is evidently not the only recommendation of the rock-drill. These tools are used to some extent in England, but less than in the United States. The earlier forms introduced in this country, as the Burleigh and the Ingersoll, are successfully introduced into the market,

* The rock-drill of Professor DeVolson Wood has accomplished this on several occasions, and has drilled 66 feet in limestone and 90 feet in magnetic iron-ore at Mineville, N. Y.

Digitized by Google

and the remarkably effective drill more recently introduced by Professor De Volson Wood, of the Stevens Institute of Technology, has now been patented in Europe, and its beautiful combination of theoretical with practical excellences, its strength and durability, ought to bring it rapidly into use.

Remarks similar to the above apply to the great coal-fields of South Staffordshire. The immense "ten-yard seam" is one of the interesting features of the district. It is usually worked by the "pillar and stall" method; but, when of exceptional depth, it is worked in two parts, called the top and the bottom workings. The pillars are usually about 25 or 30 feet square; the stalls are 150 feet square, the roof supported by four pillars, and the chamber separated by a wall 20 or 30 feet thick from the adjacent stalls. But little trouble is experienced from either fire or choke damp. Deaths occur from this cause in the proportion of about one man to 850,000 tons of coal raised. Near West Bromwich, this seam has been worked at a depth of 1,200 feet. In some parts of the field the receipts from sales have amounted to £20,000 per acre. Coal from this seam was used by Dud Dudley in 1620, and has always been in demand for manufacturing purposes. All of the South Staffordshire coals are of fine quality. The district also yields an argillaceous iron-ore, containing 40 or 50 per cent. of metal, from which is taken about 1,000,000 tons per year.

About 5,000-horse power is required to drain the mines, raising daily 220,000 tons at an annual cost of £125,000, amounting to about 3½*d.* per ton of coal.

There are about 550 collieries at work, raising 10,000,000 tons of coal, of which 9,000,000 goes into market. The district produces 855,000 tons of finished iron per year.

This is the oldest manufacturing district of Great Britain. The Romans worked the mines and made iron in the county, and it was here that Dud Dudley, the pioneer of modern iron-makers, did his work. In 1788, there were no furnaces here melting iron with charcoal, but there were nine using mineral coal. In 1806, there were 222 blast-furnaces in Great Britain, of which 162 were in blast, and 42 were in this district. There are now about 175 here. The larger make 250 tons of iron per week; the average size yields about 150 tons per week.

At Stourbridge, in Staffordshire, is raised the celebrated Stourbridge fire-clay. It has the following composition:

	Silica.	Alumina.	Prot. iron.	Lime.	Magnesia.	Potash.
Sample 1	59.87	33.49	3.01	1.42	0.31	2.21
Sample 2	67.69	27.91	2.35	0.63	0.11	....
Sample 3	70.32	26.42	1.04	0.36	0.43	1.40

It makes excellent fire-bricks and crucibles, burns perfectly white, and makes a fine glass-house clay.

Stone, porcelain, and glass ware form an important class of Stafford-

Digitized by Google

shire manufactures. The potters consume nearly 200,000 tons of clay per year, and export wares of the value of £1,000,000. The Messrs. Chance, of Birmingham, make a large proportion of the finest optical glass in the world. They have supplied glass for all of our very large telescopes.

The whole district is alive with industry. The manufactures are of immense extent and variety. Birmingham is devoted to the manufacture of small articles chiefly, but their variety and importance make this one of the most interesting sections of the country to every stranger who is at all interested in such matters.

395. James Watt & Co.'s Soho Works.—At Soho, near Birmingham, James Watt, with his partner, Matthew Boulton, started the first steam-engine manufactory which ever existed. Watt, the mathematical-instrument maker, driven within the walls of the University by the trades-unions, who wished to prevent his practicing his trade, improved the Newcomen engine and made it the means of reclaiming the drowned-out coal-pits and iron-mines; but he could have accomplished little without the aid of Boulton, the Birmingham maker of toys.

The firm of James Watt & Co. and the Soho Works still exist, although the great founders have long since passed away.

The Soho foundery was completed and business was commenced within its buildings in 1796. Boulton was an active, enterprising, intelligent man, of great boldness and remarkable business capacity. He furnished the capital with which Watt developed his inventions. He was, however, a good mechanic also, and devoted himself to those departments of minor manufacture which brought wealth to Soho before the steam-engine in Watt's hands had begun to pay. He turned his attention to the production of mint-machinery, and Soho has furnished a large proportion of the mint-presses in use in Europe. A large amount of coin was minted at the foundery, and the firm still have their private mint, at which are made the coins of some of those nations, as Siam, which are not yet so far advanced as to have mints of their own. Watt's copying-machine was perfected at Soho, and a process of reproducing oil-painting, possibly a modification of the modern lithographic method, was commenced and worked, apparently with success, but was subsequently suppressed at the desire of Sir W. Beechey.

William Murdock, Watt's foreman and most efficient assistant, introduced the use of gas for illumination in 1802.

From 1797 to 1805 the coinage of copper at Soho amounted to 4,000 tons, valued at £800,000, for the British government alone, and immense quantities were struck off for the East India Company and for foreign nations. The amount coined from 1860 to 1866 is stated as about 3,500 tons, making over 600,000,000 pieces of coin. This early mint was pulled down in 1857, and in 1860 James Watt & Co. built the new mint, which is

Digitized by Google

now at work. There have been sent out to other mints more than a hundred coining-presses.

The works cover ten acres of ground and have produced some 2,000 steam-engines, having a power of probably 300,000 horses. The great screw-engines of the Great Eastern, with steam-cylinders 84 inches in diameter and 4-feet stroke of piston, were built by Watt & Co. They are of above 6,000 horse power.

Visiting those works, so interesting from these historical associations, they were found to be rather pleasantly situated, and better planned than are the larger number of old British establishments of a similar character. The superintendent, Mr. Reed, was very courteous and attentive to his visitors, and kindly showed us every portion of the works. There were employed at the time of this visit about 800 workmen. The tools were usually old; some were built in the time of the great inventor, from Watt's own designs. He seemed to have been remarkably fond of worm-gearing; it was used on nearly all the boring-machines, both horizontal and vertical, and, on some large lathes, mortice-gearing was very generally used.

A large pair of compound marine-engines in the Napier style were in process of construction. Their surface-condensers were given a refrigerating area of about 2½ square feet per horse-power. Four large pumping-engines for the city of Buenos Ayres were the most novel of all the engines building. They were compound, and all steam-jacketed. The steam-jackets were formed by inserting a plain cylindrical casting, or bushing, within the main casting of the steam-cylinder, as is so usually done by British builders of marine-engines. A set of pumps for London sewage was an interesting design. The mint-machinery made here is of excellent proportions and of beautiful finish. The mint, which, as already stated, forms a part of this establishment, strikes 100 coins per minute.

In the boiler-shop several "Martin boilers," similar to those so extensively used in our own Navy during the late war, were in course of construction for the British admiralty. Riveting was done both by steam and by hand. Hand-riveting was sometimes practiced in heading up snap-headed rivets. The boiler-work was usually well done. The snap-head is much oftener used in Europe than in the United States. It is somewhat more troublesome to make by hand than the conical head, but it is stronger.

James Watt & Co. make their own files, not so much with the intention of saving expense as to secure precisely the quality which they desire. They also forge their own bolts and nuts. We saw nowhere in Europe machines designed for this kind of work which appeared as effective as those of Abbe, and of one or two other American inventors.

En route between Yorkshire and the Midland district we passed through that section of the country which has always been well known to engineers and manufacturers in the United States as

Digitized by Google

the seat of manufacture of Low Moor, Bowling, and other brands of the best Yorkshire iron.* At Bowling, the refuse material from the mines has accumulated until it has formed a mountain of no small size.

The Leeds Mercury gives an account of these works, from which we learn the following facts:

The Bowling Iron-Works were originated so far back as the year 1780, although the actual smelting of ores did not commence there until 1788. The works owed their origin to Mr. John Sturges, of Sandal, near Wakefield, who saw that the minerals in the vicinity of the works were of the proper character for the manufacture of first-class iron. Subsequent events have amply justified the choice of the site. In point of antiquity, however, Bowling has to yield to the works of Kirkstall Forge, which claims not only to be the first establishment that used the rolls for slitting iron into nail-rods, but claims also to have carried on that process at so remote a period as 1594. Until the Bowling Works were started, however, the special iron for which Yorkshire is now celebrated was unknown. The first furnace at Bowling was blown in 1788, and is still in being, with the initials "S. S. & Co." inscribed upon its front. This furnace is strong even now in its old age, having the appearance of a fortification that has suffered a violent attack from the enemy, but has strength enough remaining to resist a further onslaught.

The extent of the Bowling Company's estate is exceedingly large. Its collieries extend five or six miles in various directions. In all, the company has 42 pits, worked by over 60 steam-engines, which engines are supplied with steam by 81 steam-boilers, of from 10 to 50 horse-power each. There are tram-ways from all the pits direct into the iron-works, the entrance for the whole of the tram-ways being on the higher ground toward Dudley Hill. The tram-ways cover a total distance of 21 miles, and are worked by means of wire-ropes. With the exception of the limestone, which is procured from the neighborhood of Skipton, nearly all the mineral used in the manufacture of iron at the Bowling Works is obtained from their own mines, and, of course, none of this mineral is permitted to go elsewhere than to the foundery.

Referring to the quality of this valuable mineral, the late Mr. Wilcock said: "The substratum around Bowling is part of the most extensive and valuable coal-field in England, stretching from Derby or Nottingham to this district, a distance of 60 miles, and ranging about eight miles broad." The seam of coal called the "better bed" is one of the valuable elements necessary for the production of the best quality of iron. The stone wears a dark-brown appearance, and yields about 32 per cent. of iron. Both coals are caking coals, and moderately hard. This is the same bed of minerals that the Low Moor and Farnley Iron Companies have at command, their several mineral rights extending to points at which they meet. This is the bed that all the best Yorkshire brands are made from—brands which command far higher prices in the market than the general makes of iron. A Bowling boiler-plate will fetch from £27 to £44 per ton, according to the weight, 2¼ cwt. plates being the minimum, and 7 cwt. and upward being the maximum price; while good Staffordshire plates can be got for about £14 or £15 per ton. This is sufficient to show the great difference that there must be between the Yorkshire iron and the ordinary iron.

In its general features Bowling Foundery is much like other iron-founderies. Here and there are to be seen improvements which are in advance of what is to be seen at other iron-works, but, on the other hand, it is evident that in some things the Bowling Company have been reluctant to make changes. Within the last four or five years,

**Analysis of Bowling irons.*

	Pig metal.	Puddled iron.
Carbon, graphitic	3.155	0.272 (both carbon)
Carbon, combined	.581	
Silicon	1.346	0.000
Sulphur	.070	trace
Phosphorous	.635	0.000
Manganese	1.472	0.000
Metallic iron—		
Puddled		99.727
Pig		99.903

however, many very extensive alterations have been effected, and improvements are at the present time in rapid progress.

There are three entrances to the foundery, the principal one being in Bowling, Buck Lane. Near the entrance gate-way stands a grim, residential-looking building, which has been used as offices in recent years. On the upper ground are received the minerals as they come fresh from the earth. This is the starting-point of the foundery. Here the various elements necessary to the making of iron are brought together and laid in heaps. Numerous trains of coal and iron-stone stand about on the rails, ready for being cast into one or other of the various fires that are burning and smoldering everywhere. There are long lines of cinder ovens and heaps, where the coal is being converted into coke. There are 14 iron-stone kilns, where the iron-ore is roasted. The ore is thrown into the kilns along with an admixture of black bed "breeze." It crumbles away until it reaches the bottom of the kiln, when it is carted away to the furnaces. After the iron-stone has gone through the kiln, the coal through the ovens, and the limestone has been broken into manageable pieces, they are put into capacious iron wagons. There are six cold-blast furnaces at Bowling, five refining-furnaces, 21 puddling-furnaces, and 40 heating-furnaces. The amount of iron made per week is about 360 tons. The largest of the blast-furnaces is a recent addition to the works, and is on an improved principle. It is made of iron, and is of a circular form. The other blast-furnaces are of the ancient kind. The height of the new furnace is 55 feet from the hearth to the filling floor, it being 13 feet higher than the old ones. There is no great gaping orifice exhibited here, as in the other furnaces, all the heat and gas being utilized. The minerals are raised to the top of the furnace by means of a lift. The top is closed in with a circular, cone-like iron covering, which is lifted by a hydraulic lever, and when the cavity round the edge of the cone has been filled with the due proportions of coke, iron-ore, and limestone, the lever is lifted, and down the whole mass descends into the furnace. The gas that is carried off from this furnace is conveyed to the boiler-house adjoining, and serves to feed three boilers and a half—*i. e.*, seven fires. This furnace is certainly one of the most interesting objects to be seen at the Bowling Iron Works.

