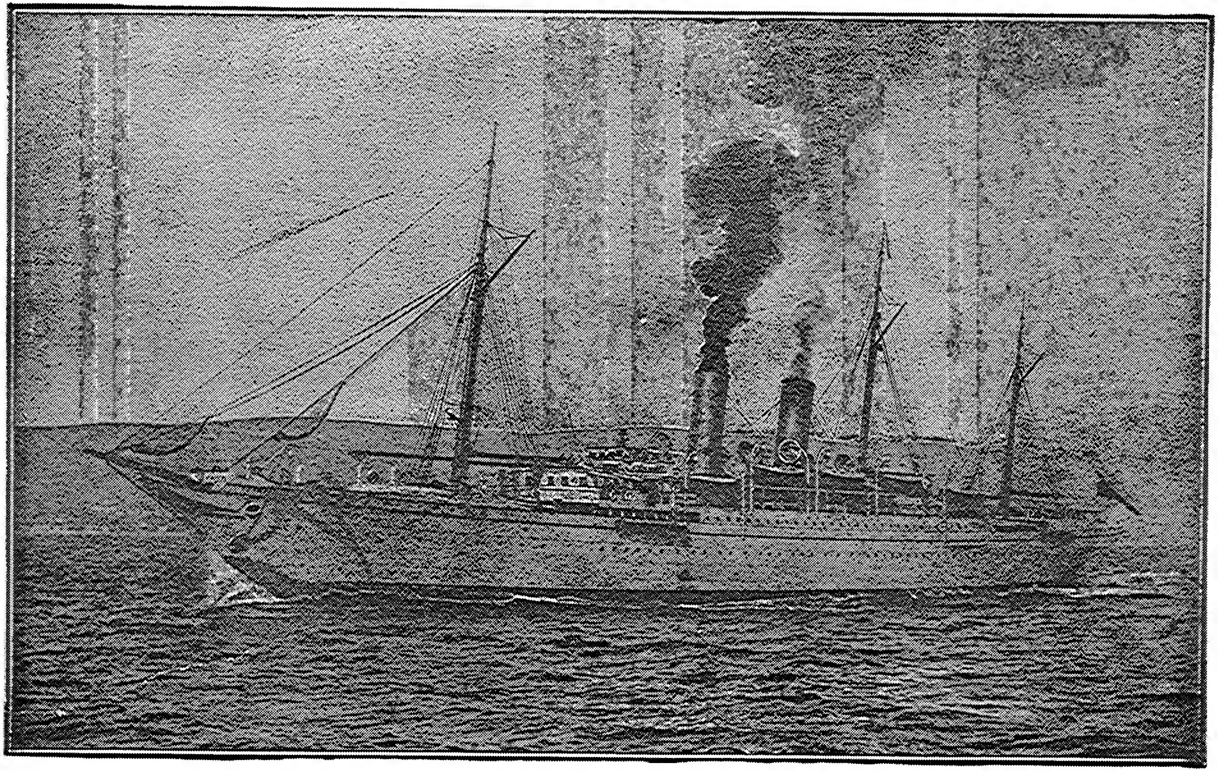
STEAMSHIPS AND THEIR MACHINERY

FROM FIRST TO LAST



THE CANADIAN-PACIFIC COMPANY'S R.M.S. "EMPRESS OF JAPAN.

STEAMSHIPS AND THEIR MACHINERY

FROM FIRST TO LAST

BY

J. W. C. HALDANE

CIVIL AND MECHANICAL AND CONSULTING ENGINEER

WITH MANY PLATES AND OTHER ILLUSTRATIONS

64267

LONDON

E. & F. N. SPON, 125 STRAND

NEW YORK: SPON & CHAMBERLAIN, 12 CORTLANDT STREET

1893

[ALL RIGHTS RESERVED.]

LIVERPOOL:
D. MARPLES AND CO.
LORD STREET.

LIBRARY
AUG 16 1893
U. S. PATENT OFFICE.

PREFACE.

The very high appreciation of my book on "Civil and Mechanical Engineering" by readers of all classes has encouraged me to prepare another upon "Steamships and their Machinery, from first to last." This treatise is based upon the Author's practice, since 1852, in the Works of Messrs. Denny, Neilson & Co., and Tod & Macgregor, of the Clyde, and Laird Brothers, of Birkenhead, etc.; also as a Consulting Engineer since 1873. Its object has been to describe in a simple, unconventional, and readable manner, the latest phases of Marine Engineering and its surroundings in all departments. Its contents, therefore, include chapters upon Works and their Machinery—Shipbuilding—Design and Construction of Engines and Boilers: also Auxiliaries for hoisting, steering, refrigerating, electric lighting, etc. Chapter XXIX contains a sketch of life on board an ocean racer while "Breaking the Record," and other Notes; and Chapter XXX a few concluding remarks of a general character.

With the object of gaining the best and latest information at all points, and especially upon the great establishments to which special chapters have been devoted, I had the privilege of being allowed to critically survey these and other Works. Every opportunity was kindly placed at my disposal for this purpose by various Firms, and, in addition to this, a large amount of valuable matter concerning the latest phases of advanced practice was generously supplied by engineers, etc., throughout the country, to utilise in my own way with a free hand.

Were I, however, to particularise any of the above, it would certainly be those whose manufacturing operations have been described in detail, viz.: Sir Joseph Whitworth & Co., Messrs. Galloway, the Steel Company of Scotland, Dallam Forge Company, Fairfield Shipbuilding and Engineering Company, and Sir John Brown & Co., to all of whom I am greatly indebted for kind favours whilst visiting their establishments. Messrs. Galloway additionally permitted the use of several illustrations of their system of Boiler manufacture, and Messrs. Tangye eight Plates of their latest Constructive Machines.

Many other Firms, whose names are given in the text, also kindly consented to the publication of views of their Machinery, and, amongst shipowners, may be mentioned Messrs. Ismay, Imrie & Co., who allowed the use of six Plates and other views of their R.M.S. "Teutonic," and Mr. Archer Baker, of the Canadian Pacific Company, who provided the Plate of their R.M.S. "Empress of Japan," which forms our Frontispiece.

The primary object of this treatise has been to glance generally at the various phases of Workshop Design and Mechanical Arrangement as the bases of financial success, before proceeding with the very numerous considerations affecting Machinery Design and Construction. With such an immense field to cover, the greatest brevity and clearness of expression have been necessary.

Owing to the desirability of writing lightly and simply, I have adopted, as far as possible, the style of language which largely contributed to the success of my first book, in the hope that it will again prove acceptable to many.

J. W. C. H.

30 North John Street,
Liverpool, *June, 1893.*

CONTENTS.

CHAPTER I.

WORKS, AND THEIR INTERIORS.

CHAPTER II.

MACHINERY OF THE WORKS.

CHAPTER III.

MACHINERY OF THE WORKS.—*(Continued.)*

PAGE

CHAPTER IV.

OPENSHAW ESTABLISHMENT OF SIR JOSEPH WHITWORTH AND CO.

CHAPTER V.

BOILER WORKS AND SYSTEM OF MANUFACTURE.

CHAPTER VI.

MANUFACTURE OF STEEL FOR SHIPBUILDING, AND OTHER PURPOSES.

PAGE

CHAPTER VII.

MANUFACTURE OF IRON AT THE DALLAM FORGE, WARRINGTON.

CHAPTER VIII.

THE FAIRFIELD WORKS, GLASGOW.

CHAPTER IX.

APPLICATION OF SHIPBUILDING MACHINERY AT FAIRFIELD, AND OTHER WORKS.

PAGE

CHAPTER X.

SHIPYARD MACHINERY. *(Continued.)*

CHAPTER XI.

WOOD-WORKING MACHINERY OF SHIPYARDS.

CHAPTER XII.

ATLAS WORKS OF SIR JOHN BROWN AND CO., SHEFFIELD.

PAGE

CHAPTER XIII.

"THE EMINENT ENGINEER"

CHAPTER XIV.

NOTES FROM A MODERN CARGO LINER.

CHAPTER XV.

COMMENCING A NEW ENGINEERING AND SHIPBUILDING ESTABLISHMENT.

CHAPTER XXII.

DETAILS OF ENGINES.—*(Continued.)*

CHAPTER XXIII.

MARINE BOILERS, AND THEIR DESIGN.

CHAPTER XXIV.

MARINE BOILERS.—*(Continued.)*

PAGE

CHAPTER XXV.

THE SCREW PROPELLER—PATTERN SHOPS—FOUNDRIES.

CHAPTER XXVI.

MACHINING AND ERECTING SHOPS AT THE SIRIUS WORKS.

CHAPTER XXVII.

AUXILIARY MACHINERY OF A SHIP.

PAGE

CHAPTER XXVIII.

LAUNCH OF THE S.S. *VENCEDORA*.—LATEST APPLICATIONS OF ELECTRICITY.

CHAPTER XIX.

A GIGANTIC MAIL LINER ON LONG VOYAGE STATION.

CHAPTER XXX.

GENERAL REMARKS.

LIST OF PLATES AND OTHER ILLUSTRATIONS.

CHAPTER I.

WORKS, AND THEIR INTERIORS.

Best Position for Marine Engineering Works—Arrangement of Buildings—Constructive Materials—Old and New Works compared—Future Extensions—Transmission of Motive Power—Various Applications of Power — Examples of Works — Arrangement of Machinery — Arrangement of Departments — Constructive Machinery—The Turning Lathe—Planing Machines—Slotting Machinery—Recent Improvements in Constructive System—Colossal Machinery of the Present—Early Master Strokes in design.

In the following pages we hope to show, as clearly as possible, the leading features of Shipbuilding and Marine Engineering; by describing, firstly, the Works and their connections. Secondly, the peculiarities of the Constructive Machinery now most successfully employed in them. Thirdly, the application of that machinery in the manipulative processes which economise labour. And, generally speaking, the design, construction, and application of propelling machinery, and its various auxiliaries in the different departments of a ship.

As a general rule the best position for heavy Engineering establishments, and especially those connected with marine work, is one which will allow a good navigable water frontage on one side, easy access to a railway on the other side, and also the shortest and most direct communication with iron and steel works, copper works brass and iron foundries, and all the minor industries that aid, in some form or other, the various operations.

The arrangement of the various shops in plan depends very much upon the shape of the land on which they are to be erected, and, if in a populous neighbourhood, upon their surroundings, which in many cases are in no way favourable. The height of the buildings, or at least the number of floors, is governed partly by the nature of the work to be executed in them, and partly by the value of the ground. In locomotive establishments, the one storey system throughout is very popular on account of its greater security from fire, and the avoidance of lifting from one floor to another. On the other hand, however, immense buildings for the manufacture of light gear, such, for example, as those of the Singer Sewing Machine Company, &c., are frequently run up to three storeys in height, even in a country district.

The principle frequently adopted in main buildings is, to make their lengths and breadths multiples of 8. For example:—the Fitting and Turning shop of the Bridge Building and General Engineering Works of Messrs. Morton & Co., at Garston, on the Mersey, is 200′ 0″ by 120′ 0″, and the Foundry has the same dimensions. The rows of columns are 40′ 0″ apart, and the roofs, girders, and travelling cranes have in every case an interchangeable span. A similar system has been employed in the Crystal Palace at Sydenham, and also in many other vast edifices, on account of the economy in drawings, patterns, fitting, and erection, it inevitably produces.

The walls of the buildings may be of any suitable materials, from granite downwards, but in general they are of 14″ or 18″ brickwork, which may be panelled externally, and should have internal piers at every point where a heavy concentrated permanent load is sustained. Red sandstone, as at the Naval Construction, &c., Works at Barrow, and elsewhere, has a handsome appearance, but it is not always convenient. Both of the above materials are very suitable when a good foundation can be secured, but in made ground, such as that at Queen's Island, Belfast, a different system is necessary, and indeed has been very successfully adopted by Messrs. Harland and Wolff. In their immense establishment, the walls of the buildings are formed by placing strong cast iron stanchions at certain distances apart, and filling the intervening spaces in the "weather board" style, with light timber, which is safer than brickwork, as it will not crack through unequal settlement of the ground. The stanchions, however, are prevented from sinking at all, even with the heaviest loads that can come upon them, owing to the large area of the well-bedded foundations on which they rest. It may be added that Messrs. Laird Brothers' new and magnificent Boiler Works at Birkenhead, are of similar construction. The roofs of such fabrics may be of timber, or iron, according to circumstances, or even to the fancy of the designer. At Garston, however, the principals are of iron in the arched form, covered with corrugated sheets which require only a light construction, and last well in an atmosphere free from chemical fumes.

There are many important points in the design and arrangement of engineering buildings that require very careful consideration, not only with a view to facility in manufacture, but also in the economical movement of heavy gear from one department to another. As a general rule, however, the raw material should enter the premises at one end, and progressively pass onwards until it is delivered in a finished condition at the other end, or at least at the heavy crane, or sheerlegs, which lifts it on board a ship, or places it on a railway truck. In establishments like Woolwich Arsenal, or Lord Armstrong's, or Sir Joseph Whitworth's, where an immense variety of work is executed, the internal arrangements must necessarily be extensive and elaborate, but in marine and other establishments generally, they are comparatively simple.

Some of the old-fashioned but famous Works that have been extended bit by bit in crowded localities during the last fifty years, now experience great inconvenience in this respect, owing to the cramped and irregular configuration of the premises, as we have frequently seen.

When you visit these places, it is difficult to take the necessary bearings so that the return journey may be easily accomplished unaided. For instance you go upstairs to one range of shops, and downstairs to another. After that you will probably be transported across a yard to a similar block of buildings with the object of repeating the above process indefinitely, and underneath drums, shafts, and pullies, so low, that your shiny hat may be taken off if you don't look out. Then you cross a street by a lofty flying bridge, only to discover that the world-renowned establishment is very much larger than it appeared, and when you have at last reached the end of your tether in zig-zag fashion, the friendly guide will lead you safely back again.

One method of rectifying these evils is to rebuild the works by degrees, but this cannot always be accomplished without considerable trouble, and even at the best, the area of the ground is often far too small for the requirements of a greatly extended business. What would be better is to remove, if possible, to some open land in the suburbs where a spacious and handsome new establishment can be erected upon the very best lines, and having full control of the railways and perhaps a canal or a river. Let the new premises be stocked with the most improved machinery, and sell off all antiquated gear, which will help to pay expenses. You will thus be in a position to benefit the world much more extensively than before, and also be enabled to make greater financial headway amidst the severe competition of the present day.