There are thirteen steam-hammers at the Bowling Iron Works, some of them of a very heavy, ponderous kind. It is the custom to give a premium to the puddlers who produce the best specimens during a turn.

The new plate-mill, built in 1873, is a very noticeable place. It is worked by a pair of reversing engines, on the locomotive principle, by which the necessity of heaving the plate over the top roll of the rolling-machine is obviated. It is stated that in this plate-mill wider plates can be rolled than at any other works in England.

In making what are known as the Bowling iron weldless tires, "stampings" only are used. First, the "bloom" is taken, and a hole about five inches in diameter is made in the center. When this has been done, the ring of iron that has thus been formed is fastened to the back of an anvil, where a flange is raised by hammering it, care being taken by constant rotation to get all the parts evenly worked. The ring then assumes something of the shape of a proper tire, and is finally perfected by being submitted to a rolling process.

The steel-works were commenced in 1866. Siemens's gas process for melting crucible-steel is in operation.

Boiler-making has always been a great feature of the Bowling Iron Works, and a large new boiler-shop has been lately erected, which is capable of turning out from two to three boilers per week. All these shops are fitted up with movable cranes that adapt themselves to any piece of iron or any elevation.

In the making of weldless hoops for boilers there are a great number of workmen employed.

The model-shop is one of the finest shops of its kind to be found. It is a large brick building, two stories in height, and many thousands of models are kept. They are all catalogued, so that any model that is wanted can be found immediately. Among wheels of all sorts and sizes, giants and liliputians, is to be found the original model

Digitized by Google

from which the first wheel for Blenkinsop's locomotive was cast. This has a label attached to it, informing visitors what a very distinguished model it is.

There are altogether between 2,000 and 3,000 work-people employed in the foundery and collieries of the Bowling Iron Company. The total horse-power of the engines employed about the iron-works is about 900, and in providing steam for these engines there are 38 boilers.

At Low Moor, the works seemed still more numerous, and the pile of refuse was even larger. These works have been celebrated for many years for the excellent quality of their boiler-plate and other wrought-iron products. Visiting Low Moor, we found in blast six blast-furnaces of about 40 feet height, working a native clay iron-ore, with coke as fuel and a cold blast. There are employed in the mines and mills about five thousand people, who produce 500 tons of finished iron per day. The pay-roll amounts to about £6,000 per week.

All pig worked in the mills is refined by melting down in open furnaces, using coke as fuel, and running out into flat cakes, which are broken up for the puddling-furnaces. There are six of these refining-furnaces and thirty-five puddling-furnaces. All iron goes from the puddling-furnace to the hammers, of which there are twenty, of several sizes and of various kinds. One steam-hammer will work the puddle-balls of seven furnaces. The manager states that the old style of helve-hammer is generally preferred for this work. It gives invariably the heavy blow required to force the cinder out of the sponge, and the hammer-man *cannot* modify the blow to keep a defective ball in shape. The billets made are piled and again hammered before rolling.

Each furnace usually works off nine heats per day, and ten have been made. The heaviest hammer weighs 12 tons.

The plate-rolls are reversed by a clutch, which is used whenever the weight handled exceeds about 800 pounds.

Nearly all furnaces in this neighborhood are open-topped and are worked with cold blast. At night the whole country seems lighted up by the flames from them and from the numerous coke-ovens scattered thickly in all directions.

396. Scotch iron making and working.—There is little that need be said of Scotch methods of iron-making. We found nothing novel in Scotch practice, either in the building or the working of furnaces. They are never of large size, are usually open-topped, and, when hot blast is used, it rarely exceeds a temperature of 700° or 800° Fahrenheit. The fuel used is raw coal, and its friability limits the height of furnaces usually to less than 60 feet. The whole district contains something less than a hundred and fifty furnaces, and the production is estimated at about 1,500,000 tons annually, the average product being about 200 tons per week per furnace, and rarely much exceeding that amount.

The ore is the remarkable "blackband," and contains 10 per cent. carbon, as an average for rich ores, and the proportion sometimes rises to above 20 per cent. The ore is roasted before charging into the furnace, and it is sometimes found that it contains fuel enough for its calcination without the use of additional fuel. The amount of fuel used in

Digitized by Google

the furnace is, however, very large, probably double that used per ton of iron made in the Cleveland district, and an additional expense is incurred for cheap fuel with which to make steam and to heat the blast.

The pig-iron made is usually a dark, soft, easily-fusible foundery-metal. The grades of Glengarnock, Gartsherrie, Coltness, Eglinton, and one or two others are well known in the Eastern iron-markets of the United States. In the Western States the phosphoritic ores of Tennessee and other districts are capable of supplying quite as good metal for all those purposes for which a fusible, free-flowing iron is required.

The forge-grades are worked into a moderately good but rather cold short iron, and, with the irons from Cleveland, supply the Glasgow and Clyde markets with a considerable proportion of their ship-plates.

397. GLASGOW, AND IRON-SHIP BUILDING.—The receipt of communications from Vienna, immediately after landing at Glasgow *en route* from the United States, indicating a desire that we should reach the former city in time to take part in the preliminaries of jury-work, hastened us away from this interesting district before we had time to do more than take a rapid glance over the ground and make a very brief examination of the work in progress in the city and on the banks of the Clyde, and pay a short visit to the University of Glasgow.

The business of the ship-builders was not as prosperous as it was found at the earlier visit to this place, in 1871. We counted about fifty iron vessels, nearly all steamers, in the yards of builders on the river between Govan and the city, and probably nearly an equal number were in progress in the yards nearer the mouth of the river. All business had received a check which was very seriously felt, and no new contracts were offered or taken. The uncertainty of the direction of the movement of prices, the recent rise in cost of material, and the embarrassment caused by the strikes which had recently taken place here, had completely stopped work, both here and in the districts supplying coal and iron. The work on hand was nearly all on old contracts, and very little new work was anticipated until the cost of both labor and stock should be reduced to a point which would enable building to be resumed with moderate profit.

The consequences of this state of business were exceedingly unfortunate. The unemployed workmen were either lying idle at home, indulging in dissipation, to which they had been before unaccustomed, or were leaving the neighborhood. The result is, as a matter of course, moral depreciation and physical suffering, as well as loss of skill to the workmen and the loss to the country of its best talent and of considerable wealth.

The increase of Glasgow in wealth and population has been very rapid during the last twenty years, and the population now amounts to 600,000 people. The proximity of districts supplying coal and iron, her position at the head of navigation on the Clyde, and, above all, the intelligence, thrift, and energy of her people, have been the prominent causes of her prosperity.

The enterprise and intelligence of the people of Glasgow have been

Digitized by Google

well illustrated in the mannèr in which they have improved their harbor.

The prosperity of a city is seldom dependent upon local natural advantages alone; and the proximity of the iron and coal producing districts of Scotland, her experience in manufacturing, and the advantages arising from the fact that Glasgow is the birthplace of modern British marine engineering, could hardly have given that city her present position as the second in population and the first in the realm in several branches of manufacture, had not her people, long ago, had sufficient foresight and energy to expend enormous sums in the improvement of the water-approaches to the city.

Two hundred years ago the port of Glasgow was on the Ayrshire coast. To-day, ships drawing 23 feet of water can reach the city-wharves.

The work of maintaining and improving the ship-channel below Glasgow is, by act of Parliament, placed in the hands of the Clyde Trust Company, which is controlled by Glasgow capital. This company have expended in this work about $28,000,000, and they are still engaged in this great work, and are removing a million tons from the channel annually. They are permitted, by a special act, to lay a limited tonnage-tax on all vessels, and their income from this source has risen from $286,487, in 1840, to $493,346, in 1870. The registered tonnage of vessels at the port of Glasgow now exceeds 5,000,000 tons annually.

398. Iron-ship building.—This industry, although its history dates back many years, is really but of very recent general introduction. At the beginning of the present century, Lord Dundas built an iron boat for the Caledonia Canal, and occasionally an iron vessel was built in succeeding years. The "Great Britain," built nearly thirty years ago, was the first large sea-going vessel ever constructed, and the success of that venture probably determined the rapid introduction of iron hulls which has subsequently taken place.

The advantages possessed by iron over wood are very great, and the disadvantages, although in some respects serious, are, nevertheless, not sufficient to counterbalance them. The value of iron in ship-building is now universally recognized.

Wood has the advantage, with us, of being well adapted to the resources of our naval and private shipbuilding-yards. The coppered hull is less liable to become foul at sea and to impede the vessel. Minor repairs can be made promptly and at little expense. For naval vessels, its penetration is less liable to prove a source of danger when shot strike beneath the water-line, and, aside from the presence of water-tight bulkheads, it is perhaps safer when struck by a ram or by a torpedo. It has the disadvantage of being vastly less strong and in being quite incapable of giving that strength of joints and at points of contact of distinct members given by iron, and it is necessary to make the hull very much heavier than in iron. These facts place an early limit to the increase

Digitized by Google

of size of vessels which is so remarkable a feature of recent naval architecture. It decays very rapidly, particularly if the timber is unseasoned, and is exceedingly treacherous. It absorbs water after a time, and the vessel becomes slower and of deeper draught, and loses cargo-carrying capacity equal in amount to the weight of water absorbed.

In naval vessels, except in the case of teak, it injures the armor-plating by promoting oxidation, both by the direct action of the acids contained in the sap and by the galvanic action induced by the voltaic influence of the copper-sheathing. When iron is near or in contact with the sheathing, it fouls even more rapidly than an iron vessel. Its seams are liable to start in a heavy sea or on striking, even though without great violence, upon shoals or rocks, and, in bad weather, the seams at the stern are peculiarly liable to become loosened by the vibration of the screw as it leaves the water and is suddenly plunged in again by the pitching of the vessel. In iron-clads it is impossible to caulk seams covered by plating, and the defect of strength already noted prevents preservation by removal from the water, either in dry-docks or in slips. The liability to loss of wooden vessels by fire is a very serious objection to them.

Iron has the advantage of being more readily procured, promptly, and of any specified quality for work of any size or kind. It may be examined in the structure with convenience and with confidence that its condition may be accurately ascertained. It may be given any form that may be desired, and without loss of strength. It may be united firmly by welding or by riveting, and the strength of the joint may be known with an approximation to correctness. It makes a lighter as well as a vastly stronger hull, is capable of being put into place with any desired rapidity, and the vessel, once constructed, has vastly more durability than a wooden ship. Repairs are less frequently required and can be more thoroughly made than in wood. The shaking of the screw or the shock of a projectile is not likely to start seams or to produce other than local injury, and even the iron vessel is driven on shore it is less certain to go to pieces than the wooden vessel. The "Great Britain" lay several weeks on the coast of Ireland, exposed to the storms and waves of the Atlantic, and was finally brought off, and is still a sea-going steamer. The convenience with which efficient water-tight compartments may be fitted is a very essential and peculiar advantage in iron shipbuilding. Freedom from danger of loss by fire, convenience of cleaning when foul, and unlimited endurance of the greater portion of the structure are important advantages.