In new works, where a large and increasing business may be expected, it is wise to provide for future extensions in the choice of site, while at the same time confining the first outlay only to what will be immediately remunerative. This has been well exemplified in many well-known cases, where easy access to railways, &c., was attainable, and where the most improved and liberal scale of workshop arrangement, and the very best system of constructive machinery and appliances have been introduced.

The transmission of *power* for driving machinery, in common with its generation and application, has received very great attention from engineers, since in each case we find the very germs of economy not only in coal consumption, but in the cost, maintenance, and also in the effectiveness of the means employed. For instance, in tunnelling and mining operations nothing can be better than compressed air as a motive power, because it can be carried long distances in pipes at a very small percentage of loss in pressure, and because when liberated from an engine or machine, it acts as a ventilator.

Hydraulic power is another valuable agent, especially when pressures are very great, or intermittent, or both together, as in the enormously powerful presses used in the manufacture of heavy steel shafts or guns. Here, however, the working load is generated by means of steam engines, but for ordinary purposes in towns, the very easily applied low pressure of about 50 pounds per square inch in the water mains, is extensively made use of in a variety of ways. The cheapest power is that given out by rivers, and this has been exemplified on a large scale by means of turbines and water wheels, whose energy has frequently been transmitted to a distance of many miles through rope gear, or electrical connections.

After all there is, in the main, nothing like steam for driving purposes, or for creating the Hydraulic power now so much employed in shipbuilding and boiler making. This is especially observable in all the great works where the most powerful machinery is employed, such, for instance as those of Sir C. Mark Palmer & Co., at Jarrow, the river frontage of which is about three-quarters of a mile in length, and the total area fully 100 acres. Within this space five distinct branches of industry are most successfully carried on, as follows :—

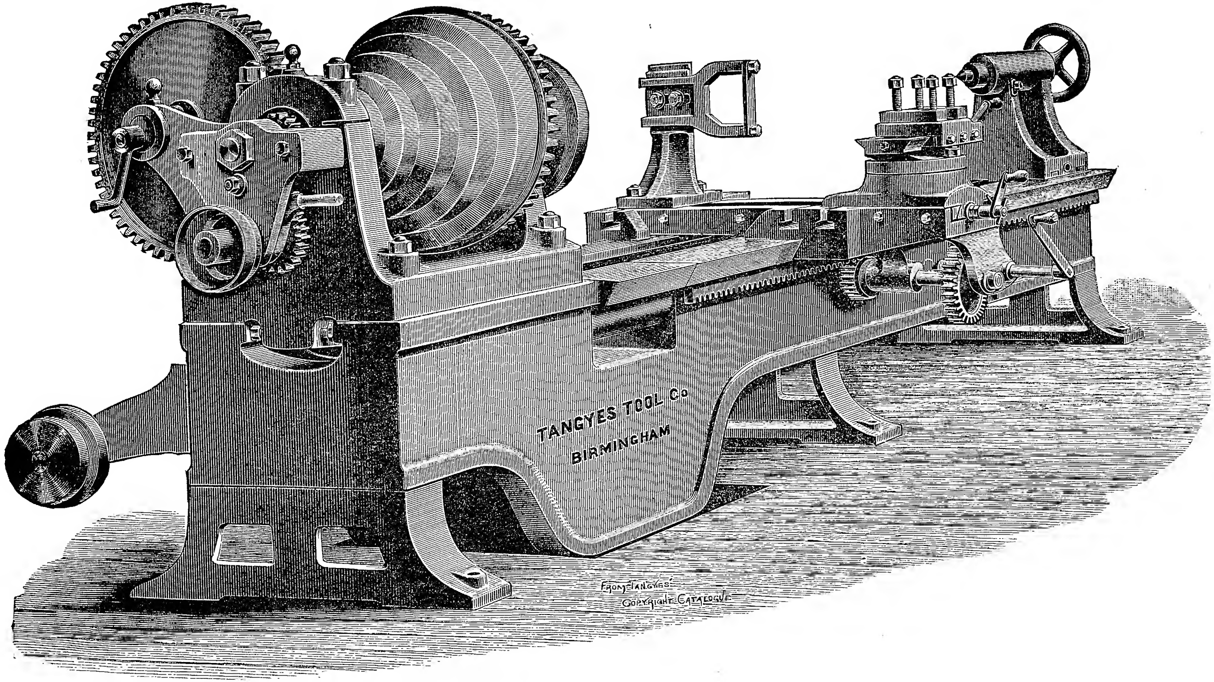
Firstly, we have four large *Blast furnaces* capable of producing 120,000 tons of pig iron annually.

Secondly, there are the *Rolling Mills*, where upwards of 50,000 tons of finished iron can be produced in one year.

The third industrial area is covered by the *Steel Works*, which comprise the most recent improvements in the furnaces, and also in the mills, which are driven by engines of 6,000 horse power.

The *Constructive Departments* come next in order, and these include the engine and boiler works, fully equipped in every respect, and also the brass and iron foundries, forges, coppersmiths' and brass finishing shops, which supply the whole of the materials required for the machinery, &c., in progress.

PLATE I.



SLIDING, SURFACING AND SCREW-CUTTING GAP LATHE.

The *Shipbuilding Yards* contain fourteen launching berths, for the construction of naval and mercantile vessels of every description, and are capable of turning out 70,000 tons of shipping annually, which in itself clearly indicates the immense resources of the above establishment.

For marine engineering purposes, we may take the establishments of the Fairfield Company on the Clyde, the Naval Construction and Armaments Company at Barrow, and those of Messrs. Harland and Wolff at Belfast, as very good examples of the best modern practice, externally in brick, and stone, and timber, and internally in the selection and arrangement of machinery. In each case the turning, fitting, and erecting shops occupy the body of one gigantic building which is divided into three or more bays having rows of strong cast-iron stanchions supporting the roofs, the girders upon which the travelling cranes run, and also the lines of shafting with their drums and pullies. Rails are also sunk into the floor for convenience of transport of heavy material. There is also abundance of light provided by means of spacious windows, and sky lights, and also by electricity. The main lifting gear in the heavy turnery and erecting shops consists of light and heavy travelling cranes in each bay, to suit the extremely varied loads that constantly come upon them. In the fitting department, however, the work is controlled by light iron jib cranes, which are very handy and efficient.

The machines on the ground floor are of a more or or less heavy character, and allow considerable scope for skilful arrangement, not only on account of their variety, but also of their dimensions, and number. Here, however, much is left to individual taste or fancy. It is nevertheless advisable that the heavier machines should be placed nearest the engine that drives them, and thus save the more distant shafting from unnecessarily severe torsional strains.

Marine establishments, may be said to comprise :—

1. A *Building* containing private offices of the firm, drawing offices, general office, and any additional rooms that may be considered necessary for minor purposes.

2. A *Pattern Shop*, into which one current from the engineer's drawing office continually flows, while other streams are directed to :

3. The *Forge and Smithy*, where all the wrought iron or steel productions are made from the drawings supplied to them, and also to :

4. The *Coppersmiths' Department*, where the copper pipes are similarly produced. From the pattern shop the patterns for iron, steel, or brass castings are sent to :

5. The *Main Foundry*, and

6. The *Brass Foundry*, from whence all the rough castings are brought to :

7. The *Heavy Turnery* where the cylinders and cylinder covers, pistons, condensers, framings, bed plates, screw propellers, shafts, and similarly massive gear are bored, planed, slotted, &c., and fitted up, as independent details, ready for erection in their respective positions in the engines. On the other hand, all the smaller gear of one thousand and one different kinds, is operated upon in :

8. The *Light Turnery*, which is generally on an upper floor of the same building, and as the various details are completed in regular order, they are sent to the boiler and other departments, and also to :

9. The *Erecting Shop*, where the engines are built

complete, until ready for taking down and transferring by instalments, as required, to the sheerlegs in:

10. The *Yard*, where they are lifted on board the ships lying in the fitting up basin. Whilst everything has been progressing in the engine department from first to last as described, a full set of working plans has been supplied by the drawing office to:

11. The *Boiler Works*, for the construction of the various boilers. This is greatly facilitated by the rapidity with which the steel and iron plates, &c., are supplied by outside firms, and by the excellence of the machinery employed in their manufacture. When the boilers are finished, tested, and painted, they are sent to the aforesaid sheerlegs to be put on board a steamer immediately after the launch. In number

12. The *Shipyard*, a similar system is employed in all departments, and these are set in motion by their own drawing office, by the full sized mould loft plans, and by working models of the vessels. Here, too, the swiftness with which a ship is built, greatly depends upon the manner in which the plates, frames or ribs, keel, stern and rudder posts, deck beams, &c., are manipulated in this part of the premises from first to last. The above departments, however, will be described in detail later on.

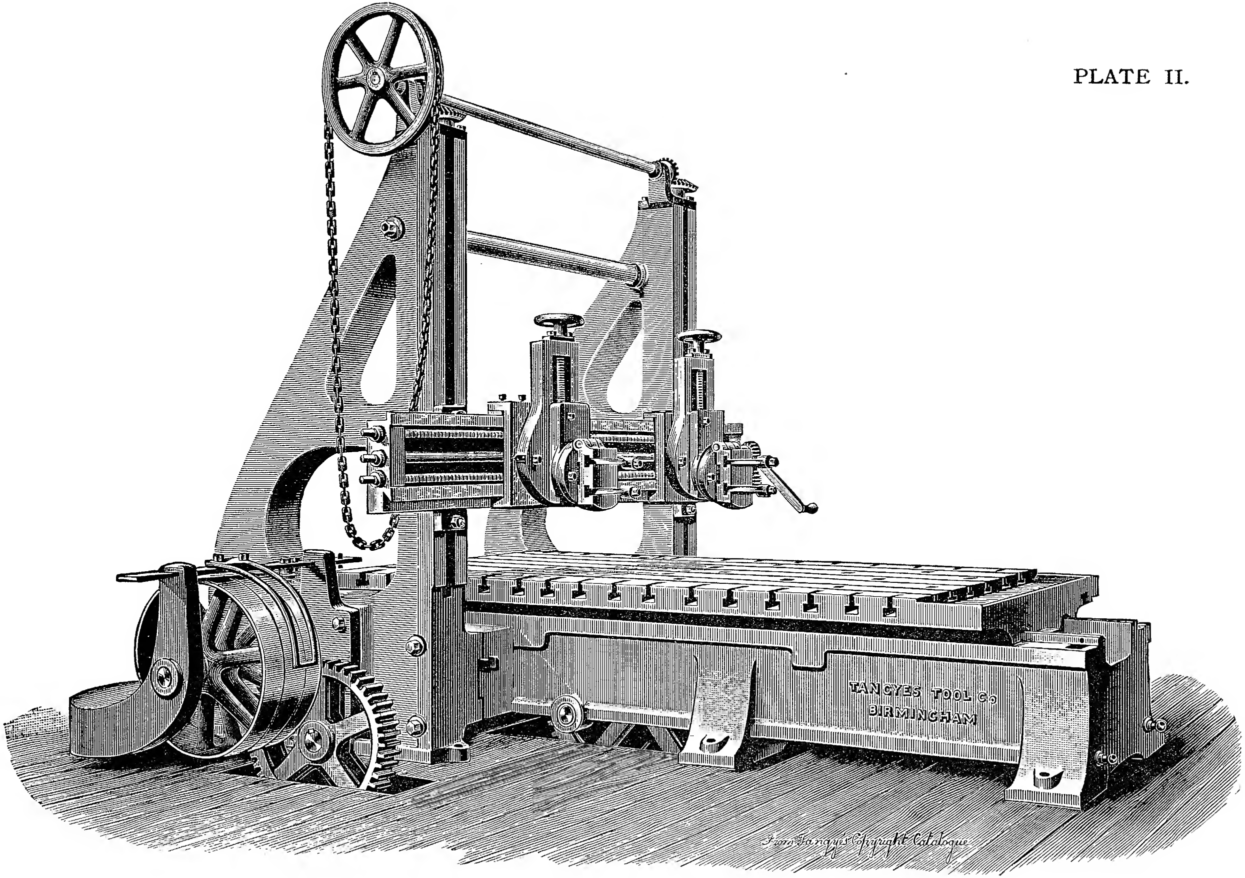
When we come to the *Machines* themselves we at once enter upon a field so vast that at least a whole volume would be required to do them justice. Those most in use, however, are employed in turning, planing, slotting, drilling, boring, milling, screwing, punching and shearing, plate bending, &c., all of which represent certain classes of tools capable of subdivision in a great variety of ways. These have now attained great perfection in every way owing to recent discoveries in the highest ranges of practical science.

The monarch of machines is the *Turning Lathe,* which was first employed by the ancient inhabitants of Northern India. When those people wished to turn anything, they placed their rude " headstocks " close to the branch of a tree, which provided the motive power by means of a cord attached to it at one end, while the other end was coiled round the block of wood or other material to be operated upon. The spring of the released branch thus rotating the piece of work on its axis as required.

Such, it is said, was the origin of a machine that, for general usefulness, cannot be equalled, as the modern lathe can do the work of several others, as well as its own, which reduces the labour and expense of accurate fitting and finishing to the utmost, owing to the *continuous* action of the cutting tools. The varieties of the lathe are endless, and its dimensions nearly so. On the one hand we may have a household specimen, only large enough to be driven by the foot of an amateur, and on the other hand, a gigantic engine capable of taking between its centres a 120 ton gun, and costing £6,000 to £7,000. In this case, eight tools may be employed at one time, each of which will take a cut 1½" deep in tough steel, thus removing about two tons of metal per hour.

The extensive employment of steel in mechanical undertakings generally, and the great increase in the weight of forgings and castings during recent years, have caused many important improvements to be made in constructive machinery. This has been necessitated by the extremely refractory nature of the metal, and also by the extra quantity which has frequently to be cut away to save the expense of forging. Hence we now have

PLATE II.