The disadvantages attending the use of iron are the rapid fouling of the hull, except under peculiarly favorable circumstances, the cost of docking and frequent repainting, and, more serious than all else, the danger of the loss of iron ships by changed course, produced by the variation of the compass from local attraction. They are also peculiarly liable to injuries of kinds which are very difficult to repair promptly when in collision with other vessels or when struck by shot.

Digitized by Google

An iron vessel may safely be given much greater length and much finer lines than a wooden ship, and if laid up the hull and machinery can be preserved indefinitely without serious injury.

Formerly a considerable amount of iron shipbuilding was done in other parts of Great Britain, and the yards of the Tyne and the Mersey still retain some business, but the Clyde has acquired by far the greater part of the trade of the country.

In 1870 about 180 vessels, having an aggregate registry of nearly 200,000 tons, were built here. In the year 1869, the number built was 180 and the tonnage 160,000, almost all steamers.

In 1873 there were built 194 vessels, having 261,500 tons total burden; and for 1871 and 1872 the figures were 196,200 and 224,000 tons, respectively. These vessels cost about £16 per ton as an average price for slow steamers to carry freight, and from £20 to £25 per ton for fast transatlantic passenger-ships.

399. THE FAIRFIELD WORKS, formerly Elder & Co., and earlier, Randolph, Elder & Co., were among the pioneers in the introduction of the now familiar iron steamer with compound engines and the peculiarities of engineering practice which distinguish them.

Among the successful vessels built by them nearly twenty years ago were the steamers of the Pacific Steamship Company, plying on the western coast of South America. They formerly built engines having high and low pressure cylinders whose pistons were coupled to cranks set opposite each other. They now build the so-called "Napier style," in which the cranks are placed at right angles, and which are thus made as simple in form, as light, and as cheap as the earlier style of low-pressure engine which they displaced. The firm have now the largest establishment on the Clyde, and can lay down fourteen ships at one time. A fine new engine-building establishment has recently been completed, and has capacity sufficient for the employment of between two and three thousand men. The building is very large and is well constructed The light tools are all placed on galleries which run across the building at the lines of posts carrying the roof. Many of the largest and most successful transatlantic steamers have been built here. Among them. are several vessels of the National and the Anchor lines.

The Italy is one of the most successful of the former. That vessel makes her passages in from ten to twelve days, on a consumption of from 500 to 600 tons of coal, and an indicated power of about 2,000 horses. The vessel registers 3,700 tons.

The Bolivia, of the Anchor line, is 410 feet in length, of 40 feet beam, and of 4,250 tons burden. The displacement is nearly 8,000 tons.

These long ships are rapidly coming into favor. They carry their cargoes at comparatively small expense, make their trips with regularity and at high speed, and are found to behave well in the worst of weather. Such vessels, with machinery disabled and once in the trough of the sea, are less easily cared for than shorter ships, but they ride well

Digitized by Google

with the sea on the bow, pitch and "scend" very little, and seem to roll very little, if any, more than vessels of the older proportions. Where not built of good iron and where the work on the hull is not well done, they are very apt to start the vertical seams amidships and to become leaky, or even to founder, as one or two have actually done. When this happens, however, it is good evidence of bad material or bad workmanship, or both; it is the evidence of faults of construction which are inexcusable. Messrs. Elder & Co. have always been well known for good work. They have employed as many as 6,000 men.

Nearer Glasgow, and on the Govan side of the river, is the establishment of Messrs. *J. & G. Thompson.* They have built the excellent steamers of the Cunard line. They can employ from 2,000 to 2,500 men. During the late civil war, this firm built some of the fastest and most successful of the blockade-runners.

An older and a well-known firm, having its works still farther up the river, is that of Messrs. *R. Napier & Sons.* The machine-shops of the firm are in the city. The ship-yard is quite large and is well arranged. The firm has for many years been one of the few firms intrusted with the building of the naval vessels of Great Britain. Its founder, Sir Robert Napier, was one of the earliest and greatest of the steam-engine-builders of Great Britain. It is here that the Napier style of compound engine, which is now almost exclusively adopted, was first built.

400. A few firms on the other British estuaries are doing work which should interest every visitor from the United States. On the Tyne, below Newcastle, are the works of the Messrs. *Palmer & Jarrow.* It was here that some of the latest and finest steamers of the Guion line were built. The Palmer Shipbuilding Company have a very large establishment. It includes several blast-furnaces, a large rolling-mill, machine-shops and founderies, and a ship-yard. The number of men employed in busy times was stated at 6,000. This firm also have built some naval vessels, among which the most interesting are the sister-ships Triumph and Swiftsure. The iron hull in these ships was covered with a wooden sheathing, over which the copper sheathing was fastened. This plan is not likely to be frequently adopted, for the reasons already given in the comparison of the relative advantages and disadvantages of wood and iron.

Some shipbuilding is also done on the Wear, the Tees, and the Mersey.

At Birkenhead, opposite Liverpool, are the works of the Messrs. *Laird,* who are best known to Americans as the builders of the Alabama, the confederate cruiser which, after a long career of successful privateering, was finally sunk, after a short fight, by the United States steamer Kearsarge. The firm had, in former times, been very prosperous, but its most successful days are probably gone by.

401. The relative merits of the compound engine and the engine of older type have already been considered in that portion of the report on

Digitized by Google

the Vienna Exhibition which treats of marine-engines. A good marine steam-engine of the form which was considered standard fifteen or twenty years ago, having low-pressure boilers carrying steam at 20 or 25 pounds pressure as a maximum, expanding twice or three times, and having a jet-condenser, would require about 30 or 35 pounds of feed-water per horse-power per hour; substituting surface-condensation for that produced by the jet brought down the weight of steam used to from 25 to 30 pounds; increasing steam-pressure to 60 pounds, expanding from five to eight times, and combining the special advantages of the superheater and the compound-engine with surface-condensation, has reduced the consumption of steam to 20, or even, in some cases, 15 pounds of steam per horse-power per hour. Messrs. Perkins, of London, guarantee to furnish engines capable of giving the horse-power with a consumption of but one and a quarter pounds of coal. Mr. C. E. Emery, who is one of the most successful designers of compound engines in the United States, reports the United States revenue-steamer Hassler to have given an ordinary sea-going performance which is probably fully equal to anything accomplished abroad. The Hassler is a small steamer, of but 151 feet length, 24½ feet beam, and 10 feet draught. The engines have steam-cylinders 18.1 and 28 inches diameter, respectively, and of 28 inches stroke of piston, indicating 125 horse-power; with steam at 75 pounds pressure and at a speed of but 7 knots, the coal consumed was but 1.87 pounds per horse-power per hour. This is the best performance of which we have record.

402. THE BRITISH NAVY.—The International Exhibition of Vienna gave the visitor no idea of the relative power of European navies, and it requires a visit to the dockyards of Great Britain, and to the great steam-engine-building establishments which furnish machinery for the royal navy, to give a conception of the magnitude, cost, and strength of the navy of this most powerful of all maritime countries. The little model of a naval engine exhibited in Group XIII at Vienna gave as little idea of the character of naval machinery as did all other naval exhibits of other classes of naval material.

The British navy now contains between six hundred and seven hundred vessels. All recently built are iron steamers, and about forty of them are iron-clads. The modern iron-clad is necessarily an iron vessel. No structure of wood, or any material of less strength than iron, could be made capable at once of sustaining the immense weight of armor now considered necessary and the tremendous strain of the 8,000 horse-power or more which drives them at such high speeds as fourteen or fifteen knots an hour, or of giving anything like this speed with the weight of machinery which could be carried. Of these iron-clads a large majority are broadside vessels, but the usual form, as now built, is the turret iron-clad, or monitor type, first introduced into the United States Navy when Capt. John Ericsson designed, and Mr. T. F. Rowland built, the Monitor which saved our fleets from destruction by the Merrimac.

Digitized by Google

The thickness of armor carried varies from $4\frac{1}{2}$ inches in the ships built after the Crimean war to 24 inches in the later ships, backed usually with a considerable thickness of teak. The heaviest plating on broadside vessels is that of the Hercules and the Sultan, which has a maximum over the battery and at the water line of 9 inches. These vessels have the heaviest armament, although not the heaviest guns. They carry eight 18-ton rifles of 10-inch bore, two 12-ton rifles of 9-inch caliber, and four $6\frac{1}{2}$-ton rifles of 7-inch bore. These are all of the kind made at Woolwich, and closely resemble the Armstrong gun. Their structure is somewhat peculiar, and their lightness in hull and machinery is as remarkable as their strength and power.

403. This extreme lightness in machinery has been the result ot very careful and skillful designing, of intelligent construction, and of care in the selection and use of material. British builders had, until after the introduction of these later types of vessels of war, been distinguished rather by the weight of their machinery than for nice calculation and proportioning of parts. Now the engines of the heavy iron-clads are models of good proportions, excellence in materials, and of workmanship which are well worthy of study. The weight per indicated horse-power has been reduced from 400 or 500 pounds to less than half that amount within the last ten years.

This has been accomplished by forcing the boilers—although thus, to some extent, losing economy—by higher steam-pressure, a very much higher piston-speed, reduction of friction of parts, reduction of capacity for coal-stowage, and exceedingly careful proportioning.

The reduction of coal-bunker capacity is largely compensated by the increase of economy secured by superheating, by increased expansion, elevation of piston-speed, and the introduction of surface-condensation. A few vessels have been fitted with compound engines.

404. The improved structure of both hull and machinery may be best illustrated by an account, in some detail, of the iron-clad Monarch, the fastest and one ot the most formidable of the vessels designed by Mr. E. J. Reed, formerly the chief constructor of the British navy. This vessel is a turreted iron-clad, built in competition with the designs furnished by the Lairds for that unfortunate ship the Captain, subsequently lost by capsizing in a gale of wind in the Bay of Biscay.

The writer was sent by the Navy Department to inspect the Monarch on the occasion of her arrival in the United States with the body of the distinguished philanthropist George Peabody, and was then and subsequently able to secure very complete data of construction and performance,* the most essential of which are here given.

405. CLASSIFICATION OF WAR-VESSELS.—It is only recently that the attempt seems to have been made to determine a classification of war-vessels and to plan a naval establishment which shall be likely to meet

* For a more complete description, with illustrations, see a paper by the writer in the Journal of the Franklin Institute, 1870.

Digitized by Google

fully the requirements of the immediate future. It has hitherto been customary simply to make each ship a little stronger, faster, or more powerful to resist or to make attack than was the last. The fact that the direction of progress in naval science and architecture is plainly perceivable, and that upon its study may be based a fair estimate of the character and relative distribution of several classes of vessels, seems to have been appreciated by very few.

In the year 1870 the writer proposed* a classification of vessels other than torpedo-vessels which has since been also proposed in a somewhat modified form by Mr. J. Scott Russell.† The writer then remarked that the increase so rapidly occurring in weight of ordnance and of armor and in speed of war-vessels would probably soon compel a division of the vessels of every navy into three classes of ships, exclusive of torpedo-vessels, one for general service in time of peace, the others for use only in time of war.

"The first class may consist of unarmored vessels of moderate size, fair speed under steam, armed with a few tolerably heavy guns, and carrying full sail-power.

"The second class may be vessels of great speed under steam, unarmored, carrying light batteries and as great spread of canvas as can readily be given them; very much such vessels as the Wampanoag class of our own Navy were intended to be—calculated expressly to destroy the commerce of an enemy.

"The third class may consist of ships carrying the heaviest possible armor and armament, with strongly-built bows, the most powerful machinery that can be given them, of large coal-carrying capacity, and unencumbered by sails, everything being made secondary to the one object of obtaining victory in contending with the most powerful of possible opponents. Such vessels could never go to sea singly, but would cruise in couples or in squadrons. It seems hardly doubtful that attempts to combine the qualities of all classes in a single vessel, as has hitherto been done, will be necessarily given up, although the classification indicated will certainly tend largely to restrict naval operations."