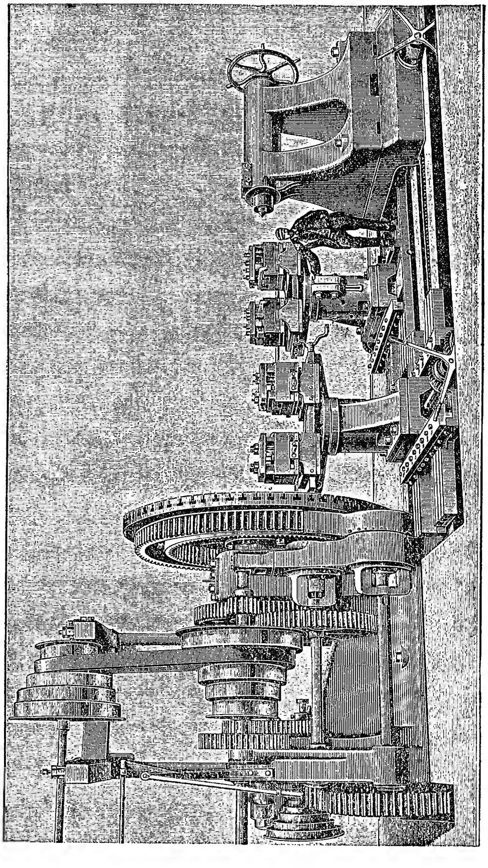
PLANING MACHINE.

increased strength and power in the machines themselves, and also the introduction of special modifications, so that the number of removals or resettings of the work may be reduced to the utmost.

Besides the lathes for heavy shaft or gun turning, there are many other varieties in ordinary use, which include those for surfacing or circular planing, screw cutting, copying from original articles used as specimens, multiple work, &c., and also for oval turning, and many other purposes. Thus it will be seen that this machine stands alone, and that without its aid the whole system of engineering would become dislocated, and very much of it rendered impossible.

A very useful type of 18″ Centre Sliding, Surfacing, and Screw cutting Gap Lathe, is shown in Plate I, which represents one of Messrs. Tangye's latest arrangements. The two first named motions are caused by a separate shaft at the back of the machine, which is driven by cone pullies as shown. The above produce four different rates of speed, and these, as well as a quick independent motion, are regulated by handles at the front of the saddle. A compound slide rest, capable of swivelling when required for conical turning, and an adjustable stay for steadying long shafts, together with other accessories are additionally fitted. The engraver has clearly shown the end wheel work and gear for screw cutting purposes, which, it may be added, are more or less applicable to lathes in general.

In this case, many change wheels are employed, for producing screws in great variety, including, for instance, the guide screw shown on the plate. A quantity of small details are also supplied, such as overhead counter shaft with its hangers, fast and loose pullies, belt bar, forks,



QUADRUPLE-GEARED LATHE.

and handles, face plates of different sizes, chucks, spanners, &c. As a whole, the lathe is a very fine one, and, we hope, descriptively intelligible to every reader.

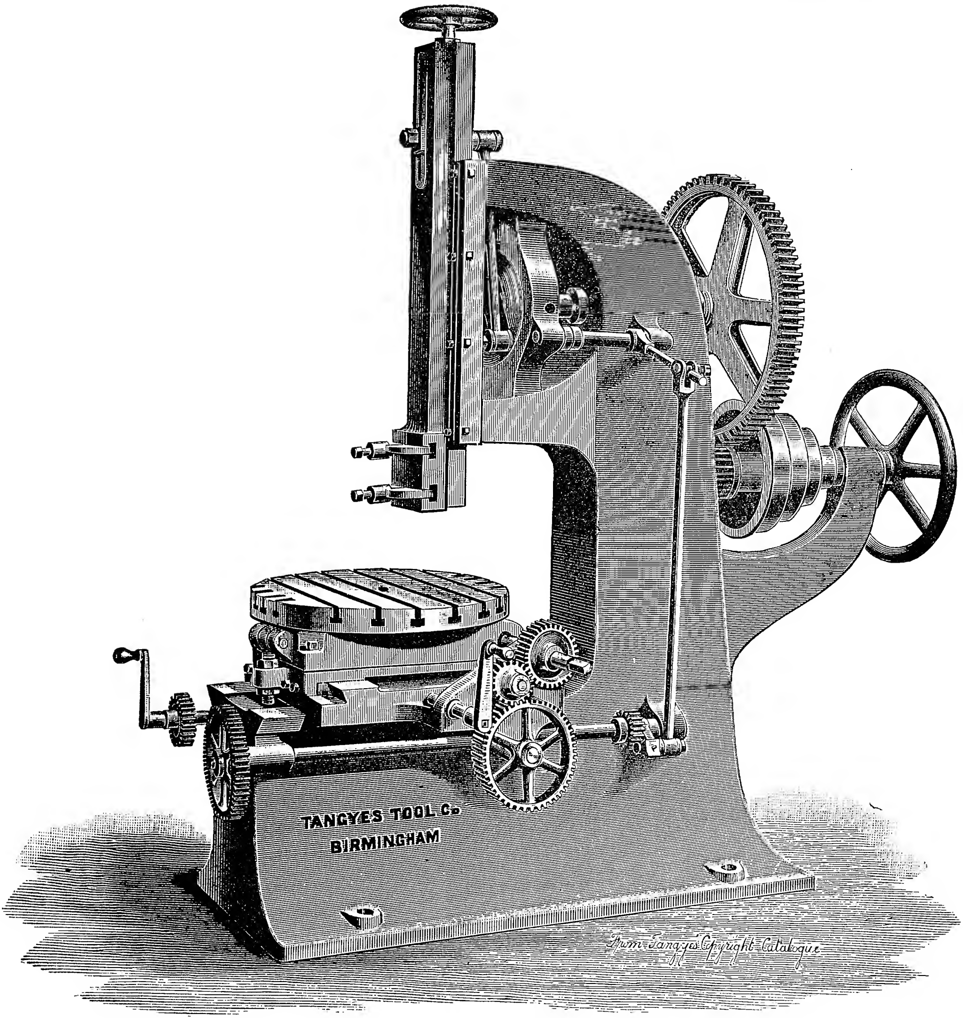
Machines of this class are capable of unlimited application according to circumstances, to which, none know better how to accommodate themselves, than Messrs. Whitworth, Hulse, Smith & Coventry, Kendall & Gent, and Shanks, amongst all of whose productions I was chiefly educated during many years' practice in the Works, and these, along with more modern friends, will be frequently noted in the following pages.

The annexed view of a 72″ Centre Lathe, by Messrs. Galloway, of Manchester, gives a good idea of what we have now come to in this respect. The bed is 50′ 0″ long, by 9′ 0″ wide, and the fast headstock is fitted with a face plate 10′ 3″ diameter, and also gearing capable of producing 20 changes of speed, whilst the total weight of the parts, below and above the ground level, is about 130 tons. When it is considered that some lathes have 20′ 0″ face plates, it will be seen that the operation of turning the aforesaid guns, or a Cyclopean triple crank shaft, or boring a gigantic screw propeller, is indeed picturesquely interesting.

In 1825, Clement of London received the award of the Society of Arts for his original *Planing Machine*, which was, in later years, so much improved by Whitworth, that it soon became a most valuable acquisition. Previous to this, however, working engineers did their own surfacing by means of the hammer, the chisel, and the file, sometimes without the latter, as the barbarous rust constructional joints, and thickly red-leaded steam joints, were greatly in favour. All these passed gradually away as the Planing machine gained the ascendancy, and ultimately became master of the situation under the lathe, as Ruler-in-chief.

The best known, and most highly appreciated type of machine for general work, is shown in Plate II, which, with a few modifications, clearly exemplifies one important branch of the great planing family, up to the gigantic engines now to be found at the Atlas Works, Sheffield, and elsewhere. This machine is by Messrs. Tangye, and embodies the latest improvements, including *flat*, instead of V slides for the table, as the former takes the side thrust better under heavy cutting. Amongst the makers of the most powerful class are Messrs. Buckton, of Leeds, the largest of whose machines are able to plane surfaces at least 30′ 0″ long, 12′ 0″ wide, and 12′ 0″ in height, by means of four tool boxes capable of taking the heaviest cuts either by belt power, or by the application of separate driving engines. They have also patented a double cutting tool holder which has proved most useful. In this case, the tools are placed nearly back to back, and each is made capable of an automatic and slightly rocking motion fore and aft, by means of which, the disengagement of the forward tool from a cut brings the backward one into play almost in the continuous action style of the lathe.

In Engineering work generally, there is much that neither planers nor lathes can execute. This led the highly talented Mr. Roberts, of Manchester, to introduce about the year 1820, his original *Slotting Machine*, or vertical planer, which still retains its early leading peculiarities, although immensely improved in detail. Long ago, Messrs. Napier & Sons made, for their own use,



SLOTTING MACHINE.

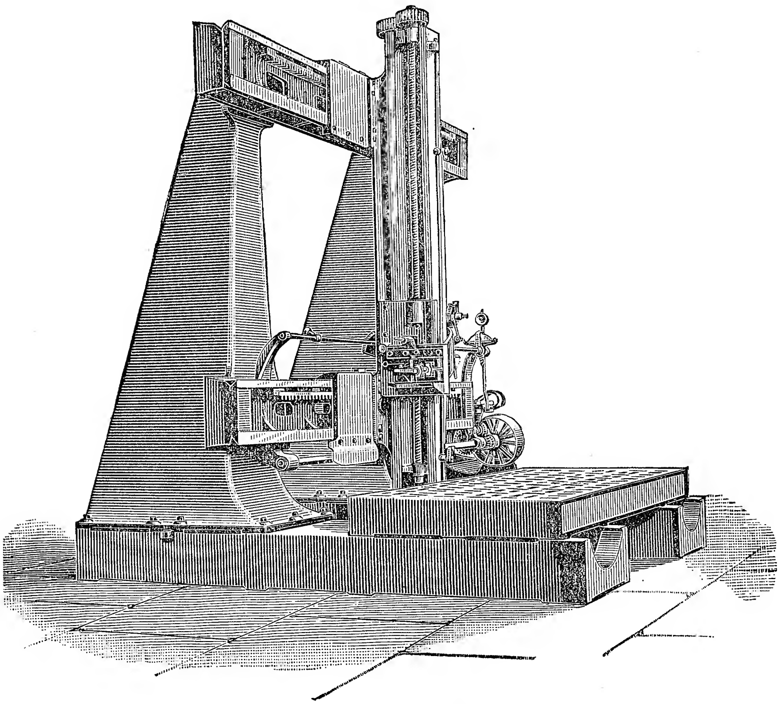
a slotter of the old style, which, even yet, is, we believe, the largest of its class. Now, however, the modern Titans are chiefly to be found in armour-plate works, the vast forges, and also in the great marine establishments, where they have proved invaluable.

The leading features of one of the latest, and most useful types of machine, may be gathered from Plate III, which represents one of Messrs. Tangye's productions. As will be clearly seen, everything is easily adjustable, to suit ever changing circumstances, from the stroke, &c., of the sliding bar itself, down to the smallest detail. The driving disc revolves *within* a bearing, instead of outside of it, thus giving additional steadiness in action, and the table is capable of being slightly tilted for the purpose of cutting tapered key seats in levers, &c. In short, the whole machine is an elegant and well designed specimen of its class.

In all Slotters the revolving table enables inside and outside partial and variable curves to be cut with great facility. Apertures, or "slots" of every kind can also be similarly treated. With disc driving gear, as shown, these machines advance in size from 4″ to about 19″ stroke, and then by stages up to at least 5′ 0″, with screw gear, and double framing of the most massive character. They are also fitted, when required, with double or quadruple tool holders to suit particular cases. Beyond the above, *Vertical Side Planers* come in very handily, since, by their action, castings of the largest dimensions may be operated upon to the finish.

One of these machines, by Messrs. Buckton, is shown in the annexed engraving, which clearly indicates how the work is done by means of independent horizontal and vertical slides, that, in the largest sizes, will accurately surface an area of 50′ 0″ long, by 12′ 0″ in height. An additional traverse of tool in and out, of say 3′ 0″ may also be given, and the top of the table can be sunk flush with the erecting shop floor, which is much more convenient in many cases.

Amongst the numerous varieties of Slotting machines



SIDE PLANING MACHINE.

may be mentioned the *Combined Millers and Slotters,* designed by Mr. Dixon, of Messrs. Kendall & Gent, of Manchester, to suit heavy cutting in steel. These are intended to rough shape details with the ordinary tool, and finish exactly with the milling cutter, by means of specially constructed slotting bars, which can be fixed rigidly in any required position. Thus producing excellent and highly finished work at one setting.

In this chapter we have only described three leading machines that are now absolutely indispensable in every engineering establishment. But however much Whitworth, and his successors, and in many cases his pupils, and others, may have ultimately improved them, it is an interesting fact that the lathe owed its origin to some benighted ancient Hindoo, and the planing and slotting machines to master strokes of design by the aforesaid Mr. Clements, and Mr. Roberts, who thus inaugurated a new order of things that has proved of inestimable value to the world at large.

It may be added, however, that unless Mr. Whitworth had introduced his ingenious method of making *true planes*, which led to his improvement of the slide rest, the machines just described might—so far as accurate workmanship is concerned—have been complete failures, instead of some of the most beautiful specimens of constructive art to be found throughout the realms of Engineering.

CHAPTER II.

MACHINERY OF THE WORKS.

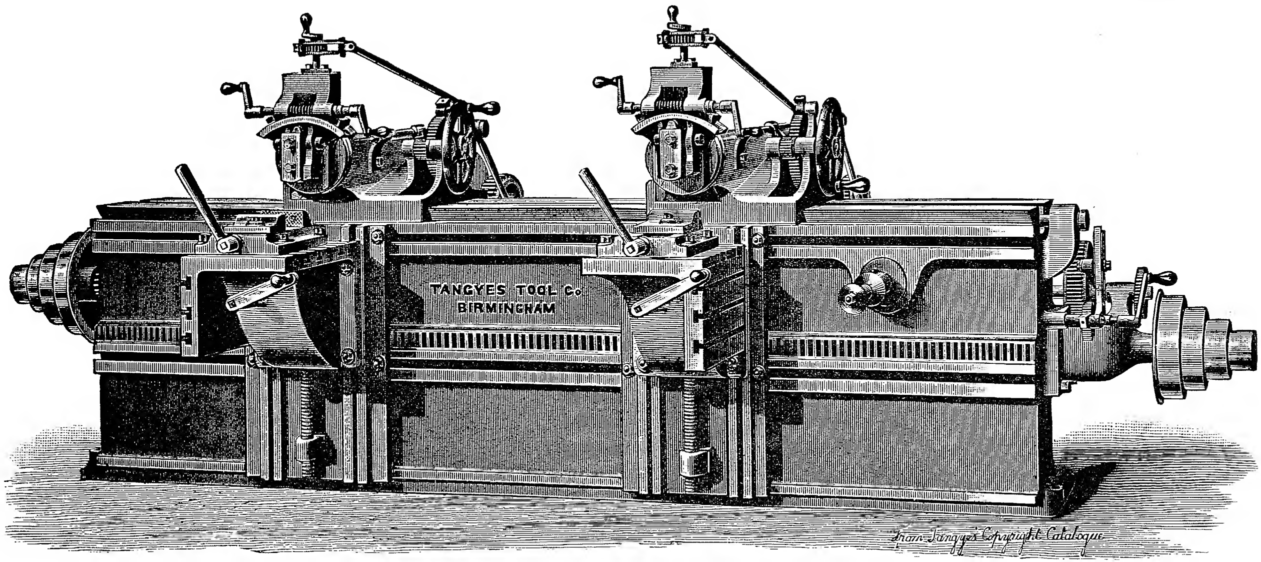
Shaping Machines, and their peculiarities—Milling Machines, and their uses—Slot Drilling Machine, and its application—Ancient and Modern Systems of Boring Metals—Effect of latter on Boiler Construction—Multiple Drilling Machines—Portable Drilling Machines and Flexible Shafts—Modern Tools for the above—Radial Drilling, and its Modifications.