The introduction of the stationary, the floating, and the automatic classes of torpedoes and of torpedo-vessels has now become accomplished, and this element, which it was predicted by Bushnell and by Fulton three-quarters of a century ago would at some future time become important in warfare, is now well recognized by all nations. How far it may modify future naval establishments cannot be yet confidently stated, but it seems sufficiently evident that the attack, by any navy, of stationary defenses protected by torpedoes is now quite a thing of the past.

It may be perhaps looked upon as exceedingly probable that torpedo-ships of very high speed will yet drive all heavily armored vessels from

* Journal Franklin Institute, 1870. H. B. M. S. Monarch.

† London Engineering, 1875.

Digitized by Google

the ocean, and complete the historical parallel between the man in armor of the Middle Ages and the armored man-of-war of our times.

406. The following is a brief description of the most important features of construction of the Monarch, above referred to, and of her machinery, armor, and armament:

The hull of the Monarch is of iron, and is built on what is called by Mr. Reed the "combined longitudinal and bracket-plate system."

Its length is 330 feet, beam $57\frac{1}{2}$ feet, and depth about 36 feet. The mean draught is $24\frac{1}{2}$ feet, measured tonnage 5,102, and displacement 8,100 tons. The iron is all of good quality, having a tenacity of over 50,000 pounds per square inch and extensibility of nearly one-fifth. A double bottom extends under the whole space occupied by engines and boilers, and up as high as the lower edge of the armor; the bow retreats as it rises above water, and below the surface it is well strengthened to serve as a ram; the stern-overhang is brought down to the water-line and armored, in order to protect the rudder-head.

The vessel is ship-rigged, carrying about 21 square feet of canvas to each square foot of midship-section, giving a large aggregate but small proportional spread of sail. The outside plating of the hull varies in thickness from $1\frac{1}{8}$ inches in the garboard-strakes to $\frac{13}{16}$ and $\frac{3}{4}$ on the lightest portion of the side.

The armor-plating is 7 inches thick along the water-line and 6 inches on exposed portions of the hull that are included between two armored athwartship's bulkheads, which inclose the bases of the turrets and the "funnel." The other parts of the hull are unarmored, except that casemates are raised forward to protect two guns pointing ahead, mounted under the forecastle, and aft also, to protect a single gun firing directly astern.

The armor is backed by 12 inches of teak, and supported by the inner $1\frac{1}{2}$ inches iron skin-plating in two thicknesses of $\frac{3}{4}$ inch each. The inner skin is stiffened behind the armor by the ship's frames, 10 inches deep and 2 feet apart, and also by longitudinal frames riveted to the skin outside and imbedded in the backing, but not in contact with the armor-plating.

The athwartship armored bulkheads have 5-inch armor, backed with 10 inches of teak and a supporting inner skin.

The double bottom is made water-tight, and is divided into compartments like the hull itself; it is also provided with means for filling and emptying each of its compartments as may be necessary to ballast or to trim the ship; its greatest value consists in the safety which it affords against loss of the vessel from injury to the outer skin by the bow of an enemy, by torpedoes, or by striking a rock.

Heavy stringer-plates are worked on each deck, and the spar-deck is wholly of $\frac{1}{2}$-inch iron, with a covering of wood. Above the double bottom, the ordinary transverse framing is adopted. A wing-bulkhead lends additional security by strengthening the hull and resisting shot capable of penetrating the side armor.

Digitized by Google

The hull is divided transversely by several water-tight bulkheads. One of these bulkheads is placed near the bow, in order that, should the bow be strained or torn open by a collision, the ship may still float safely; another is built at the screw-shaft stuffing-box near the stern, two inclose the engine-room, two others inclose the boiler-space, and another divides it equally; others inclose the magazine and the holds. All openings in these bulkheads have water-tight sliding iron doors fitted.

There is no external keel, its absence being pretty nearly compensated, perhaps, by the "bilge keels." A "balanced rudder,"* similar to those so long used in our own Navy, is fitted, and its weight is taken on a set of conical rollers at the rudder-head. Double chain-riveting is employed in butts and laps throughout the hull. The weight of the hull without armor is given at 3,674 tons, and the weights carried at 4,632 tons. The load-draught is 22½ feet forward and 26¼ feet aft. The cost of the hull was not far from £300,000.

407. The turrets of the Monarch are 26½ feet in diameter, plated with 8-inch iron, backed with 10 inches of teak and an inner 1¼-inch iron skin; they are strengthened by girders in the same manner as the side armor of the hull.

On the side in which the ports are cut, the outer plating is 10 inches thick; these plates are 19 feet long.

The turrets rest upon 32 conical rollers, bearing on a circular bed-piece fitted upon the main deck; they rise through the upper deck to a sufficient height to allow the line of fire of their guns to clear that deck, and are only armored where exposed above the upper deck.

The turrets are turned either by hand-power or by a pair of engines of about 10 inches diameter of cylinder and 12 inches stroke of piston.

The turrets may be turned completely around in slightly more than a half minute. The pilot-house or "conning-tower," as it is called, is separate from the turrets, and immediately forward the funnel, an arrangement vastly less convenient in action than that adopted in our monitors. It has no sight-holes, but a reflecting mirror may be used above its open top, to obtain a view of the enemy; otherwise the head must be raised above the protecting shield.

The guns are carried 4 feet above the level of the spar-deck, or 16 feet above the water. The bulwarks are hinged, and in action are let down out of the way of the guns.

The armament of the Monarch consists of seven guns, two twelve-inch rifles in each turret, two seven-inch rifles in the forward casemate firing ahead or on either bow, and one seven-inch rifle in the after casemate pointing astern.

The twelve-inch guns weigh 25 tons each and throw shot weighing

* The balanced rudder was used many years ago on the ferry-boats built under the direction of Robert L. Stevens, for the ferry between New York and Hoboken. It is also used on the fastest iron-clad yet designed, the Stevens Iron-clad Battery.

Digitized by Google

600 pounds with an initial velocity of 1,212 feet per second and an energy of 6,145 foot-tons, the charge of powder weighing 70 pounds. At 70 yards they are capable of driving their shot through 13½ inches of iron; their range at 10° elevation is 4,000 yards, or 2¼ miles, and at the proving-station a maximum range of 5½ miles has been obtained.

The turret-guns cannot be trained directly forward or right aft, being restricted in lateral training by the forecastle and other obstructions; the forward turret has been trained to within 19° of the line over the bow, while the after-turret guns train within 14° of a line running aft with the keel.

The seven-inch guns weigh 6½ tons each, and, with their regular charge of 22 pounds of English L. G. R. powder, throw a shot weighing 115 pounds, with an initial velocity of 1,425 feet per second and an energy of 1,650 foot-tons, this energy becoming reduced at 1,000 yards to 1,140 foot-tons. They are capable of penetrating nearly 9 inches of iron.*

All of these guns are of the regular Woolwich pattern, consisting of an inner tube of "Firth steel," re-enforced by two iron cylinders or bands shrunk one over the other. The twelve-inch guns are rifled with 9 grooves, making one revolution in 50 feet. The shot from the seven-inch rifles turns once in 20½ feet. The twelve-inch guns have a preponderance of 6 cwt. and the seven-inch guns of 3 cwt.

The ports in the turrets are cut very small, and, in consequence, a very novel method of obtaining elevation and depression of the turret guns is resorted to. The carriages of the guns are of iron, very similar in form to those used in our service. The compressors are made like those which were years ago fitted to heavy guns in our monitors by Captain Ericsson, consisting of a set of timbers lying under the carriage parallel with the slides of the gun, which are simultaneously clamped by a single motion of the compressing-gear, the friction between the beams and the jaws of the clamps resisting the recoil.

The device for elevating and depressing the guns referred to above consists of an arrangement of screws and hydraulic cylinders by which the gun is raised bodily in its carriage to obtain depression or dropped to obtain elevation. It requires five or seven minutes to raise the gun from the extreme of 15° elevation to the other extreme of 7° depression.

408. The engines are of the "back-acting" or "return-connecting-rod" type, steam-jacketed, and with surface-condensation, built by Messrs. Humphreys, Tennant & Co.

They have cylinders of 120 inches diameter, 4 feet 6 inches stroke of piston; their nominal horse-power is 1,100, and they have worked up to more than 8,100 indicated horse-power.

---

* The following formula was constructed by the writer as approximately determining penetration: With Palliser chilled shot, $P=\sqrt{\frac{W V^2}{400,000 d}}$, where P = penetration of armor-plate in inches. W = weight of shot. V = its velocity on striking. d = its diameter.

The main valves are the common double-ported slide, balanced by a ring on the back; they are worked by a link-motion. The balance-ring moves with the valve, the wearing-surface being upon the valve-chest cover.

The expansion-valve—a gridiron-valve driven by an independent eccentric—is rendered adjustable by a half-link.

The steam-chest cover and cylinder covers are steam-jacketed. The main links are of the solid or "sector-bar" pattern, and give perfect satisfaction.

The outboard-cylinder heads are fitted with stuffing-boxes to accommodate 20-inch half-trunks, which it has been found necessary to add, in consequence of the fact that the great pistons cannot support their own weight—8 tons each—without seriously injuring the cylinder. The cross-head is fitted with "slipper-guides."

The surface-condensers are arranged, as is very usual in English engines, with vertical tubes ⅝ inch diameter, 6 feet long, water outside and steam within; they contain 16,500 square feet of condensing-surface, equal to about 18⅓ square feet of surface to each foot of boiler-grate surface, or equal to about two-thirds the heating-surface. The vacuum obtained during a run down Chesapeake Bay was 27½ inches, as noted by the author, without using the jet injection, which is also fitted.

The main links are moved by a pair of reversing-engines mounted on the platform over the large engines; reversing occupies about fifteen seconds.

All the work is well done; very little, however, is highly finished.

The engines drive a two-bladed Griffith screw of 23½ feet diameter and 26 feet 4 inches mean pitch, expanding 5 feet. Its apparent slip is about 9 per cent., and it works with very little shake; it does not lift. A "separator" is attached to the steam-pipe near the engines. The crank-shaft journals are 3½ and 4½ feet long, and usually run without water, unless at full speed; the lubricant is Rangoon oil. The cranks carry heavy counterbalances, and at 40 revolutions, the highest number made under our observation, the engines turn their centers very smoothly.

The boilers are of the horizontal tubular kind, and have 20,900 square feet of heating-surface, 3,600 feet of superheating-surface, and 900 feet of grate-surface, or 27.2 square feet of total heating-surface to the square foot of grate. The boiler-tubes are 2½ inches by 8 feet; the superheating-tubes are 4 inches diameter by 2½ feet long. The dampers are so arranged that the gases may be sent either through the superheaters or to the smoke-pipe direct. The "funnel" is oval in section, with a cross area of about 125 square feet, or one-seventh the grate-surface. The superheating-surface is said to be ample, and the draught, which at full power is urged by blowers forcing air into the boiler-room, is all that is desired. The coal-bunkers are behind and at either end of the boilers, and the coal is transported without difficulty in large buckets,

Digitized by Google

carrying 400 pounds each, which are suspended from a carriage running on an overhead tramway.

The ashes are thrown overboard by a steam-jet which acts like the steam-jet pump which is sometimes fitted on board steam-vessels as a bilge-pump. It is said to work well.

The engines and boilers occupy a length in the ship of 135 feet and a breadth of 45 feet. The following are their weights:

	Tons.	Cwt.	Qr.	Lbs.		Tons.	Cwt.	Qr.	Lbs.
Engines	318	5	2	5¼	Spare articles and gear	52	9	3	4½
Boilers	355	19	3	22¾	Water in boilers	159	11	3	23
Screws	14	19	0	6¼	Water in condensers	45	0	0	0

The total of all weights in the engineer's department, exclusive of 600 tons of coal and inclusive of bunkers, floor-plates, and fittings, is 1,136 tons.

The engines and boilers and all their appendages were built, placed in the ship, and the cost of steam-trials defrayed by the contractors for the sum of £66,500, an extremely low price when compared with the expense of building machinery in this country, but not so surprising when it is known that the best class of mechanics are paid but seven or eight shillings per day in England, and the cost of stock is pretty closely proportioned to the prices paid for labor.