BESIDES the ordinary form of curved and straight work usually performed by the slotter and planer individually, as mentioned in the last chapter, there is a large quantity of small sized details, that could not well have been operated upon by either of them. This led to the introduction of the well known *Shaping Machine*, which combines the actions of both in a very satisfactory manner, in all cases where details are of a complicated, and especially of an almost circular, or otherwise irregular form.

Plate IV shows very clearly an improved *Double Headed Shaping Machine*, whose movable heads can be worked independently of each other. The length of stroke usually ranges from 6″ to 18″, and the length of bed from 6′ 0″ to 12′ 0″; the illustration is of a machine having a 12″ stroke and 10′ 0″ bed.

In all cases there is a quick return motion of the rams, which work in long slides that are easily adjustable in every direction. The tables are cast with the usual ⊥ slots for

PLATE IV.



DOUBLE HEADED SHAPING MACHINE WITH QUICK RETURN.

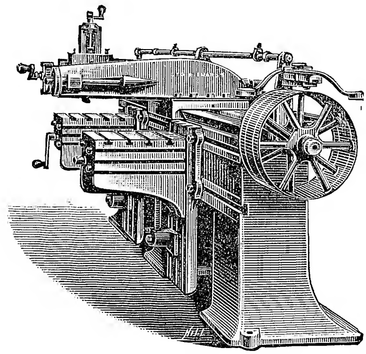
bolts, and are adjustable along the bed and also vertically by means of the handles in front. For small gear otherwise difficult to secure in position, parallel vices come in most usefully, and when the mandrel is revolved by circular feed motion, the bosses of levers, or similar details fixed upon it, can be finished with little trouble.

The gear for moving the carriages longitudinally, and also for actuating the mandrel, is conveniently arranged, whilst the tool boxes themselves are provided with circular movements for internal curves, and can be set for cutting at any angle by means of an index. A modification of this class of machine for performing special work, such as the planing of several surfaces at different angles in valve boxes and other castings at one setting, is made by the Britannia Company of Colchester. Here, however, circular tables with vertical faces, capable of circumferential movement, are employed, instead of those of the usual kind shown in the Plate.

An excellent example of a very compact and simple *Shaping Machine* by Messrs. Tangye, is shown in Plate V. This illustration not only clearly explains itself, but enables the action of some of the parts of the Double Headed Machine to be more easily understood. The mandrel for circular planing is provided with two cones and end adjustable screw, by means of which suitable work can be instantly fixed in position.

Messrs. Richards & Co., of Broadheath, near Manchester, have a very useful and variously modified *Side Planing* system of their own, differing from both of the above, as shown in the annexed view.

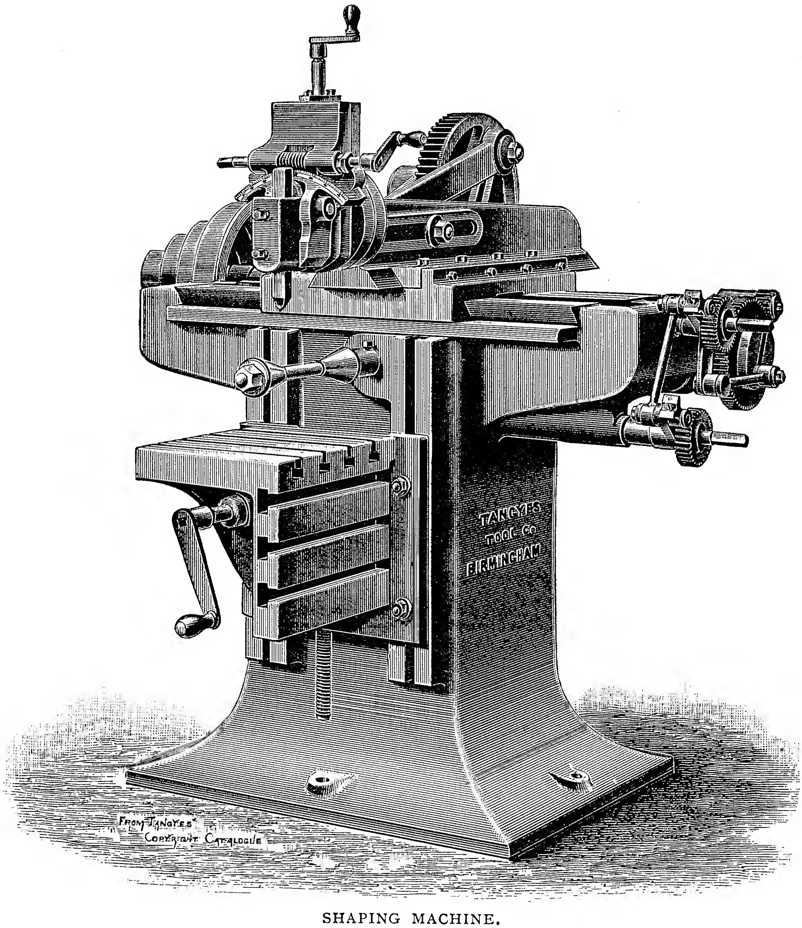
It will be seen that whilst the overhung arm has no transverse motion, it is fitted with a tool box and slide which do all the work, as the arm is traversed longitudinally by means of a guide screw driven by the end pulleys. This machine is capable of planing a surface 20″ wide, and 16′ 0″ in length, but in the larger sizes the dimensions are as great as 40″ in one direction, and 30′ 0″ in the other.



SIDE PLANING MACHINE.

The foregoing remarks upon lathes, planers, slotters, and shapers alike, have reference to machines whose special feature is the power of taking more or less heavy cuts. We now, however, come to those of a totally different kind, which of late years have become indispensable.

The *Milling Machine*, to which we refer, is peculiarly adapted for continuous action of a somewhat nibbling character, and for performing a great variety of work that cannot be so well or so economically done by any other process. In short, it can be used with astonishing effect for anything of delicate shape, and especially in cases where exact similarity, or interchangeability of parts, is required, or where copies have to be made from original designs, without the intervention of highly skilled



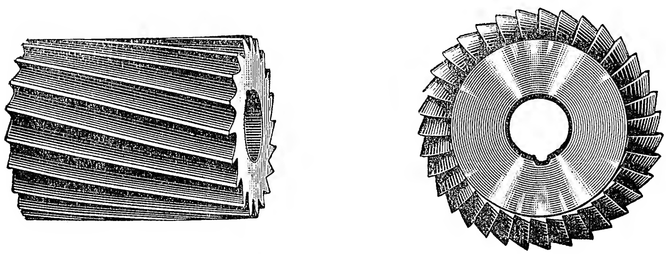
SHAPING MACHINE.

labour, as in fire arms, and sewing machine manufactories, &c.

The tool has been employed in England for about one hundred years, but until recently only on a limited scale, owing to the difficulty and expense of softening, sharpening, and re-tempering the cutters, the last of which processes frequently twisted them out of truth. Now, however, the introduction of emery grinding machines has enabled their teeth to be easily and accurately trimmed to standard sizes without being softened, thus forcibly exemplifying the immense benefit that may be conferred by one good invention upon another. At the same time it should be stated that various alterations in the original form of the teeth enables this result to be accomplished with great accuracy.

Although the Miller is by no means a powerful shaper, it compensates in a great degree for this defect, not only by continuity of action, but by a higher rate of speed, owing to the edges of the tool being successively relieved from contact with the metal operated upon, and thus more fully exposed to the cooling action of water. Hence it follows that the velocity of these edges may be somewhere about three times that of other tools of the ordinary description.

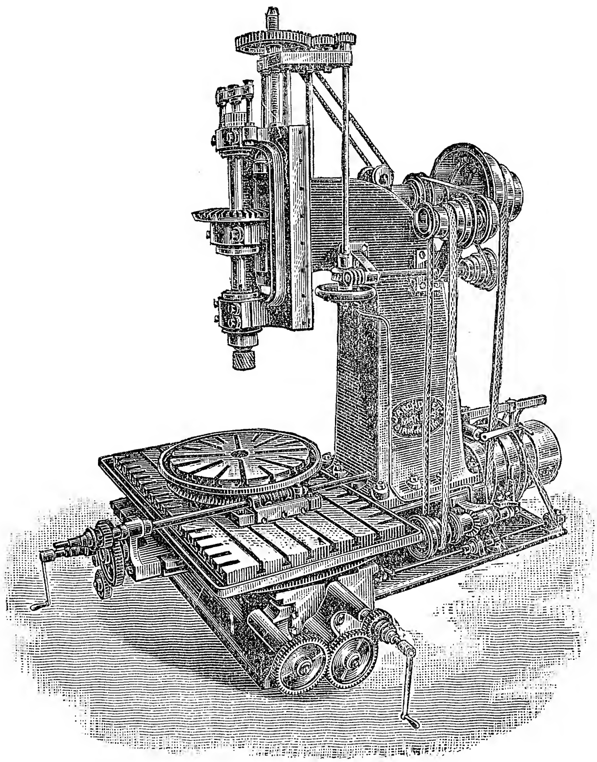
There is still much to be learnt respecting the most economical rates of speed and feed for milling cutters to suit the various metals now in use, but advancing practice is gradually showing how this operation can be most efficiently performed. The same practice is also indicating the necessity of designing details, when possible, to suit the powers of this machine, instead of the lathe, planer, and slotter conjointly, as is generally the case. As screw-cutting lathes are provided with tables of change wheels for various pitches of thread, so that the turner can see at a glance the required arrangement of gearing, milling machines should be similarly furnished with tables giving the number of revolutions per inch of feed for cutters of all diameters, and depths and widths of cut—roughing and finishing—for brass, cast iron, wrought iron, and steel. So fully have Messrs. Musgrave & Sons, of Bolton, recognised the value of these, that they employ, in their extensive heavy engine and other practice, elaborate tables of this nature suited to diameters ranging chiefly from ½″ to 8″. In some cases, however, much larger cutters have been used.



MILLING CUTTERS.

Specimens of two of those in general favour, by Messrs. Kendall & Gent, are adjacently shown, both of which can be accurately sharpened to the last, without softening, by means of Messrs. Smith & Coventry's *Improved Universal Cutter Grinding Machine*. The cylindrical or barrel cutter is employed in a great variety of plain work, such as the bosses and webs of small cranks, levers, etc., where a high finish can be given without further trouble. The disc cutter, round or flat, is extensively employed, either singly or in combination with others, and it is here that the extraordinary powers of the machine become most apparent, as we could clearly perceive during a special visit to the establishments of the above firms, and also in other places.

Excellent examples are given in the accompanying engravings of two machines specially designed and made by

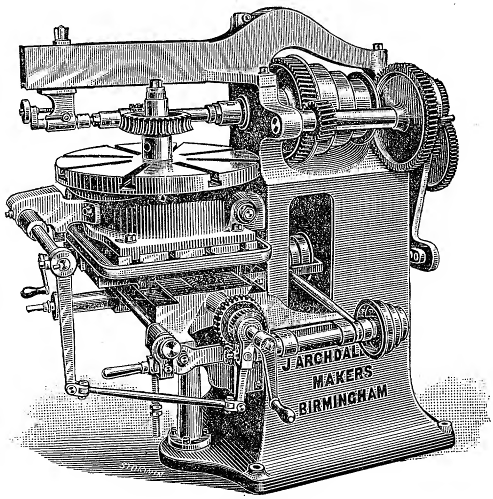


VERTICAL MILLER.

Messrs. Archdale, of Birmingham, for Portsmouth Dockyard. One view represents a very powerful *Improved Vertical Milling, Boring, and Drilling Machine* for marine engine details, while the other view clearly illustrates a

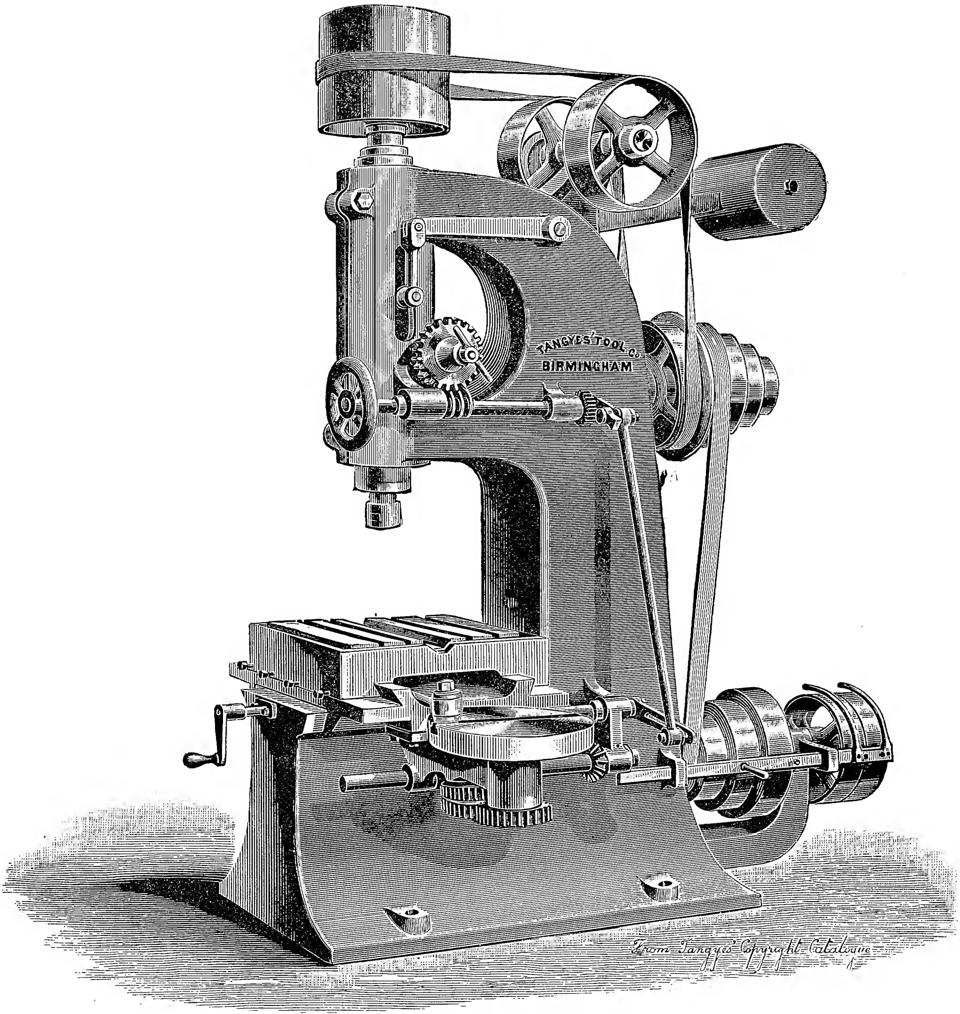
Combined Milling and Worm Wheel Cutting Machine, capable of excavating from 10 to 100 teeth out of the solid without any aid from a dividing engine.