409. The performance of the Monarch is satisfactory under sail or steam. When under sail she carries 20° weather-helm with the screw dragging, but with the propeller disconnected it reduces to 7°. Though carrying but two-thirds the amount of sail that is usually given men-of-war, she has made eleven knots under sail alone. The Monarch is a remarkably steady ship, dry in the heaviest weather, yet pitching very little; her maximum roll is stated at 21°. The guns were worked without serious inconvenience during a gale in the Bay of Biscay, when no one of the half-dozen broadside iron-clads in company could fire a gun.

Under steam, and on the measured mile, with a displacement of 8,070 tons, midship section 1,208 square feet, and mean draught of 23 feet 1 inch, a speed of 14.937 knots on an average horse-power of 7,843—maximum 8,139—was attained, the steam-pressure being 31½ pounds, revolutions 63.61—maximum 65—and coal-consumption about 2⅝ pounds per horse-power per hour. The formula—

$$\text{“}\frac{V^3.\ M}{I.\ H.\ P.}\text{” gave a co-efficient of 513.4, and “}\frac{V^3\ D^{\frac{2}{3}}}{I.\ H.\ P.}\text{” gave 171.}$$

On a six-hours' trial the results were as follows: Speed, 14.715 knots; I. H. P., 7,470; steam-pressure, 30.58; revolutions, 62.67; coal per H. P. per hour, 2.789; co-efficients of performance, 515.3 and 171.6. These co-efficients are low, but that fact is not discreditable to the designer, as it was considered advisable to sacrifice something in this respect, in order to obtain a cheaper and "handier" ship, and the lines were therefore made rather full.

Digitized by Google

The Monarch can steam 125 hours at 12½ knots; 210 hours at 11 knots, or 475 hours at 8 knots nearly, running distances of 1,600, 2,310, and 3,800 knots before consuming her 600 tons of coal. Acting as a ram, the Monarch has an "*energy*" of 33,415 foot-tons at 12½ knots, 25,200 foot-tons at 11 knots, and 13,040 foot-tons at 8 knots, or a destructive power, at those speeds, equal to 5½, 4, or 2 Woolwich 600-pounders simultaneously discharged against the same spot.

The magnetism of the Monarch has now become permanent in amount and distribution, with a *maximum* deviation of the standard compass of 10° 30′, and the course may be laid with all the certainty that could exist in any wooden ship.

In conclusion, although we may agree with the designer of the Monarch, who, after the designs had been issued and the ship laid down, stated his conviction that "no satisfactorily designed turret-ship with rigging has yet been built or even laid down," and though we may go even further and assert that, very probably, none ever will be designed it must be admitted that the Monarch is a very effective and powerful fighting machine. Her speed is greater than that of any war-vessel in the world, with the exception of one or two broadside-ships recently built in England; her armor, though not impenetrable, will yet enable her to fight a considerable time in an action in which she may usually choose her own position, without probably receiving vital injury; her guns have the greatest penetrating power of any yet worked on shipboard, and they can be worked in any weather, while their height above water gives them advantages, in other respects, that should not be underestimated. Her power as a ram is immense, and her construction is such as will enable her, with tolerable safety, to make use of that power. Her spread of sail, though comparatively small, will enable her to circumnavigate the globe, if required, independent of steam. On the other hand, the ship is large, costly to build, and expensive to keep afloat; she is not impenetrable to the heavy guns of the present day, to say nothing of those next year or of the next decade; she is seriously restricted in lateral range of guns, carries comparatively little coal, and is liable to become completely disabled by the fouling of the screw by rigging shot away in action, a danger shared, of course, by all masted vessels. In our harbors, her great length and depth would be fatal disadvantages.

410. BRITISH NAVAL POLICY.—Great Britain has a definite naval policy which is carried out with tolerable consistency. In her liberal action and intelligent appreciation of the importance of the improvements which are continually being made in naval engineering, including architecture and ordnance, that nation exhibits a marked contrast with the United States. The British navy is greatly increased by the construction of new vessels, and it has been the declared policy of the admiralty to build annually about 20,000 tons, of which about 10,000 or 12,000 tons are to be armored. While keeping up her fleet, however,

Digitized by Google

the fact that we may be approaching a complete revolution in naval methods of warfare is not lost sight of, and the administration is not only steadily and carefully following a system of experiment with the various forms of torpedoes, but officers of the navy and government officials in foreign countries are continually watching naval movements in those countries, and, in some cases, officers are detailed to the special duty of observing and reporting upon everything of interest and all novel and promising improvements. So intelligent a policy must inevitably produce satisfactory results in increasing the efficiency and the economy of naval administration.

411. LATER VESSELS.—Until the Monarch was built, there were no monitors in the British navy. Since the successful performance of that and of other turreted ships, several very formidable ships have been laid down.

The most powerful of these iron-clads are the Devastation, the Thunderer, and the Fury; and the latest and most formidable of all is the Inflexible. The former are 285 feet in length, 62½ feet beam, and 26 draught. They are registered as of 4,406 tons burden. Their side-armor is 12 inches thick in single thickness along the water-line and on breastworks and somewhat thinner below water. The armor rests on teak-backing 18 inches thick, and an inner skin 1½ inches thick. The deck rises 4½ feet above water. The turrets are 31 feet in diameter, armored with 14-inch plates on the side through which the ports are cut, and 12 inches on other parts, backed with 15 and 17 inches of teak on an inner 1½-inch skin. The bow is strengthened to be used as a ram. These vessels carry each four 35-ton twelve-inch rifles in two turrets, at a height of twelve feet above water. The shot weigh over 600 pounds, and are propelled by 100 pounds of powder, like that used in the 70-pound cartridges of the Monarch's guns. The vessels have a speed of 12½ knots per hour, and carry 1,600 tons of coal, a quantity sufficient for ten days' steaming; they have twin-screws, driven by engines of 800 nominal horse-power, collectively.

The Inflexible, the most powerful British iron-clad yet designed, has recently been laid down. This vessel is 320 feet long, of 75 feet beam, and about 25 feet draught, displacing 11,000 tons. The hull is somewhat similar to that of the Monarch in construction, but "low steel" is used in the frames. The battery is to consist of four 81-ton guns of the Woolwich pattern, each throwing a shot weighing a half ton, with, probably, an initial velocity of nearly 1,500 feet per second. Two are mounted in each of the two turrets, and the line of fire of all can be directed directly forward, directly aft, or on either beam. At certain angles the turrets come in line, and the sweep of one pair of guns is interrupted for a limited angle of training. This peculiar arrangement is secured by placing the turrets one on each side of the immensely wide deck, and the one abaft the other, so that, when firing on the one beam, the line of fire of the one turret is ahead of the other, and, while

Digitized by Google

firing on the other beam, the line of fire of the second passes aft of the first turret. Firing ahead or astern, the removal of the turrets from the center-line of the ship gives them ample clearance. The turrets are protected by armor 2 feet in thickness, and are carried above a rectangular box 110 feet long, also armor-plated, and protecting the machinery and other essential portions of this fighting machine. The remaining portions of the vessel, forward and aft the armored bulk-heads which terminate this fighting house, are unarmored, but are divided into numerous compartments by water-tight bulk-heads. The armor is backed by 17 inches of teak. The "ram" extends 15 feet in advance of the bow. Deck-houses extend along the middle line of the vessel and between the fore and aft lines of fire of the guns. In these are accommodations for the crew. The engines are expected to develop over 8,000 horse-power and to drive the ship 14 knots, or nearly sixteen and one-half statute miles, an hour. The coal-bunkers will store 1,200 tons of coal, which will suffice for five days' full steaming, carrying the ship something over fifteen hundred miles, or, at 10 knots, across the Atlantic, leaving a reserve in the bunkers. As the later British ships have usually, on trial, been found to come well up to the estimates of their designers, this vessel will probably prove by far the most formidable vessel afloat. The only defect is in speed. The Monarch has steamed 14.9; the Wampanoag class of the United States Navy and the iron-clad designed by Robert L. Stevens and reconstructed by General McClellan and Mr. I. Newton will steam about 17 knots at load-draught.

The cost of the Inflexible is stated at between £500,000 and £600,000.

412. Sir Joseph Whitworth & Co., machinery and gauges.—The establishment of Sir Joseph Whitworth & Co., at Manchester, is among the few well known to American engineers.

Sir Joseph Whitworth was one of the first to introduce fine workmanship, accurate fitting, and precise measurement into the manufacture of tools and general machinery. Many years ago he constructed measuring instruments capable of indicating dimensions correctly within the ten-thousandth of an inch. He introduced systems of screw-threads and of gauges, which are now very generally adopted. The accuracy of his work may be imagined when it is stated that a set of Whitworth gauges was furnished the Stevens Institute of Technology from which any combination of sizes may be selected and they will be found to be equally perfect fits if introduced together into a ring which precisely fits over the larger gauge of which the diameter is equal to the sum of the diameters of the combination. Warming a ring-gauge slightly, the plug-gauge of corresponding dimension will fall freely through it; warming the plug and leaving the ring at normal temperature, the former will refuse to pass through the latter.

Messrs. Wm. Sellers & Co., who introduced this system of work into the United States, make similar gauges.

Digitized by Google

In many respects the styles of the tools made by these two firms and their methods of work resemble each other closely, and, excellent as is the work of the Whitworth Company, the American firm will not suffer by comparison. The remarks already made in reference to the machinery of Sellers & Co. will well apply here.

Messrs. Whitworth & Co. were the first manufacturers in Europe to adopt the Allen engine; it was brought to their notice by Mr. Charles T. Porter, who also introduced it on the continent.

Sir Joseph Whitworth has long been engaged in the manufacture of a peculiar form of ordnance, and has succeeded in obtaining results, on trial, which have not been equalled by the Armstrong, the Woolwich, or any ordnance yet introduced.

Its efficiency is largely due to its general form, its peculiarities of rifling, and the method of its manufacture, and, also, in great degree, to the wonderful endurance of the peculiar metal used in its construction.

413. WHITWORTH ORDNANCE.—The Whitworth ordnance has a power of penetration and a range exceeding other guns by probably 30 per cent. The maker claims, under some conditions, a superiority of 50 per cent. The fact that the British government has persistently refused to adopt, or even countenance, this system is one of those singular instances of wilful disregard of proven facts, or of official indifference to public interests, which it is difficult to account for, except on the supposition that private prejudice or private interests have been permitted to control the action of the departments. The result is unfortunate for Great Britain, but it may prove fortunate for her enemies.

The Whitworth gun is a rifle, now usually constructed of what the inventor terms "compressed steel," having a bore of hexagonal section, and throwing a projectile of the form of a hexagonal prism with conoidal or ogival ends, and of great length and weight in comparison with the projectiles used with other ordnance of equal size of bore.

The powder-charge is very large, even for this weight of shot.

The advantages possessed by the Whitworth form of rifling are: the ease and accuracy with which it can be produced in the manufactory; the great extent of bearing-surface, and consequently the slight wear and small loss by windage due to such area of rubbing-surface; the great strength secured to resist stripping of either shot or bore, and the facility with which it can be applied in construction of ordnance of any form or of any size.

The shot has, after a long series of experiments, been given a length of from three to four diameters, and the solid shot are given the conoidal form at each end. Shell are made parallel at the back end, to give them capacity for heavy bursting charges, and some sacrifice of range is thus made.

In 1871, a little 12-pounder Whitworth rifle, with a shot weighing 17¼ pounds and a charge of R. L. G. powder of 4¼ pounds, was fired at an

Digitized by Google

angle of elevation of 33°, and attained a range of six and one-sixth miles.

Whitworth uses a flat-headed projectile in attacking armor-plate. This form will not penetrate thicker metal, when striking perpendicularly, than the shot with rounded head; but it will readily enter at angles of inclination which would invariably cause the latter to glance, and it will enter water and will penetrate under water. With the submarine gun proposed by Fulton, and but recently brought forward in modern shape, this form of projectile and the powerful gun from which it is fired are likely to prove essential elements of success.