In the marine butt and strap connecting rod days, we used to have splendid practice in fitting up these details, and in cutting cottar holes of every size through them, and also through many others of various kinds, all of which required very exact workmanship, as many of my es-



WHEEL CUTTER.

teemed contemporaries will remember. The operation consisted in drilling four holes nearly equal to the width of the aperture right through the rod and strap, or socket, then chipping out the metal to a fair rectangle, and lastly, finishing with the file to a true surface, thus involving considerable skill and trouble in making parts interchangeable. Now, however, all this has been abolished



SLOT DRILLING MACHINE.

by the introduction of admirably designed *Slot Drilling Machines*, which do their work in splendid style from first to last.

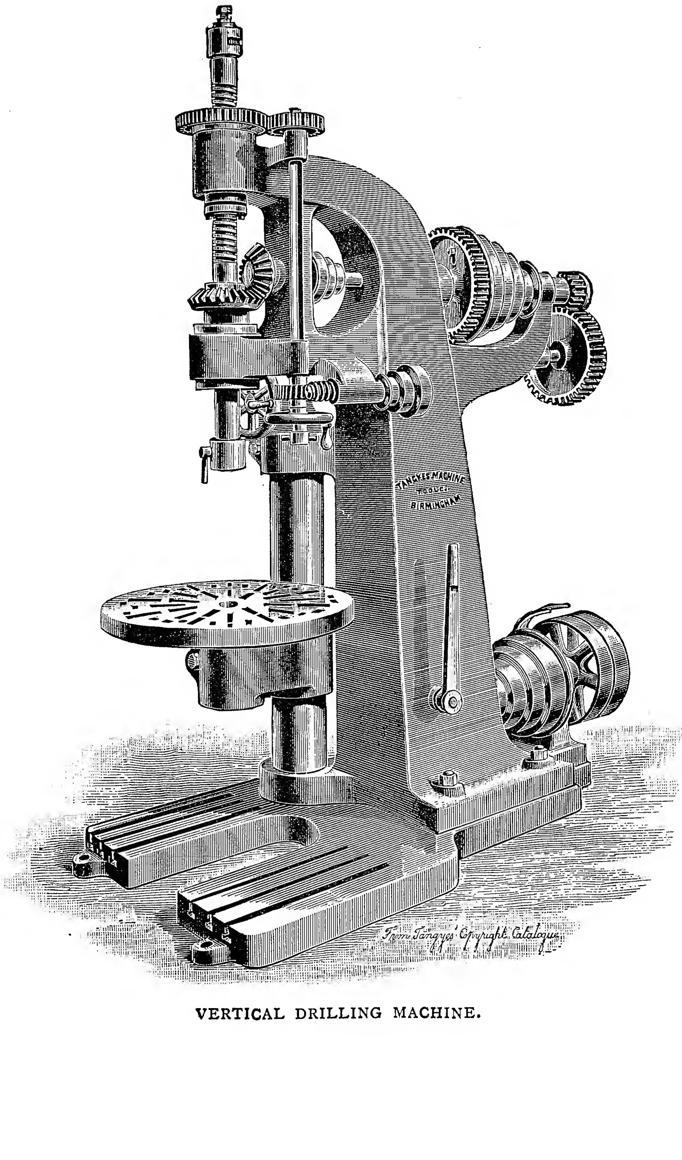
An excellent specimen of one of the latter, by Messrs. Tangye, is shown in Plate VI, which hardly needs explanation. It may be noted, however, that the drill spindle is directly driven by the very smooth belt motion, instead of wheel gearing of the usual description. The table is so constructed that everything can be easily fixed in position. The feed motions are self-acting and variable, and the arrangement of details for regulating to a hair the length of a slot, by means of an alternating traverse movement, and also for the intermittent downward action of the drill, leaves nothing to be desired. This machine will cut apertures up to 10″ by 1¼″, but much larger sizes are sometimes employed.

Messrs. Kendall & Gent have designed excellent machines, both single and double headed, and with adjustable tables on the Shaping Machine principle. In the latter case, however, two operations at the same time may be carried on independently of each other, on holes up to 20″ in length and depth, by 4½″ in width, and, when necessary, plain drilling can be executed with equal facility. It may be added that a most important incidental advantage gained by this process is the additional strength imparted to a rod by the *semi-circular* ends of cottar holes, when compared with the sharp-cornered apertures that used to be formed by hand labour.

The *Drilling or Boring Machine*—like the Lathe—is of ancient origin, and in past ages consisted of a small hand tool, which was alternately rotated by means of a bowstring apparatus, having its cord wound round the drill spindle, and kept in a state of tension when in use, as it still is for minute work. This machine is now made in endless varieties, which include the ordinary verticals bolted to stone foundations, or to walls, or benches, and also the radial, horizontal, and the now most extensively employed class to which the term "*Multiple*" is applied. Here, however, we touch the borders of a latter day revolution that affects bridge building and boiler making alike.

When steam boilers were made for low pressures, their iron plating was invariably punched, and then rivetted by hand, even after pressures of 60 to 80 pounds per square inch had caused the cylindrical form to become a necessity, on account of its enormous natural strength. The much greater pressures, however, of 150 pounds employed in the early triple engines caused boiler shells to be made of such thick steel plates that the punching process, with its attendant evils, was superseded by the special drilling machines that now reign supreme.

There is perhaps no machine except the lathe that has so many ramifications throughout the whole domain of Engineering as the one now under consideration—one, indeed, which belongs to the great family of borers in wood and metal, that range in size from those for $\frac{1}{8}''$ holes to the colossal engines capable of boring and facing with the utmost accuracy a 120″ steam cylinder. Excellent examples of many of these are to be found in marine establishments, where numerous "Combination" machines are also employed, with the object of saving unnecessary hauling, and lifting, and re-setting of heavy castings. For the same reason, we have quite a large



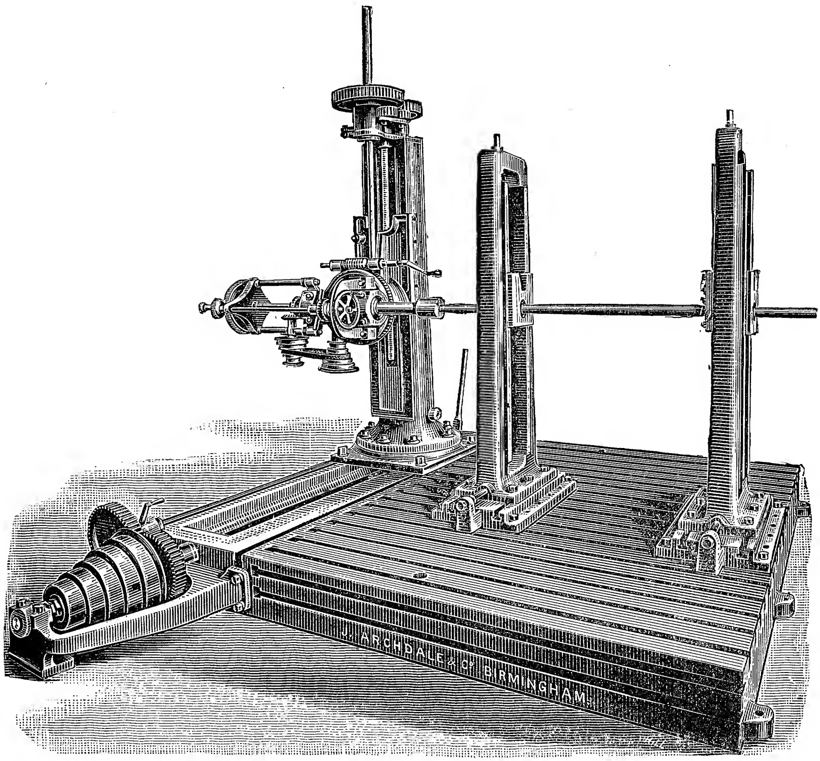
VERTICAL DRILLING MACHINE.

assortment of small portable drillers which may be planted on ponderous castings, and either driven by rope gear, or by the Stow flexible shafting that has now become so useful in transmitting power to otherwise inaccessible places.

Plate VII forms a good example of one of Messrs. Tangye's *Vertical Drilling Machines* which belongs to a very popular type that may be greatly modified in detail to suit ever varying requirements. In this case the table is well supplied with bolt slots, and a central hole for steadying boring bars. It is easily revolved on the vertical column, can be locked at any point, and is capable of moving up and down by means of a screw and hand wheel. The table can also be swung to one side, so that large work may be secured to the planed base plate, or laid upon trestles if more convenient.

As *Horizontal Drillers and Borers* occupy a most important position in machine shops, we give on the next page a powerfully built example of one of them specially made by Messrs. Archdale for a foreign Government. The table of the massive bedplate is ten feet square, and is planed on the top, sides, and in the bolt slots. The pillar carrying the boring apparatus is capable of traversing the full width of the table, and the slides that move upon it are made to act automatically up and down, and also to swivel, so that holes may be bored obliquely when required.

In our 'prentice days all the holes in large castings, such, for instance, as condensers, etc., were made either by the ratchet brace or by the crank brace. They were then screwed by hand, and similarly the studs were fixed; if not quite true, a smart blow or two from a hammer set them fair—and perhaps *broke* them off. With such a



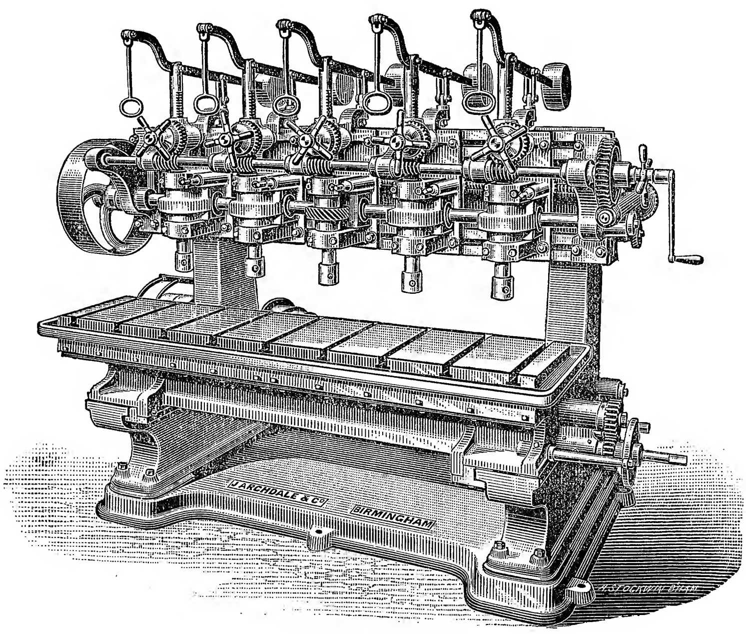
HORIZONTAL DRILLER.

machine, however, as we have described, the heavy casting is secured to the bed plate, and as the drill spindle traverses its whole surface every hole is bored and truly tapped and studded at one setting. In addition to this, the heavier class of work can be executed by means of boring bars and cutter blocks, and adjustable standards. Such performances by this valuable machine have no doubt amply repaid its proprietors for their large outlay upon it.

As previously remarked, there is such variety in drilling machines and their arrangements, that it would be impossible to describe them for want of space. It may be stated, however, that in some cases the table simply rises and falls, but in others it is additionally fitted with compound slides that traverse a large horizontal area most usefully. In wall and radial drillers, however, it occasionally happens that temporary supports are found most suitable, as they can be so easily removed when not wanted, and thus leave the ground space perfectly open. Then again, the back motion and driving gear are often more or less picturesquely arranged to suit the ideas of the makers or purchasers. At other times the machine is made to swivel and travel in every direction, as in the last example, and for the same reason.

When, however, holes closed at one end are screwed by a drilling machine spindle, there is a risk of breaking the tap in the hole, and thus causing great inconvenience. To avoid this, Messrs. Smith & Coventry attach to these spindles, when required, a very simple and adjustable appliance which, by means of a spring coupling, at once relieves the tap when the strain becomes excessive, and prevents even the possibility of fracture.

It may be readily supposed that when boiler shell punching was abolished, the expense of boring rivet holes would become too great for economical practice. Here, however, my learned brethren showed their originality and skill by inventing and improving the *Multiple Driller*, which enables many holes to be made in about the same time that formerly was occupied with only one. In this it



MULTIPLE DRILLER.

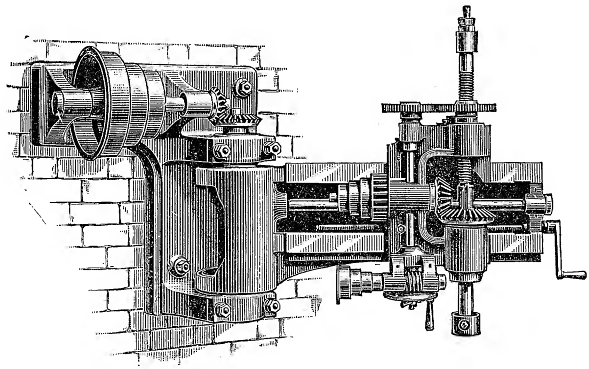
may be said that they are greatly aided by the *Improved Twist Drill* of Messrs. Smith & Coventry, which not only bores a true hole, and clears itself automatically of the cuttings, but dispenses with fire "dressing" and tempering, and works more quickly and more closely to standard diameter than the ordinary kinds.

Quite a picture gallery of the above machines by different makers might be arranged to suit the varying peculiarities of modern practice, but we shall only give adjacently one good example of a *Multiple Spindle Driller*, specially constructed by Messrs. Archdale for the Italian Government. The whole apparatus is self-contained, as the countershaft and cone pullies are at the back. The table has also a compound movement with a dividing arrangement each way, and is provided with a channel all round for catching the drill lubricant, and keeping everything clean.

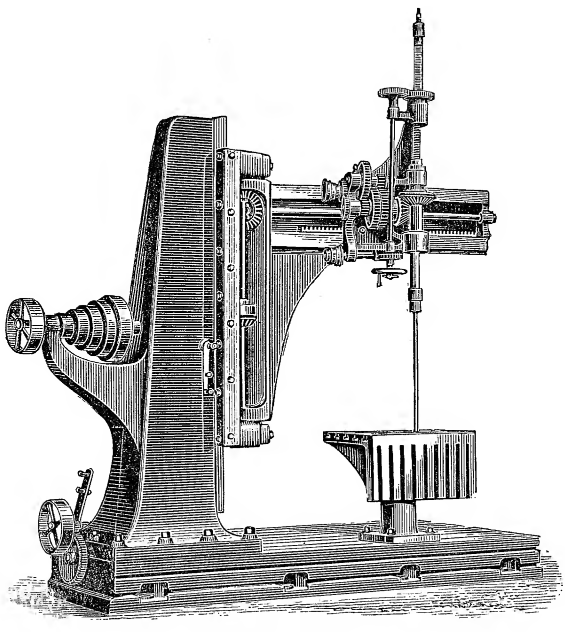
The distance of the spindles apart may be regulated to suit the pitch of the holes, and as the helical gear, worms, and worm wheels, etc., are of hardened steel, it is evident that the whole machine is not only most useful, but capable of standing severe wear and tear. For boiler shell drilling other arrangements are necessary, as illustrated to some extent in the chapter upon the Galloway Works. But whatever those arrangements may be, the objects aimed at are easy adaptability of the machine to different sizes of boilers and varying pitches of rivet holes, combined with excellence and rapidity of execution.

The *Radials*, as a class, are not so numerous as the others, but are equally indispensable, as every old hand well knows. These machines resolve themselves into whole and partial traversers of circles on independent standards, or the latter only when fixed to a wall, as shown in the adjoining view of one of Messrs. Francis Berry & Sons' Sowerby Bridge productions.

Here we have a very compactly designed swinging arm complete, which is so much in accordance with the best practice, that we need only add that the sizes range from a 3′ 6″ to a 5′ 0″ radius. The independent machines, however, are sometimes made as much as



WALL RADIAL.



LARGE RADIAL.

10′ 0″ for the heaviest purposes, with at the same time a 30″ vertical feed of spindle, and a 190° traverse. One of these, by the same firm, is exhibited in the annexed view, in which it will be noted that the back motion gear is attached to the radial arm instead of the framing, as it is considered an advantage. This arm can be raised or lowered to suit the height of the work in hand, and can be made to sweep over every point of a large casting, thus enabling the holes to be drilled, screwed and studded at one setting.

CHAPTER III.

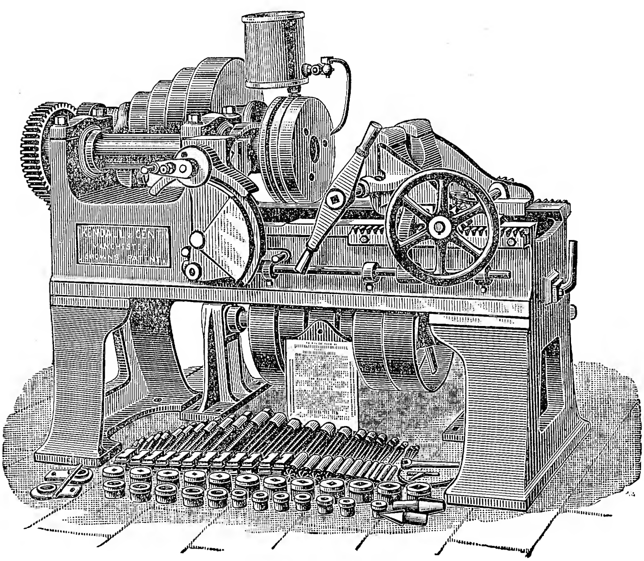
MACHINERY OF THE WORKS. (*Continued.*)

Screwing Machinery—Standard Gauge System and its results—Method of rapidly manipulating small Brass Details—Present Workshop System—Emery Grinding Machinery—Good Example of very rapid Construction.

In all engineering establishments there is an enormous amount of *Screw cutting* of a minor character that has to be performed by special machinery, quite apart from the heavier class generally run in the lathe. Long ago a great deal of the former was executed by hand tools, or in very slow working Screwing Machines, until advanced practical science showed how a much larger quantity of better work could be done in less time. Thus it came to pass that the screwer of to-day is so greatly superior to his early predecessors.

There is no method of fixing the parts of machinery together that is so simple, so efficient, or so easily adaptable to the different phases of engineering practice as that of the bolt and nut. Of course, we fully recognise the indispensability of the gib and cottar, or the latter alone, in many cases, but for all round suitability on a truly gigantic scale there is nothing to equal the above, which has quite a history of its own.

In early times the threads of screws were irregularly made, according to the ideas of the designer. This, however, caused great inconvenience when bolts and nuts from different firms would not interchangeably fit each other. As a means of rectifying this serious evil Mr. Whitworth experimented wlth a large number of screws so that he might ascertain their best form and relative number of threads per inch. When this was done he made them of all diameters to fit a standard set of gauges, which in a short period became universally popular. Thus it came to pass that a "one inch" or any other nut made in England accurately fitted a bolt of the same diameter from Bombay or Melbourne, etc., to the very great advantage of the world at large.



SCREWING MACHINE.

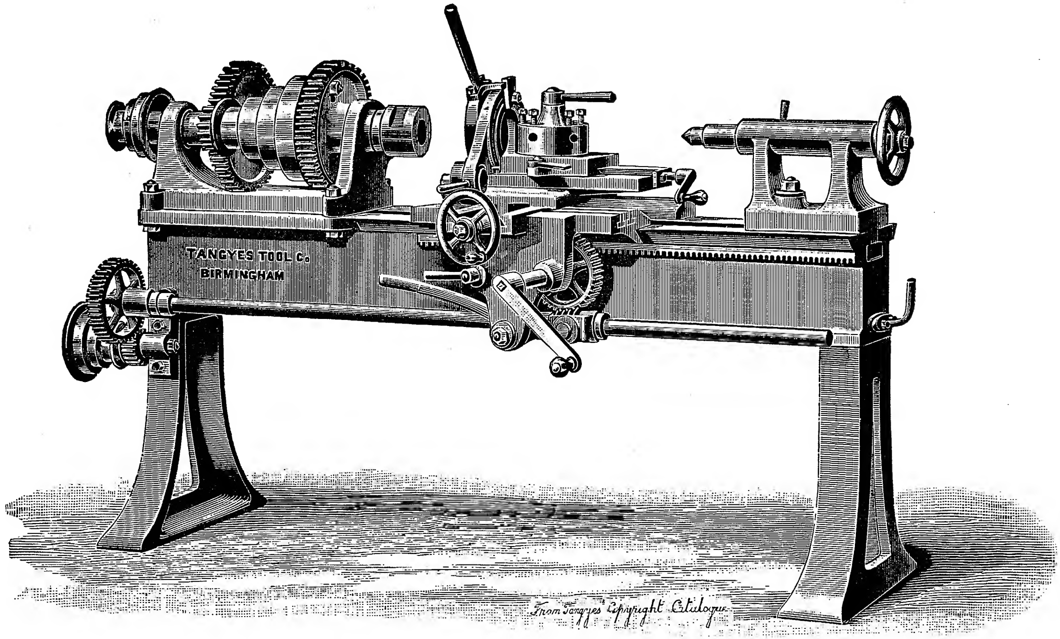
A good example of an *Improved Screwing Machine* by Messrs. Kendall & Gent is shown in the adjacent view. This, however, includes top driving gear, taps, dies, etc., which are somewhat picturesquely arranged. One of its leading features consists of Dixon's patent automatic opening and closing movement of the dies at any desired point, thus enabling unlimited numbers of bolts to be screwed to an exact length at one cut. The dies can also be opened, the carriage run back, and the former closed again to the standard diameter, ready to begin new operations by the thousand, in the most economical manner possible.

The foregoing remarks upon Screwing Machines refer to those employed in the manufacture of bolts say from ½″ to 3½″ diameter, which in the smaller sizes are endlessly made. For larger screws, however, up to about 16″ diameter and 70 feet in length, the work of the lathe must ever reign supreme.

In the innumerable varieties of brass fittings and small details used throughout the realms of philosophical and mechanical engineering, the *Special Lathe* is paramount, since its performances are carried out in every respect with marvellous swiftness and accuracy. This is chiefly accomplished by means of a hollow spindle through which long objects may be passed whilst being operated upon—a capstan rest that enables at least six tools to be used in rotation for ever-varying purposes of sometimes momentary duration—and a back shaft so simply arranged to produce threads of different pitches, that brass castings, etc., can be turned, bored, notched, cut, chamfered, and screwed, at one setting with the greatest ease. In out of the way parts of the earth's surface, however, where the two last named machines have not yet penetrated, screw cutting must still be performed by hand gear in the primitive and laborious fashion of early days.

Plate IX. shows a *Capstan Rest Lathe*, embodying Messrs. Tangye's latest improvements, the arrangement

PLATE IX.



CAPSTAN REST LATHE.

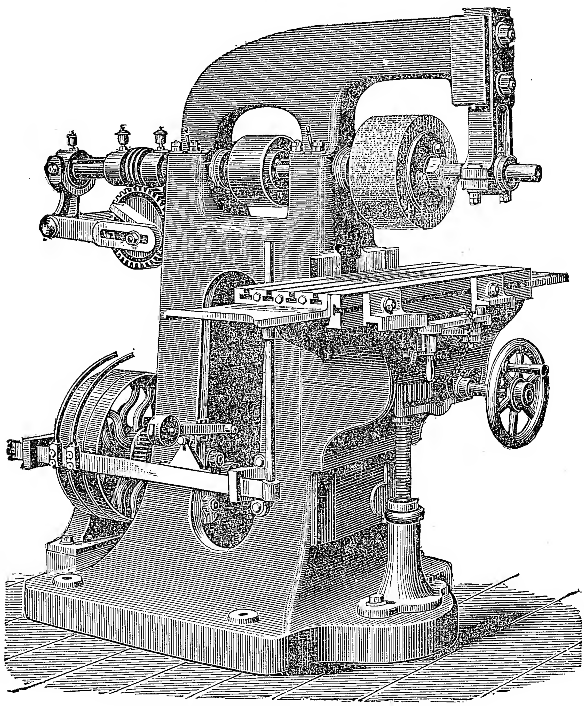
of which may be variously modified by means of supplementary gear to suit the requirements of a greatly diversified practice.

The introduction of *Cutting Tools* that do not require forging and tempering when broken, is one of those landmarks in Engineering history that deserves notice on account of its importance. I wonder how often my contemporaries, as well as myself, when apprentices, used to go to the smithy with a broken drill, or turning, planing, or slotting tool, for the purpose of getting it "dressed." We liked it in cold weather, and even in summer it was a pleasant change of surroundings. The smith, too, was well pleased to see us, and have a chat upon things in general.

Now, however, all this has passed away, since the modern system requires that instead of skilled hands wasting their valuable time at a forge or a grindstone, thus keeping their machines idle, the various tools throughout a workshop shall be carefully looked after by professional grinders. Hence, although many tools must still be forged when broken, the bulk of them can be made of special cast steel bars of suitable sections throughout, and carefully ground to the approved angles for cutting in steel, brass, and cast or wrought iron. The system answers admirably, and saves a very great amount of time and trouble, aided as it may be by the use of the *Improved toolholders*, patented by Messrs. Smith and Coventry.

The *Grinding Apparatus* at which these, or similar tools may be rapidly, systematically, and accurately ground, is also a modern machine that greatly influences the economical management of engineering establishments. The special feature of this arrangement is that the slides, which usually rest upon the top of the trough, and thus become rapidly disorganised by grit and water from the stone, are entirely dispensed with. The tool holder can also be set at any required angle in the simplest possible manner.

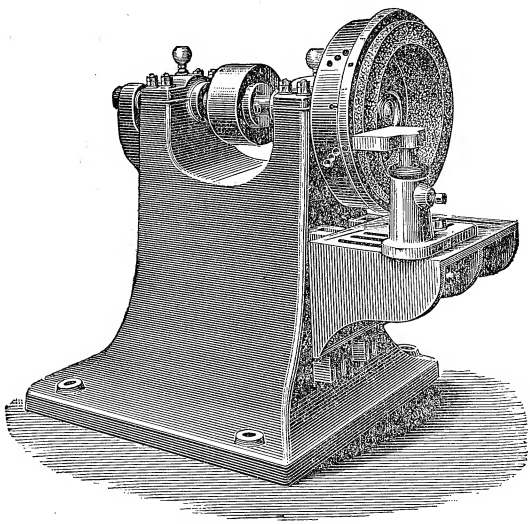
Advanced modern science has caused the introduction



GRINDING MACHINE, LARGE SIZE.

of *Emery Grinding Machines*, which are now used very advantageously in many ways. This is especially the case where a high but inexpensive finish can be given to castings, by simply grinding off the steely outer skin of the metal that is otherwise so difficult to remove, previous to burnishing. The emery wheels are made to suit different kinds of work, and are extremely useful in surfacing castings that may be too thin for turning, also in trueing up *worn* piston-rods as exactly, and more economically than by the lathe.

The annexed view clearly illustrates a powerful machine by Messrs. Luke and Spencer, of Manchester, specially adapted for the rapid and exact grinding of



CUP EMERY GRINDING MACHINE.

case-hardened surfaces, or for work such as the guide bars of small engines, etc. The table is vertically adjustable, and self-acting in its sliding movements, and the emery disc has a reciprocating motion given to it by means of suitable gear at the back.

Another machine, of a different kind, by the same firm, adjacently shown, is also an excellent labour-saving apparatus, the spindle of which is fitted with a cup emery wheel mounted in an improved safety chuck. The table can also have sliding movements attached, but for ordinary work hand rest gear is sufficient. Both the above firm, and also Messrs. Sterne and Co., of Glasgow, make Emery Grinding machines for purposes too numerous to mention, but which nevertheless enter very largely into the economical engineering operations of the present day. It may only be added that the wheels are made up to 36″ diameter and from $\frac{1}{8}$″ to 8″ in thickness.