A Whitworth 9-inch gun, with a charge of 50 pounds of powder behind a steel shell 3½ diameters long and weighing 404 pounds, drove its shot through three 5-inch iron plates and two 5-inch layers of iron cement, at 200 yards, the shell remaining in the target, with the ends protruding, front and rear. This is the most extraordinary case of penetration which has come to the knowledge of the writer.

These guns are manufactured very readily by modern methods, and there is no objection to their adoption on the score of economy. Their ammunition is cheaply made, and can be produced in large quantities, when demanded by the exigencies of war, promptly and at comparatively small expense. Whitworth estimates the time of fitting the rough casting to gauge, and turning it out ready for use, at 12 minutes, and the expense at less than threepence. Allowing for the difference in value of British coin and the depreciated paper-currency of the United States, the probable cost in this country may be estimated at about 6 cents.

In proving his guns the maker has sometimes adopted the novel expedient of securing the projectile in the gun and firing a diminished powder-charge behind it, permitting the gases to escape only by the vent.

The Whitworth breech-loader is another interesting product of the ingenuity of this great mechanic. It has a strong, easily fitted, and heavy breech-plug, is easy-working, and can be handled with great rapidity. One of these guns, throwing a solid shot weighing twelve pounds, four diameters long, and a charge of 2¼ pounds of R. L. G powder, with an angle of elevation of 40°, attained a range of 10,600 yards. It penetrated a 3-inch armor-plate at 200 yards, although the plate was inclined at an angle of 45°, and the shell was found imbedded 5 feet in the sand behind the target. The Whitworth gun has given better results than the Woolwich gun where the latter have 25 per cent. greater nominal weight of shot. The difference is even greater between small sizes. The 3-pounder Whitworth has equalled the 6-pounder Woolwich.

In putting the gun together Sir Joseph Whitworth dispenses entirely with the rude and usually awkward and hazardous process of shrinking the cylindrical "rings" upon the core, and adopts the more mechanical and satisfactory plan of turning and boring the parts to an exact fit,

Digitized by Google

and forcing them into place by means of the hydraulic press. The hydraulic press is also used by Whitworth in forging the parts of the gun as Haswell uses that machine in forging the details of locomotive-work. The writer found the first-named using this method in 1870, and is uncertain to whom to give credit for the earliest introduction of the process into regular work.

In making shot and shell, Whitworth uses a molding-machine, and has succeeded in making such smooth and accurate castings that they can be used without loss of time or money in tool-dressing. They are, when of iron, cast of Pontypool (Welsh) white iron, which chills well and makes remarkably smooth and solid castings.

The following list of sizes and prices was furnished the writer at an earlier visit.

FIELD-GUNS.

Size of gun.	Weight.	Price.
3-pounder	315 lbs.	£40
6-pounder	630 lbs.	65
9-pounder	945 lbs.	85
12-pounder	1,260 lbs.	100

NAVAL ORDNANCE.

20-pounder	$18\frac{3}{4}$ cwt.	£160
32-pounder	30 cwt.	320
70-pounder	$75\frac{1}{2}$ cwt.	600
7-inch	7 tons.	950
8-inch	$10\frac{6}{20}$ tons.	1,400
9-inch	15 tons.	1,800
11-inch	27 tons.	3,200

In the year 1870 the writer examined the principles, the design, and the methods of manufacture of the Whitworth ordnance, and made a report* on the rival systems of Great Britain, at the request of the Admiral of the Navy, exhibiting its superiority to the other systems of ordnance then known, and urging its thorough and immediate experimental examination and provisional adoption. There seems no reason to doubt the correctness of the conclusions then arrived at. The system is philosophical, mechanical, effective, and economical.

414. COMPARISON OF WHITWORTH AND WOOLWICH SYSTEMS OF ORDNANCE.—As then stated, the objections to the Woolwich system are:

(1.) The use of a combination of steel and iron or of any two metals is objectionable when, as is to-day the case, a single metal may be employed without special difficulty.

(2.) The numerous welds required in building up guns of forged coils are so many weak points in the structure, and their presence is to be deprecated, no matter how skilful the smith who makes them.

(3.) The material itself, although the best of forged iron, is by no means the strongest material that can be obtained.

*Report of the Secretary of the Navy, 1870, p. 172, *et seq.*

Digitized by Google

(4.) The heating of the bands preparatory to shrinking them on the gun unavoidably oxidizes their surfaces to a greater or less extent, and this layer of oxide must prevent metallic contact between the two surfaces.*

(5.) The impossibility of adjusting accurately the amount of force with which the bands will seize the barrel of the gun entails a possibility of loss of strength from either too great or too little strain; of this fact our experience during the late war with Parrott guns is good evidence.

(6.) The repeated heating and cooling of the metal while the gun is under construction weakens it and lessens its elasticity and resilience to a serious extent.

Whitworth avoids these objections—

(1.) By the use of a single metal of extraordinary strength and resilience.

(2.) By the use of cast-metal instead of welded up bars and coils.

(3.) By using the strongest and most ductile metal yet known in the arts—his "compressed steel."

(4.) By making such mechanically perfect fits of the bands that the hydraulic press may, with a given and safe pressure, just force them fully home, giving a uniform and firm grasp, which makes the gun act like a solid mass in resisting internal strains.

(5.) This method of adjusting the force with which the inner barrel is grasped enables the proper strain to be applied without danger of either overstraining the band or leaving it so loose that the strength of the gun is endangered by loss of its support.

(6.) The gun being made of a cast metal, is given its shape with a single cooling from the molten condition.

The advantages of the form of the bore and the proportions of gun and of projectile have already been considered.

This subject may yet be found one of vital importance to the country, and particularly to the naval branch of the service, and the writer is compelled, no less by that public spirit which should influence every citizen than by that personal interest which he retains in the service with which he was for so many years connected, to present it at some length and to urge its consideration. His experience and judgment both as a civilian and as a naval engineer unite in dictating this action.

415. WHITWORTH'S COMPRESSED CAST STEEL.—The remarkable metal used by Whitworth for his ordnance and for such constructions as demand material of exceptional strength was first publicly described by its manufacturer several years since, and was first experimentally used by him nearly twenty years ago.

In some directions, progress in engineering is limited by the strength

* Mr. Hitchcock proposes to the United States Ordnance Department to avoid this difficulty by the ingenious expedient of heating in the neutral or deoxidizing flame of a gas-furnace and of forging without removal from the heating-chamber.

Digitized by Google

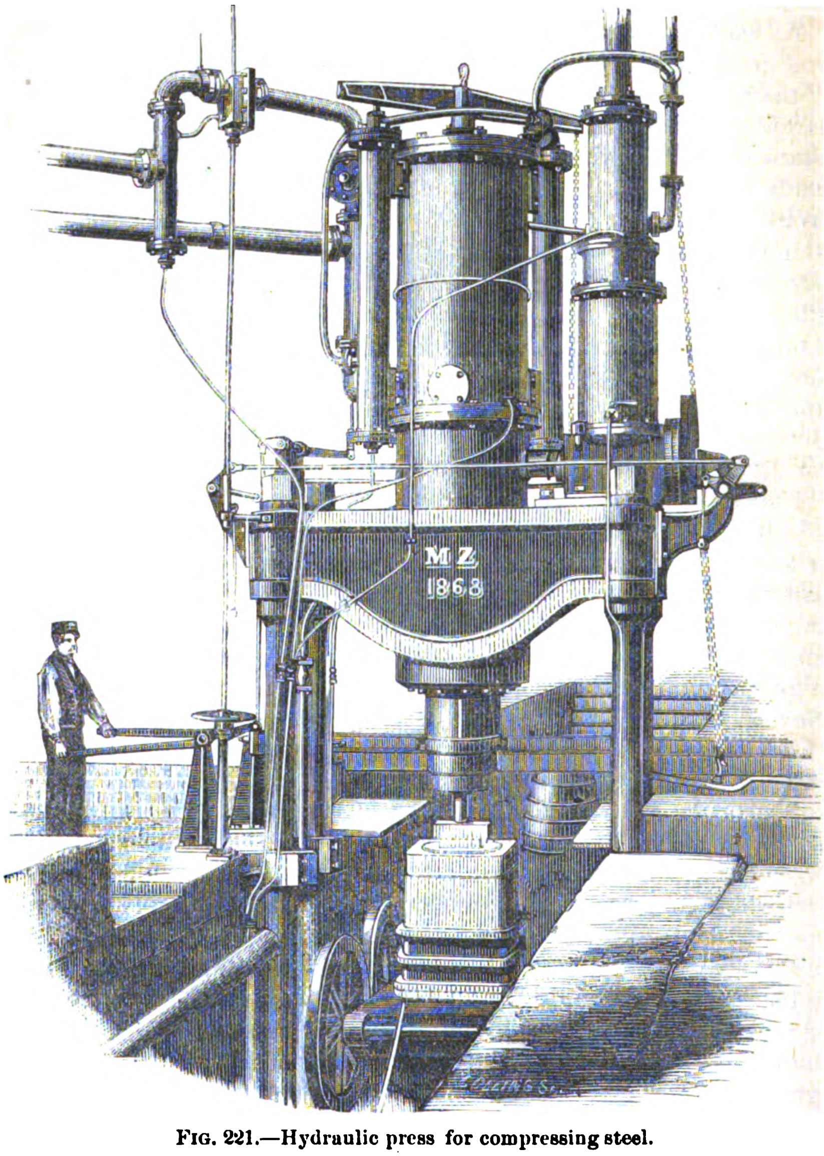


FIG. 221.—Hydraulic press for compressing steel.

Digitized by Google

and toughness of the material available. Where a combination of strength and lightness is essential, as in marine steam-engines, or where increasing the amount of metal is of no assistance beyond a certain limit in resisting strains tending to produce fracture, as in hydraulic presses, and especially in ordnance, the production of an improved metal is the essential step to further advance.

As has been already stated in another portion of this report, the several grades ot steels are the strongest, the toughest, and the most ductile of the metals used in the arts. But the steels are subject to the very serious objection that castings made of them lose these distinguishing characteristics of the worked metal. Poured into the ingot-molds or made into castings, they are found to be porous and comparatively heterogeneous in texture and to be weak and brittle. It has not been found possible to remove the gas the occlusion of which produces these effects. Whitworth long ago adopted the very simple but perfectly effective expedient of subjecting the ingot or the casting, while still molten, to the tremendous pressure of the hydraulic press. Although a simple expedient, it has required a considerable amount of experiment and ingenuity to produce this "compressed steel" with uniform success. Success was, however, attained, and Whitworth has used the material for all of his recently-built ordnance and for apparatus requiring to be made of exceptional strength. It has now been introduced on the Continent—in France by Messrs. Révollier & Co., of St. Etienne, and in Austria by the Neuberg works. The latter establishment exhibited, at Vienna, samples of this steel of unusual beauty and excellence. The enterprising editors of London Engineering had photographs taken of the specimens of compressed and of uncompressed metal, from which the engravings given below were made, and were reproduced by the Iron Age, of New York.

Fig. 221 shows the form of press used in their production. The ingot-mold is placed on a carriage mounted on rails leading from the converters to the press. When the metal is poured from the ladle into the mold, the latter is rapidly transported to the press and subjected to a pressure of from 500 to 700 tons while solidifying. Sir Joseph Whitworth uses still a higher pressure, 2,500 tons, and even proposes to use a press of a capacity of 8,000 tons. With this press the pressure will be 15 or 20 tons per inch, and no metal can probably be used for ingot-molds except the Whitworth metal itself. The molds are strengthened by steel hoops to resist this pressure. The pores and bubble-holes are thus effectually closed, and the compressed steel is given a strength and homogeneousness unequalled by any other known metal.

Fig. 222 shows how perfectly the process effects the object aimed at. Fig. 223 shows the appearance of the fracture of an unpressed ingot. The essential precaution to be observed is merely to get the metal under the press while quite fluid. This is sometimes found to present

Digitized by Google

some difficulty. At Neuberg, where Bessemer metal is used, the process is stated to have given satisfaction. Compression thus does for steel castings, but even more effectually, what forging and rolling do in ordinary treatment.