As a notable example of the manner in which good constructive machinery—exact workmanship to standard gauges and dimensions—combined with excellent organisation and general good feeling, can be made to produce the highest results, the following recent experiment at the works of the Great Eastern Railway Company, at Stratford, near London, may prove interesting.

With the object of ascertaining the shortest period in which a six-coupled $17\frac{1}{2}$″ by 24″ cylinder engine and tender could be built, Mr. James Holden, the locomotive superintendent of the line, had, on the above occasion, all the details laid in order upon the floor of the erecting shop, ready for use. At an appointed moment the hands in attendance raised the side frames off the ground, and fixed them in position over a line of rails. The cylinders and all their attachments, with leading, driving, and trailing wheels, etc., were at once located, every bolt being tightly driven home, and every nut screwed hard up. Then the connecting and coupling rods, motion bars, valve gear, etc., etc., were as swiftly and silently linked to their attachments as if the men had been "on the job" all their days.

After this was done, down went the boiler on its seat only to be fixed up in a twinkling. Next came the mountings, fittings, and all other gear in rapid succession. Finally, the boiler was lagged, and everything finished off outside, inside, and around it. Whilst these performances were in progress, the details of the tender were rapidly united, and when everything had been executed "to the entire satisfaction of the Engineer," and the costly set of machinery ready for the photographer, and for running on the line, it was found that the *net* time occupied from first to last had only been 9 *hours*, 47 *minutes!* which is much ahead of similar records elsewhere.

To prevent any reader from fancying that the structures had been previously built up, and taken to pieces, we may add that all the parts were sent from the machine shop to the erectors just in their usual state. The whole affair simply resolved itself into one of "record breaking," in which the *most accurately machined details*, "Stow" flexible shaft rhymering, etc., and a specially powerful staff, systematically arranged, were at the head and front. Powerful enough to win a professional triumph, but too numerous and expensive to produce commercially economical results.

These vast works turn out at least one hundred locomotives in a year, make all their own carriages and wagons, and do the repairs for the whole line. They also most effectually employ petroleum, instead of coal, for firing purposes throughout the establishment, which appears to be a great advantage. To the kindness of Mr. Holden and his accomplished manager, Mr. Macallan, I am indebted for a most pleasant and instructive visit to the works, where so much was to be seen of a somewhat unusual character.

CHAPTER IV.

OPENSHAW ESTABLISHMENT OF SIR JOSEPH WHITWORTH AND CO.

Visit to Openshaw—Sir Joseph Whitworth's Inventions—Secret of his Success—His Improved Guns—Magnificence of the new Works—Their various Departments—Fluid Compressed Steel Machining Processes—Gigantic Lathes—Whitworth's Reversing Tool-box as a Steel Cutter — Colossal Circular Planing and Pit Planing Machines—Special Slotting Machines—Heavy Cast Steel Wheels—Method of cutting their teeth out of the Solid—Forging Department—System of Manufacturing Fluid Compressed Steel—Eight and Ten Thousand-Ton and other Hydraulic Presses — How Interchangeable Gauges are made—Miscellaneous Notes.

DURING a recent and special visit to the above truly magnificent establishment, Mr. Barber, the Managing Engineer, most kindly spent a considerable time with me in a very pleasant and instructive manner. Whilst thus going over the premises, we could not help feeling that these Works, containing an immense quantity of the most costly machinery, were based upon the fame of one man, who, in the year 1833, began business in a very small way in the city of Manchester. Mr. Whitworth was a genius of no common order. He was a bold schemer and close thinker, a persistent worker, and one who took the most painstaking care even in the smallest details. Hence his advancement came by leaps and bounds, and his productions gradually became of world-wide celebrity.

His inventions were of a masterly and wide-sweeping, or revolutionary order, since they abolished all previous practice in certain directions, and laid the foundations of the present methods of constructing machinery. His improvements connected with the standard screw and interchangeable gauge system we have already referred to, as well as that universally important invention of the slide rest, and to these we may add the beautiful little measuring machine, which, by means of a micrometer screw and delicate wheel work, will indicate a difference in size of one millionth of an inch.

In 1853, Mr. Whitworth was requested by the English Government to undertake the construction of machinery for the improved manufacture of fire arms, and this led him to make a series of exhaustive experiments upon guns themselves, with the object of developing a new system which would give them much greater range and penetrative power than they had hitherto possessed. The great success that attended those investigations opened out quite a new field for the exercise of his inventive faculties, and an enormous increase of business immediately followed, which in time became so overwhelming as to necessitate the erection of an additional establishment of vast magnitude at Openshaw.

In 1857, Mr. Whitworth was elected a Fellow of the Royal Society, and received the degrees of LL.D. Dublin, and D.C.L. Oxford.

In 1868, he received the distinction of the Legion of Honour from Napoleon III, as a token of his appreciation of one of the field guns under trial at that time.

In 1869, he was created a Baronet, and in addition to these high honours received others of great importance from a directly professional point of view. By industry and talent he acquired affluence, as well as fame, and generously determined to devote a large portion of the wealth thus obtained to the benefit of those around him.

In pursuance of this object he wrote to Mr. Disraeli, expressing his wish to found thirty scholarships, each of an annual value of £100, for the continued instruction of youths, selected by open competition for their intelligence and proficiency in the theory and practice of engineering. This offer was accepted.

Such then in mere sketchy outline, up to this period, is the history of the man who developed the original premises and built the new works we are now describing.

The Openshaw Works occupy a closely built area of thirty-eight acres in extent, and are filled with the best machinery and appliances for facilitating operations in constructive and general work—in the manufacture of great guns—and in the preparation of extremely diversified castings, and also forgings in fluid compressed steel.

Exteriorly the buildings have a very simple and effective appearance, and are so arranged in plan as to facilitate intercommunication in every way between the various departments. The main portions of the premises consist of a principal *Machine Shop*, 560′ 0″ in length, by 200′ 0″ in breadth, with an extension 700′ 0″ by 100′ 0″. Both of these are divided into bays—as in the other parts of the premises—by rows of iron stanchions that support the roofs and also numerous travelling cranes capable of lifting weights ranging from 4 to 70 tons. For extra heavy loads, however, the combined efforts of two cranes are frequently employed.

Close to the former is the *Fluid Steel Compressing and Forging* department, 450′ 0″ by 350′ 0″, containing all the necessary Siemens' furnaces, annealing furnaces, hydraulic presses, engines, pumps, accumulators, &c., employed in the various processes.

Adjacently situated is the *Steel Foundry*, 600′ 0″ by 70′ 0″, where castings combining lightness and strength for engineering work generally are made, and also an *Iron Foundry*, 250′ 0″ by 150′ 0″. This latter supplies the castings for machines, &c., where extra weight is considered an advantage on account of the greater steadiness it produces in their working, and where lighter steel framings would not be so desirable.

Lofty buildings for the *Oil Hardening* and *Shrinking on* processes in connection with great gun construction occupy one corner of the works, while adjacently located is the *Physical Testing-house*, containing all the machines necessary for conducting the tensile, compressive, bending, percussive, and other tests, not only in compliance with the most stringent requirements of the firm, but also those of the Admiralty, the British and Foreign Governments, the Board of Trade, and others at home and abroad. So complete is this system in its details, that the above strains with their various percentages of elongation, contraction of area at point of fracture, and so on, can be read at a glance by means of special instruments to which we need not particularly refer.

This building additionally contains a *Chemical Testing Laboratory*, which, although of no great dimensions, controls in its own way the initial movements connected with the production of the high class steel and iron used throughout the establishment.

As the *Wood-working*, *Smith forging*, and other portions of the premises, are more or less similar to those of the same nature in other establishments of a heavy class, no reference need be made to them.

The *Show Room*, and also the *Offices* for the various members of the firm, the Commercial, and the Scientific staffs, &c., are all arranged upon the most improved lines, and may be considered models of excellence in every respect. The first-named is a valuable adjunct, as it contains numerous examples of finished and tested work, and is also profusely adorned with beautiful photographs of machinery, &c., of a highly interesting nature.

The *Drawing Office* is large, handsome, and well lighted, and here it may be well to state that tracings from the working drawings are carefully pasted on strong paper, then varnished, and finally secured to suitable boards before being sent into the shops. They are thus protected from dirt, and rendered easy to clean with a sponge, but if, at any time, an alteration in figures is required, it can easily be made in the usual way.

Upon entering the great Machine shops I was at once struck with the magnificent proportions of the buildings —their handsome and lofty iron roofs—their wood paved floors—their splendid light, and above all, the inconceivable quantity of machinery to the right, to the left, and in front. It was soon discoverable that every thing in progress was made of steel so tough that the machines had much more strain thrown upon them than they would have had if working in iron, and to meet this strain, proportionate strength had been given to them. Amongst the lathes were a few of enormous dimensions, one at least of which had a bed 75 feet long, provided with duplex slide rests and eight tools, capable of cutting off about two tons of turnings per hour from a steel forging or casting. It can also be used for turning the very largest crank shafts or guns, cutting screws of any size out of the solid, and performing all kinds of surfacing work.

Other admirably designed machines of this class include those for gun boring and rifling, one of which is nearly 130 feet in length, and has a cutting tool arrangement that produces an internal finish of the greatest beauty and accuracy.

The planers were very powerfully and numerously represented, and here, too, we found much of a most interesting nature; as we meandered pleasantly along, closely inspecting and mentally noting everything, we came to a dead stop amongst a cluster of these, thirteen of which had the *reversing tool box* in full operation upon steel details, including the cranks of a very powerful land engine, and other gear.

"Glad to find my old friend of early days doing such excellent work," said I, to my companion, "Look at the amount of time it saves compared with the single cutting tool so much in use. But," I ventured to add, "it does not seem to be quite in accordance with the dictates of science to have the strain of a heavy backward cut thrown upon the weak part of the slides. What do *you* think of it?"

Mr. Barber thought as I did, in the first place, but secondarily considered that my theoretical objection was overruled by the fact that the straining action of the tool in this respect was very similar to that of the back cutting tool of a duplex lathe, which practically gives the best results for finishing purposes. He also observed that by very slightly tilting the tool box, and arranging the feed motion so as to give the final cut during the return stroke of the table, large surfaces could be planed true to within the one thousandth of an inch.

As previously remarked, the great disadvantage of slotters and planers alike is the time lost during the backward motion of the cutting tool, or the table, which has variously exercised the minds of many engineers. For almost continuous cutting purposes, however, the aforesaid invention possesses a special value, and one too, which has stood the test of about fifty years practice, and although, in some establishments, the above tool box cannot be so profitably employed as it is in others, owing to the nature of the work executed in them, the fact nevertheless remains that forty years ago I not only saw Mr. Whitworth's reversing tool cutting down rails into long switches in splendid style, but found it in many cases at Openshaw doing the same thing in hard steel engine details, &c. Hence we may conclude that its continued and economical usefulness to the present day has been abundantly proved.

During our rambles we came upon a newly constructed vertical lathe, or rather *Circular Planing Machine*, having a horizontal face plate 28′ 6″ diameter, which could take in work 35′ 0″ diameter between the standards. This colossal engine is used for planing armour-clad turret roller paths, &c., and is fitted with four reversing tool boxes, and all the most recent improvements. For machining complete circles the table is revolved continuously in either direction, as may be found most convenient, but if only a segment of a circle is being operated on, both the table and the tools are reversed as in an ordinary planing machine, so that there is no lost time. Machines of this class are now becoming popular owing to their varied application, and also to the ease with which the heaviest castings and forgings can be set on their tables when compared with the old methods.

A still larger machine, in course of construction, was a *Pit Planer*, of special design, capable of trueing up a surface 60′ 0″ long, by 12′ 0″ wide, the bed of which was 72′ 0″ in length. Here, too, the powers of the reversing tool box were to be utilised in perhaps their most extended form, and with the most advantageous results.

These somewhat lengthy remarks upon this subject, are due to the fact that workshop economy is of paramount importance, and that any really good labour-saving arrangement, such as the above, is worthy of special description, even if it should occupy more of our "valuable space" than we intended to give for the purpose, or than the reader might consider necessary.

The *Slotting machines*, of greater and lesser magnitude, in the vast building were around and before us in variegated fashion as we moved onwards, and these, too, had been extensively modified in their details. One large machine in particular, of unusual shape, had its framing so arranged as to give the table full scope for a great variety of massive work, and at the same time to enable the tool to take very heavy long stroke cuts with great ease and steadiness. As a similar rate of production in steel is required from these machines as when formerly working in iron, it was only natural to find that the gear had been strengthened, and that the old cast iron spurwheels and pinions that received the direct strain of the slotting bar had been superseded by those of forged steel, whose teeth were cut out of the solid metal.

This system is now much used, especially in pinions, which are exposed to much greater wear and tear than the wheels into which they work, on account of the simplicity and accuracy of the milling operations previously referred to. The usual practice at Openshaw is to shape the teeth of wheels, up to about $2\frac{1}{2}''$ pitch, by the milling machine alone, and initially prepare all others of larger size by means of the slotting process, on account of the extra heavy cutting required.

The *Drilling*, *Shaping*, *Screwing*, and other machines were numerously represented, but as *their* peculiarities and latest improvements have been already described, nothing more need be said about them.

In the *Ordnance Department* there were some curious things to be seen, which, for obvious reasons, cannot well be described. We shall therefore pass on to the *Casting* and *Forging* part of the premises, where all the colossal machinery for manipulating the heaviest work employed in marine and other engine shafts, etc., and also for gun manufacturing purposes, could be seen.

It may be here stated that, as this necessitated in course of time the employment of the very strongest metal that could be obtained, Sir Joseph Whitworth latterly directed his attention to the improved manufacture of steel. Crucible steel was tried at first, but as the ingots were too small, and in many cases unsound, they were discarded. He next tried the Bessemer converter, and finally the Siemens-Martin furnaces, which enabled larger ingots to be made, but here again the attendant imperfections proved a serious drawback, until Sir Joseph overcame them by consolidating the fluid steel under a gradually increasing hydraulic pressure of great intensity. When this had been sustained for some hours, the metal was compressed into a perfectly homogeneous material of great density.