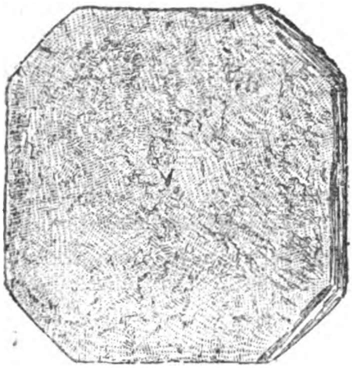


FIG. 222.

FIG. 223.

The inventor has stated to the writer that, by careful selection and treatment of metals, a steel can be produced capable of resisting a tensile stress of forty-five tons per square inch of section, and of elongating 25 per cent. before breaking. He furnishes the compressed steel in twelve grades, which he divides into groups, and distinguishes them by color-marks. The softest and most ductile is marked "No. 1, red," and the hardest is "No. 3, yellow."

The following is the classification:

No. 1, red, barrels for fowling-pieces, steam-boilers, &c.

No. 2, red, rifle-barrels, gun-carriages, &c.

No. 3, red, large guns, locomotive-cranks, &c.

No. 1, blue, lathe-mandrels, shafts, crank-pins, &c.

No. 2. blue, hydraulic presses, piston-rods, &c.

No. 3, blue, sword-blades, &c.

No. 1, brown, wire, coach-springs, hammers, &c.

No. 2, brown, cold-chisels, shears, boring-bars, smiths' punches, large taps, &c.

No. 3, brown, armor-shells, small drills, small taps, &c.

No. 1, yellow, screw-tools, dies for stocks, punches, &c.

No. 2, yellow, large drill, lathe tools, cutters, &c.

No. 3, yellow, extra hard, with least ductility.

No. 1, red, is a very strong, yet soft and ductile steel, which is particularly well adapted for small-arms. It withstands the sudden shock of quick-burning powder, and, as the projectile is of lead, is not scratched, as it would be in large ordnance. Heavy guns require a metal of great strength and toughness, but also hard enough to resist abrasion by cast-iron or steel shot and shell. Whitworth guns are made of No. 3, red. A harder quality (No. 3, brown) is used for shells in-

Digitized by Google

tended to be used against armor-plate. The "red metal" has the advantage that, should the gun be burst, it would simply open like soft copper, and would not fly in pieces like cast iron or ordinary steel.

The hardness is determined, as in other steels, primarily by the proportion of carbon. The compactness and density, the soundness and homogeneousness, of this metal are its great advantages; its hardness and durability as compared with iron, the strength and toughness secured without forging, and its power of taking any desired form, without liability to those dangerous defects which accompany welding, are advantages which are of very great importance.

The Whitworth Company produces masses up to four tons weight, and it is not too much to expect that heavy ordnance may yet be made by this process in a single piece. The metal is tested for ordnance purposes in the following manner:

A hollow cylinder is made of the metal to be tested of 7.83 inches and 2.56 inches external and internal diameter, respectively, and 26 inches in length. The ends are closed by screw-plugs, which enter just far enough to leave an intermediate cavity of the capacity required by the cartridge of powder to be fired in it. A vent one-tenth of an inch in diameter is drilled through one of these plugs. The charge being fired, the cylinder must explode, or the gases must all rush out through this vent. A cast-iron cylinder was thus burst with one charge of 3 ounces of powder; another, having a wrought-iron lining, bore the shock of three charges of 5, 6, and 8 ounces, respectively, and exploded when fired with 10 ounces; a third cylinder, of Whitworth metal, was not even cracked after thirty-one trials, with charges of 1½ pounds weight each, and the enlargement of its interior diameter one-fifth and its exterior diameter one-twenty-fifth of an inch.

The elegant expedient of testing his ordnance by this method, with gradually-increasing charges, until an increase of internal diameter is detected, enables the maker to at once test the piece by an inexpensive series of trials, and to determine the maximum safe service charge—desiderata hitherto unattained, although of immense importance.

We have long since reached a limit in the manufacture of ordnance, of hydraulic machinery of some kinds, and, in especial cases, in mechanical engineering, beyond which we cannot go without using a new and stronger material.

The well-known fact that no thickness, however great, will enable a cylinder to resist an internal pressure per square inch greater than the tensile strength of the metal, limits the life of many kinds of constructions, and absolutely forbids improvement of others except by the use of stronger material. The introduction of such a new material is therefore one of the most important events in the history of engineering, and engineers look with exceptional interest upon all promising attempts in this direction.

416. General remarks on metal for ordnance and purposes demanding strength and resilience.

Digitized by Google

In selecting a material for ordnance, it is not sufficient that it should possess great strength, but it must be resilient; that is, it must, while offering great resistance to rupture, be capable of stretching considerably before breaking. Our best cast iron, for ordnance, has a strength of 37,000 pounds per square inch, and stretches usually less than one per cent.; wrought iron of good quality has a maximum tenacity of 60,000 pounds, and stretches twenty per cent.; bronze gun-metal resists 40,000 pounds, and stretches five or ten per cent.; good Bessemer and Siemens steel, containing one-third per cent. carbon, after having been worked by the rolls or under the hammer, usually have a tenacity of 70,000 pounds and a ductility of twenty or twenty-five per cent.; tool-steels are much stronger, but only stretch about two per cent. Whitworth states that his compressed steel *castings* have all the strength of, and greater ductility than, the worked steels of similar grade in carbon.

It is evident that even our remarkable American gun-iron, of which so much has been said, is among the very worst of all these available materials for ordnance. The fact that it has been used almost exclusively in this country is simply due to the inability of our manufacturers to supply guns of a stronger material without flaws due to welding in forged and to porosity in cast metal, promptly and at a price which our Government would pay. Wrought iron is much stronger, but its working into shape involves the formation of numerous welds, and consequently of points of weakness difficult of detection and liable at any time to produce disaster.

Low steels made by puddling or by the crucible, the Bessemer or the Siemens process, is a far better material, and the quality known as "homogeneous metal" is at once strong and tough; it can be melted and cast, or it may be forged. It is this metal which is made by Firth & Son for the inner tubes of Woolwich ordnance, and by Krupp for all parts of his ordnance. The castings must always, however, be forged sufficiently to close up all pores, or they will prove faulty and weak. The manufacture of large ordnance is, therefore, expensive, and requires great experience and skill.

The theoretical energy of gunpowder of fair quality is 250,000 to 300,000 foot-pounds per pound; its actual energy, as developed in ordnance practice, is from 150,000 to 200,000 foot-pounds. The initial velocity of the projectile, in heavy ordnance, may be taken as approximately

$$V=\sqrt{64.4\frac{E\,w}{W}}$$

in which formula V is the velocity in feet per second, E is the actual energy per pound of powder as determined by experiment, w is the weight of powder, W is the weight of projectile.

Cast-iron shot on striking armor-plate usually flies to pieces, and thus wastes about one-half the energy which it should expend in perforation;

Digitized by Google

wrought-iron or soft steel is deformed by compression, and thus loses probably one-fifth its *vis viva;* hardened steel usually expends nearly all its energy usefully in penetration, but loses a little in elevation of its own temperature on impact; where the latter splits longitudinally, as it sometimes does, it loses, perhaps, a tenth. To secure the best result, it is usually advisable that the shot should have a diameter nearly equal to the thickness of the armor-plate attacked; it may sometimes prove effective when but one-half that diameter. Such slender shot demands the best of material. When steel is used, the writer has found the weight of charge, C, required for penetration to be about

$$C = \frac{t^3}{10}$$

or, the thickness t penetrable by a shot of correct proportions, driven by a given charge, C, is

$$t = \sqrt[3]{10\,C}$$

Cast-iron shot require the use of a double charge. British practice seems to indicate that where wrought iron is used for armor-plate, a tenacity of 50,000 pounds, a ductility of 20 per cent., a resistance to compression such that about 200,000 pounds per square inch of section will reduce small cubic specimens to one-half their original height, gives the best practical result yet attained, when backed with four times its own thickness of teak. With such plate, and flat-headed steel shot, if P is the pressure required to penetrate plate, U the work of the powder in foot-pounds, t the thickness of plate, and r the radius of the shot in inches,

$$P = 255360\, r\, t$$

and for steel,

$$U = 24400\, r\, t^2$$

and for cast iron,

$$U = 10640\, r\, t^2.$$

A Woolwich 9-inch gun, of the Frazer-Armstrong pattern, penetrates 40 feet of earth, or 12 feet of brick or concrete, 8 feet of rubble masonry, 2 feet of granite, or 11 inches of iron with a charge of 43 pounds R. L. G. powder and a projectile weighing 270 pounds. The 600-pounder Woolwich gun with 70 powder, has driven a 600-pound shot through three 5-inch plates*, and has broken out the rear of a target composed of four 5-inch plates, penetrating the first three plates. The same gun has broken two solid 15-inch plates, one of which was rolled and the other hammered. At these experiments two 5-inch plates were found to be as strong as one 10-inch, and three 5-inch were stronger than one 15-inch plate. The difficulty of securing perfect soundness in the thicker plate more than compensates the defect of rigidity in the thinner. The Whitworth 9-inch, as has been seen, has done better work than the Woolwich ordnance. Our largest American ordnance of cast-iron cannot show such records as these.

*Shoeburyness, June, 1868.

Digitized by Google

These experimental investigations and theoretical deductions, of national importance as they are, are of hardly less interest and importance in their bearing upon the arts of peace. For many applications in mechanical engineering, a material which is of value as a gun-metal is also essentially important, and the engineer in general practice watches the progress of improvement in ordnance with scarcely less interest than the engineer whose special work is the manufacture and use of ordnance. Both, also, are equally interested in attempts to introduce materials like cold-rolled iron, the softer steels, cold-rolled or "steel-bronze," phosphor-bronze and compressed steel, which give promise of aiding them in their efforts to produce machinery and structures more perfectly combining strength with lightness, or guns which are strong, reliable, and efficient. In all directions the progress of improvement is checked by the attainment of a limit set either by the weakness of the materials of construction or, oftener, by their deficiency in resilience.

The improvement effected by the processes just referred to would seem to be largely due to the production of that porosity which is the invariable characteristic of cast metals as ordinarily produced.

The experiments of the writer and the results of many tests of commercial materials in the Mechanical Laboratory of the Stevens Institute of Technology indicate that even with the best of ordnance bronze, as well as with the steels, defects of structure occur which must detract greatly from their value. It would seem probable that solidification under compression and other methods of securing density and homogeneousness may prove useful in many cases not yet thus treated.

417. SHEFFIELD.—The great steel and tool manufacturing establishments of Sheffield have long held a leading position, and one or two are probably ahead of their respective departments of business in Great Britain and the world. The United States, with large and more accessible deposits of rich ores, with ample capital, and the most skilful workmen to be obtained either at home or by importation, is gradually becoming perfectly independent of Great Britain in both the manufacture of steel and the making of steel instruments and tools. Our Besseme and Siemens steels are fully equal to any produced abroad. A number of our manufacturers produce tool-steels which are as strong and tough, harden as uniformly, and take as fine a temper as the best English metal, and the axes and some other descriptions of tools made in the United States are driving out English-made tools wherever competition occurs between them.* In many cases, where a special quality must be uni-

*English edge-tool makers are fully aware of the success with which certain of their business rivals in America have supplanted them in many of our home and foreign markets. So large, however, is the demand at present for good edge-tools of almost every description that there are few edge-tool firms in the United Kingdom who have not plenty of orders upon their books. The English article is not, therefore, out of use, but there is a perceptible increase in the favor in which handy and thoroughly excellent tools are held, both at home and abroad; and this is being encouraged by the growing facilities for manipulating steel, both shear and cast. Sensible of this,

Digitized by Google

formly worked and a precise temper is invariably demanded, the maker who has been brought up to the use of a certain make of steel, and with all his employés is thoroughly accustomed to its use, cannot safely give it up and attempt to substitute another steel with which he is less familiar, even though it be intrinsically better metal. This fact and the prejudice in favor of reputable makes of foreign steel retain an American market for English steels which would otherwise have been lost long since.

There remain, however, some Sheffield products which are not paralleled by anything in the United States, and we visited a few establishments partly to ascertain the character of their plans and of the methods which had yielded such excellent products as were exhibited at Vienna, and partly to see what might be found that was still novel.

Messrs. THOMAS FIRTH & SONS are the manufacturers of all the steel used for the inner tube of the Woolwich ordnance, and immense quantities are supplied for other uses. The metal is a soft steel, containing less than one-half per cent. carbon, and is made in crucibles. There seems no peculiarity in either material or method, and the secret of success would seem to be that the Messrs. Firth, by long experience in the selecting and working of their materials, can produce a steel very low in carbon of very uniform quality, and at moderate prices. Steel tested for the Midvale Steel Works and for Messrs. Miller, Barr & Parkin, by the Mechanical Laboratory of the Stevens Institute of Technology is of equally good quality, and the metal can be produced quite as well in the United States as in Great Britain. The Messrs. Firth have made large numbers of Enfield rifles and other arms for the government and for private contractors, and use the same metal in these small-arms. For heavy forgings, as for the tubes of heavy ordnance, a steam-hammer is used with a drop weighing 25 tons. The foundation on which the anvil block is carried is a single immense casting weighing 175 tons.

A considerable number of people are employed making files. The method has no novelty, and the excellent reputation of the Firth files,

certain American firms are pushing their opportunity, and American forks, shovels and axes are to be had wherever edge-tools are offered in this country. It would seem that the Americans believe they can compete with us much more successfully by having branch establishments to manufacture their specialties in this country rather than by shipping their produce from the other side. A firm of cast-steel shovel makers at Pittsburgh, (Messrs. Hussey, Binns & Co.,) who have recently brought out a shovel in which the straps, though of iron, are compacted with the steel during the process of casting, and who are making, at a very low figure, and with very little manual labor, shovels that are getting very rapidly into use throughout the States, are now, through a representative who has recently come over from Pittsburgh to England, making inquiries which will regulate their action and determine them whether they will themselves begin to make in this country, or whether they will offer their process to English firms or to an English company. If American edge-tool makers should begin to produce here goods that are already running English makers hard, then it is to be inferred that their example will be followed by other transatlantic hardware manufacturers. Whether in such an event the English firms would remain as well employed as they now are remains to be seen.—*London Times's Wolverhampton Correspondence.*

Digitized by Google

like that of their gun-steel, is due to conscientious attention to detail and to selection of materials. The number of workmen employed here varies from 1,000 to 1,500.

After a luncheon with the gentlemen of the firm whose hospitality and courtesy we are bound to acknowledge, we visited the great rolling-mills of their neighbors.

Sir JOHN BROWN & CO. have one of the largest establishments in Sheffield, or in Great Britain. They employ about 6,000 men, and produce from 2,500 to 3,000 tons of finished material every week. This product is principally steel, in the form of rails and tires. This firm and Messrs. CAMMELL & CO., who have also an immense establishment close at hand, have heavy armor-plate mills, in which nearly all of the armor of the British fleet has been rolled. The first of these plates which were but 4 inches thick, were rolled at the Park Gate Iron-Works, in the West Riding of Yorkshire. The next heavier plates were 4½ inches thick, of hammered iron, and were made by the Thames Iron-Works. Messrs. JOHN BROWN & CO. now have the heaviest rolls in the kingdom, and at our visit they were put in operation, and we were able to see the process of rolling. The rolls were reversed at each pass by the use of a heavy clutch. The heavy plates are built up of thinner plates, which are rolled separately. The rolls are about 32 inches in diameter and 8 feet long. There are two sets, the second of which has rolls 30 inches in diameter.

A considerable amount of Bessemer and large quantities of crucible steel are made here. The crucibles used are made at the works. Railroad-car springs are made in great numbers and of exceptionally fine quality. Neither here nor elsewhere in Sheffield did we perceive any radical departure from ordinary methods. The reputation of Sheffield manufacturers and the excellence of their exhibits at Vienna seems to be due simply to care and skill in selecting materials, care and skill in working them, and care and skill in inspection and preparation of the products for the market, and a conscientious adherence to the schedule of qualities placed in the hands of their customers. A spirit of emulation is encouraged in the workmen, and in some of these establishments the workmen are as much interested in the preservation of a reputation for good work as are their employers.

418. SOUTH WALES.—In South Wales, although there is less to interest or instruct the visitor than in some of the manufacturing districts already referred to, there is still something to be seen.

Near Merthyr Tydvil are the great Dowlais Iron-Works, founded by Sir John Guest, and now employing in its mines and its mills about 12,000 people, and producing annually about 30,000 tons of steel rails and large quantities of iron. The management of these mills has exhibited an exceptionally enterprising spirit, and a promising novelty, whether of mechanism or method, is seldom refused a trial here by Mr. Menelaus, the manager. The steel made here is principally produced by the Bessemer process. The mills lately put down are reversing mills

Digitized by Google

fitted with well-designed Ramsbottom reversing engines. The laboratory of the Dowlais Works is one of the most complete in Great Britain, and it has not only done good routine work, but the accomplished chemist, Mr. Snelus, has produced some really scientific work.

The ores worked for the Bessemer process are lean native ores, containing about 45 per cent. oxide mixed with a large dose of either rich Cumberland or the excellent Bilbao ores, which, until the occurrence of political troubles in Spain, seemed likely to compete with the former with some success. For common irons, the native ores, which contain a considerable amount of phosphorus, are principally used. Welsh rails are therefore not perfectly safe in very cold climates. The following analyses represent the constitution of good Welsh ores and iron:

Ore of South Wales:

Protoxide of iron	40.30
Protoxide of manganese	1.03
Alumina	1.43
Lime	1.44
Magnesia	2.77
Carbonic acid	28.33
Phosphoric acid	0.88
Sulphuric acid	Trace.
Bisulphate of iron	0.09
Water	0.78
Organic matter	0.29
Insoluble residium	22.48

Cast iron of South Wales:

Carbon	2.95
Silica	1.96
Sulphur	0.28
Phosphorus	0.68
Manganese	0.23
Nickel and cobalt	0.04

419. THE SIEMENS STEEL PROCESS.—A few miles from Swansea, the seat of the copper-smelting industry of South Wales, is the little village of Landore, where the now well-known Siemens process of steel-making was perfected.

The process has often been described, and its peculiarities and advantages have already been stated incidentally in preceding portions of this report. There is, therefore, but little that need find a place here. At Landore it has become a commercial success. It was introduced into continental establishments previous to the date of the Paris Exposition of 1867, and was imported into the United States by Messrs. Cooper, Hewitt & Co. The able report of Mr. Abram Hewitt, which is embodied in the reports of the United States Commissioners to the Paris Exposition, contains nearly all information relating to it which would

Digitized by Google

be valuable to either the engineer or the metallurgist. It is still worked at Landore with perfect success, and the visitor finds there specimens as fine in quality as any exhibited at Vienna. The modified process, called by Mr. Siemens the ore process, in which ore is used in large doses as a decarbonizer, is still passing through its experimental stages, and, as the distinguished metallurgist who has so long and persistently labored upon the problem believes, with promises of ultimate success. There are serious difficulties to be overcome in the attempt to reduce the ores and to make steel on the hearth. The most serious is that of finding a material of which to make the bed not liable to be fluxed by the ore and to cut through so rapidly as to make the delay and expense incident to its repair a serious addition to the account of costs. The subject is one of importance to the metallurgist and of great interest to the engineer.

The regular Siemens process, as carried out at Landore, is similar to that already described. Pig-metal is melted on the hearth of the regenerative furnace, under a decarbonizing flame, and is completely decarbonized by the oxidizing flame, and by the addition of wrought scraps, which assist as a diluent. It is supposed that the carbon is also partly removed by the peculiar phenomenon of "dissociation," which is known to occur in other cases in which compounds which are stable at ordinary temperatures, are exposed to intense heat. When the charge is thorthoroughly decorbonized, it is retained under a neutral flame until—the desired degree of recarburation being given by addition of *spiegeleisen*—it is found, by the examination of small test ingots, to be of the right quality, when it is tapped off and treated as in Bessemer steel manufacture. The economical value of the process will be determined to a great degree by the value of scrap-metal. In some states of the market it is probably more profitable than the Bessemer process. Skill and care are required for its successful working; but skill and care can produce a finer and more uniform quality of product in this than in the other process. For the manufacture of "steels," or more properly irons, containing less than 0.3 or 0.4 per cent. carbon, this is probably the only satisfactory and reliable method of production. It allows of the use of light grades of cast iron; it permits the addition of any "medicine" required to eliminate deleterious elements; it permits the thorough and deliberate examination of the product and its modification to suit requirements before it is tapped off; it requires comparatively inexpensive plant, can be carried on in small establishments, and can be adopted in any locality, experimentally, without very great expense or risk. Now that manufacturers of machinery are beginning to see that for many purposes the soft, ductile, but strong and homogeneous metal, produced by this process, is of peculiar value for much of their work, it is to be expected that its adoption will rapidly take place.

420. J. PENN & SONS.—While in London the opportunity was taken to visit the establishment of Messrs. John Penn & Sons, at Greenwich.

Digitized by Google

This is one of the oldest in Great Britain and in Europe. The engine-factory is at Greenwich and the boiler-works at Deptford, a neighboring village. The works are large, and are well provided with tools. The buildings are irregularly distributed over some ten acres of ground. Those recently erected are well built, large, well lighted and ventilated, and provided with all the modern tools and conveniences. The machine-shops are in both old and new structures, the latter of which are well arranged, and contain the erecting shops with their powerful traveling cranes. These buildings are 250 feet long and 200 feet wide. The roof is carried over in four spans, and provided with windows, through which the shops are principally lighted. Each section is provided with a traveling crane. There are many fine tools here, and among them some of original design and exceptional efficiency. Among the latter is a vertical planer, in which the cross-head traverses and the work remains stationary. In these shops were several small driving-engines which attracted attention by their resemblance in design to what American engineers are accustomed to call the Oliver Evans engine—an engine which was used in the United States in 1784—and by the fact that they were not provided with such an expansion apparatus as is, by us, considered essential. In the foundery we found some of the smoothest and soundest castings which we had seen in Europe, quite equal to the beautiful cylinder casting exhibited at Vienna by the Creusot Company. Carefully selected iron and molding sand, skillful workmanship, and good judgment in parting and gating the molds give sound castings, and care in venting and in washing and blackening gives this remarkable smoothness.

We found in the erecting shops several very large engines, among which were two pairs of marine-engines of 1,150 and 1,200 "nominal" horse-power, equal to about 6,500 and 7,000 indicated horse-power, respectively. These were trunk-engines, a form which has been built successfully by Penn & Sons, but by no other firm, for many years. For merchant steamers they were building the Napier style of compound engines. There is less steel used here in construction than in other establishments which have already been described; but this firm are unusually conservative, and rarely risk either capital or reputation on experiment or novelties. They have been among the very last to adopt the compound engine. They have no large hammers, and obtain their heaviest forgings from Liverpool and Glasgow.

Messrs. Penn & Sons are also building some oscillating engines, a type to which they have adhered, in building paddle-engines, for many years, and with great success. Their success, both with this and with the trunk-engines, is attributed by many engineers not to the merits of these peculiar types of engines, but to the excellence of proportion and the superiority of workmanship which has always distinguished the machinery built by this firm. Neither of these kinds of marine-engines is generally approved by engineers.

Digitized by Google

In going down the Thames, *en route* to Greenwich, we saw very little ship-building going on in yards which a few years ago were crowded with work. Samuda's yard contained several vessels, and at a few other places a ship was now and then seen hauled up for repairs. Iron-ship-building will probably never again flourish on the Thames. The river itself needs a "Clyde Trust" to preserve its depth of channel and to keep its banks in proper shape.

Digitized by Google

INDEX.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

N.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

W.

Z.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google