The system of manipulation consists in pouring the melted metal into open-topped and specially prepared moulds, having a taper sufficient to allow the ingot to be easily withdrawn. These moulds are built out of a series of steel hoops put together in ordnance fashion, with the object of obtaining suitable strength to withstand the aforesaid squeezing process. For some years an 8000 ton press was found sufficient for the purpose, but latterly a 10,000 tonner had to be erected to meet the requirements of the times. Its accumulator and intensifier combined produce a pressure of about three tons per square inch in the ram cylinder, and this is also employed in controlling every movement connected with the transference of the metal from the furnace to the mould—of the mould itself beneath the press—and of the whole of the machinery connected with the operation of fluid steel compression.

The construction and application of this press would require elaborate description on account of its unique arrangement. It may, however, be briefly stated, that steel is largely employed in its details—that the hydraulic cylinders are formed of steel hoops and rings of enormous strength, because *solid* metal would be inherently weak, and iron perfectly useless—and that the whole of the colossal structure is capable of being worked by hand with the greatest ease, precision, and economy.

The steel ingots frequently weigh as much as seventy tons, and are cast of sufficient length to allow for shrinkage, and for trimming at the ends previous to forging. When, however, they are required for gun-hoops, cylinders or other hollow work, such as heavy propeller shafts, &c., they are made hollow previous to being operated upon in the hydraulic press.

There are various kinds and sizes of *Hydraulic Forging Presses* in the same establishment—this firm being the first to design and develop the above system.

With the introduction of these presses, the important process of hollow forging on a mandrel first became practicable, the advantages of which are obvious; the metal operated on being more thoroughly worked on its interior and exterior surfaces, while a great saving in weight is effected. The main features of these presses consist of a hydraulic cylinder in the top crosshead, with rising and falling ram carrying the top *Swage* block. This crosshead is secured to the bed plate by means of four columns that unitedly bear the whole tensile strain caused by the compressing operation, as in the aforesaid Titans. The process may be repeated as often as required, and with great rapidity, in the usually silent and effective manner peculiar to such machinery, and through the employment of an index plate attached to the side of the framing, the workmen can so regulate the pressure at each stroke on a shaft, or other similar forging, as to finish it with accuracy all round.

The value of this system may be gathered from the fact that, in the manipulation of heavy forgings, the pressure is so great, and so steady throughout, when compared with the more superficial action of the steam hammer, that the whole mass of the ingot is worked and consolidated in the most complete manner possible. This is conclusively proved by the convex shape of the ends of all forgings made under the press, while those made under a hammer are concave at the ends, thus showing that the interior has not been properly worked. It may only be added that the above presses have now become very popular at many of the great establishments, where they are most usefully employed in many ways.

From the infinitely great to the infinitely little in the realms of nature is but a step, and in the domain of science it is much about the same. This being the case, we shall at once enter the department where a variety of small gear is made, such, for example, as taps and dies, and gauges of all descriptions for general use. Here we find the beautiful little Whitworth *Micrometer Measuring Machines* in full operation. The cylindrical gauges referred to are first turned in the usual way, and then ground with emery wheels and fine emery to the exact size by means of the extremely delicate touch measurements of these machines.

All the other gauges of length, breadth, and thickness are treated in the same manner, and thus we find that similar details, manufactured by their aid, become interchangeable throughout the world.

The value of the system has already been referred to, so far as bolts and nuts are concerned, but in a far more extended form it permeates the whole domain of Engineering, since spare gear kept in stock, on land and sea, for damaged machinery of every possible description, can be utilised at once without having to wait until new gear is made. Even at the worst, it can be sent from the works whenever an order is received, because in many places all the finished details of machinery made on the premises are kept in readiness to be sent off to any part of the globe, thus saving an immense amount of delay and inconvenience.

The Openshaw Works are additionally interesting and enlightening owing to the numerous branches of engineering undertaken in them, for which extensions have had recently to be made. The above include Constructive machinery of every description—Hydraulic machinery and Forging plant—Armour Plates—Heavy Ordnance and all its accessories.

Amongst the miscellaneous objects of interest we incidentally came across in our rambles were a profusion of great gun barrel and hoop forgings, marine crank and tunnel shafts, a cylindrical marine boiler shell segment 12′ 0″ diameter, forged in one piece from a steel hoop, thus avoiding loss of strength by riveting, and causing a considerable saving in weight when compared with a riveted shell. Steel castings for various purposes, iron castings for others, including machine framings, &c., rifle barrels, bored with mathematical accuracy by special machinery, to so many decimals of an inch in diameter, instead of the usual "eighths" and "sixteenths," shot barrels for sporting purposes, gun fittings for heavy ordnance, and also gauges, tools, and other gear too numerous to mention, lying about everywhere, sufficient in the aggregate to keep all the machines employed. The final operations of these upon the above gave clear indications of the soundness and excellence of the materials generally used throughout the establishment.

For the information obtained during my visit I have to thank Mr. M. Gledhill, the Managing Director of the Works, who courteously gave me permission to view the premises somewhat inquisitorially, and also for so kindly giving me every facility for learning all I wished to know. These favours are more fully appreciable owing to the difficulty of getting into such establishments, partly on account of the anxiety of some people to gain experience for themselves in our system of manufacturing great guns.

As an example of what may be done by unprincipled schemers, it is said that many years ago, when flax spinning was being introduced in the North of Ireland, a man in the garb of a workman, but who was in reality an accomplished Continental engineer in disguise, obtained employment at one of the mills. He studied the machinery carefully, sketched out at home what he had learnt during the day, and, when his information was complete, departed for his own land, where he reproduced some particular arrangement of details to the surprise of its originators.

So was it also with James Nasmyth, of Patricroft. The head of a celebrated French firm paid a visit to the works, when someone indiscreetly showed him Mr. Nasmyth's "Design Book," containing complete sketches of his steam hammers. The Continental saw quite enough for his purpose, and when Mr. Nasmyth next visited France, he found, to his surprise, that while he had been arranging for the costly process of patenting his invention, the foreign visitor had appropriated it and actually *made* the hammers. They, however, frequently broke down because the elastic cushioning of wood, between the hammer head and the piston rod end, which was originally provided for, had been omitted.

In view of professional pirates from the South, East, and West, roaming about at large, it is only natural that people, such as Krupp of Essen, Sir William Armstrong & Co., and Sir Joseph Whitworth & Co., should have no special desire to exhibit their skill indiscriminately to strangers. The Krupps are very exclusive on this point, and although the Elswick firm at one time treated visitors liberally, the favour has now been withdrawn to all but those on official business. So far, therefore, as the Openshaw establishment is concerned, I have confined my remarks entirely to machinery and processes that it would not be injudicious to describe.

My survey of these Works kept me fully occupied from first to last. It was indeed a time of sustained "cramming" under the most favourable circumstances, and, although I have similarly inspected many other establishments for the same purpose, I cannot help thinking that the whole day visit to Openshaw, described in this chapter, is ever to be remembered on account of the valuable experience thus acquired, whilst carefully studying, with Mr. Barber's kind assistance, the latest phases of one of the highest branches of practical science.

CHAPTER V.

BOILER WORKS AND SYSTEM OF MANUFACTURE.

New Works of Messrs. Galloway, Manchester—Improved Constructional Practice—System of Testing Plates, &c.—The various Machining Processes Exemplified—Planing Edges of Plates—Thinning the Corners—Bending the Plates—Drilling the same in Position—Shell Riveting Process—Welding the Furnace Plates—Flanging by Machinery—Furnace Drilling Process—Furnace Riveting Process—Method of Turning and Boring End Shell Plates—Galloway Tapered Flue Tubes—The Stamping System—Angle Iron Bending—Testing and Finishing the Boilers—Brickwork Setting—Useful Calculation Table.

IN Boiler Works we do not generally find much of the Constructive Machinery referred to in the previous chapters, at least in those forms which are so peculiarly adapted for exact Engineering operations. Of course, Drilling and Planing Machines are very usefully employed, but variously modified to suit another order of things. The former have reference chiefly to the multiple boring of boiler shells, and the latter to the squaring and finishing of the plates themselves previous to being drilled. So extensively has improved boiler practice been developed during later years, and so enormously has machinery been introduced in the numerous processes of manufacture, that a few remarks on this subject may be desirable, especially as they are based upon the practice at the very extensive Works of Messrs. Galloway, and fairly represent what is also done in the best Marine establishments.

Hundreds of patents have been taken out at different times for every conceivable variation in the design of steam boilers, a few of which are still used. Notwithstanding, however, all the ingenuity that has been displayed in the invention of new types, the Cornish or Single-Flued, and the Lancashire or Double-Flued Cylindrical Boiler still retain their old established pre-eminence. This is due to their simplicity of construction and general excellence in working, and also to the introduction of the Galloway Tubes in the flues, which have not only much increased their strength, but added greatly to the commercial value of the boiler. Since the first patent was taken out in 1848, numerous improvements have been made in the design, construction, and system of manufacture of these boilers, and so immensely has their use extended that in 1872 new works for this special branch alone were erected at Ardwick, Manchester, by the above firm.

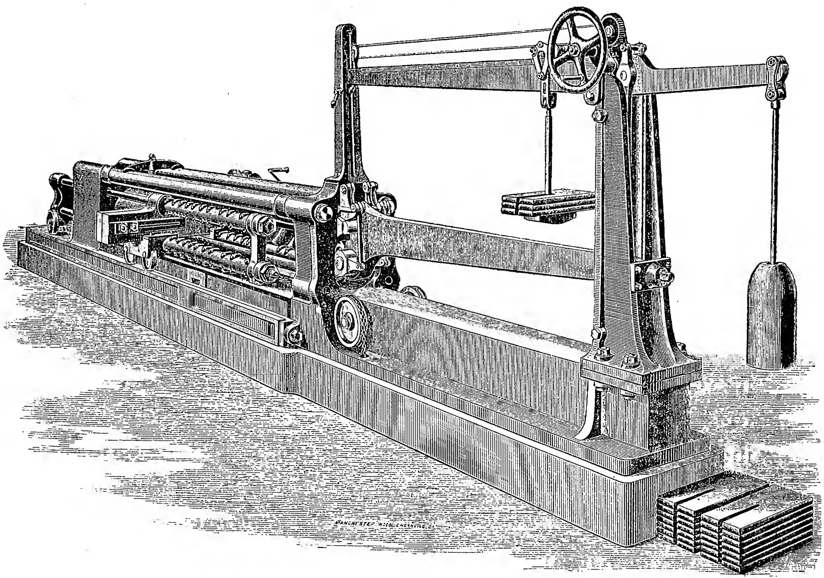
These works cover eight acres of ground, and by means of an experienced staff and the extensive employment of the best machinery have been enabled to turn out nearly 400 boilers in one year. And this, too, in addition to the Knott Mill establishment of the same firm, where engineering operations of the heaviest class are carried on. The *Central Bay* or boiler erecting department of the Ardwick Works is 420′ long, by 180′ wide, and in the bays on each side, and also in the surrounding buildings, the various processes of manufacture are fully developed from the time the raw material is received until it is delivered in the form of completed boilers on the adjacent railway lines.

The comparative silence that now pervades similar places marks in the most distinct manner the modern system of manufacture in its greatly improved forms. Those who remember the marine steam generators of thirty years ago, and compare them with the structures of the present, will clearly understand the nature of the advances made in this direction. They will also recognise the gradual change that has been made from the sheer manual labour of that period to the refined and almost noiseless mechanical operations of to-day in work which would otherwise have been impossible.

At the above establishment the railway siding is so arranged as to facilitate to the utmost the delivery in the works of large quantities of steel plates, about 1,000 tons of which are kept in stock ready for use. The attention now bestowed upon their manufacture has enabled the producers to supply them of very uniform quality, so uniform, indeed, that in the largest consignments it very rarely happens that even a single plate has to be condemned, and this in itself is sufficient to indicate the highly trustworthy nature of the material employed.

By means of an admirable *Testing Machine*, designed by Mr. David Kirkaldy, of London, and shown on the next page, very accurate tests are made of the tensile, compressive, and torsional strengths of all materials used for engineering purposes. In their general specification the Ardwick people state that every steel plate supplied to them shall have a tensile strength of 26 to 30 tons per square inch, with an elongation of 20 per cent. in a length of 10 inches, and this the above machine indicates unerringly. Hence, we have on the one hand the most improved system of manufacture, and on the other hand the most exact method of testing the qualities of materials, thus producing in combination the happiest results.

After the plates have been tested as described, those required for the shells of boilers are taken to the *Plate Edge Planing Machine*, shown in the accompanying view, which clearly illustrates its arrangement. The tool slide



TESTING MACHINE.

rest is actuated by a square threaded guide screw, and as the tool itself is reversible it becomes an almost continuous cutter. In this machine one side of a plate is clamped in position by the vertical screws, and operated upon in the usual way until completely trimmed. This process at once exposes any edge imperfection that may exist, insures absolutely tightness in the fullering without injuring the metal, and gives, at the same time, a better finish to the boiler.

Messrs. Galloway have recently put down a much more complete machine for planing plates of any length on two edges simultaneously, hence a plate has only to be moved once to obtain the trueing up of all the edges. A further improvement is that in place of manual power being required to actuate the screws for holding it in position, this is now done by means of a series of hydraulic rams in connection with the accumulator, so that by simply turning a handle the plate can be almost

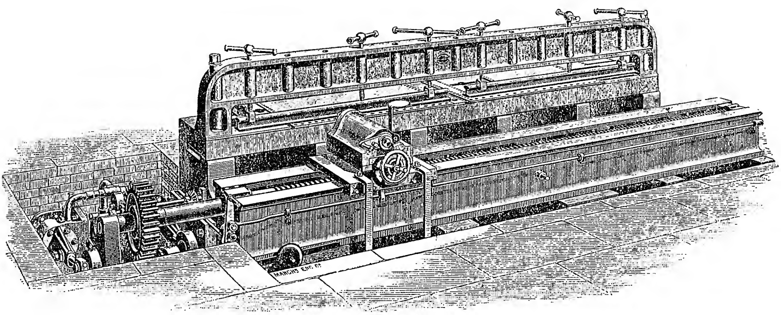


PLATE EDGE PLANING MACHINE.

instantaneously secured or released, thus effecting a great saving in time and expense.

After the above operation has been performed, the plates are taken to the *Corner Thinning Machine*, which prepares these corners for their places in the boilers, where an ordinary riveted joint is crossed by another. This thinning down process was formerly carried out by heating the corners in a fire, and then hammering them to a bevel-edge, which is decidedly objectionable, especially as steel plates require very careful treatment to prevent the annealing process they have previously undergone from being interfered with.

The next part of the performance consists in passing the plates through the *Bending Rolls*, where they are curved to the exact radius of the boilers for which they are intended. Engineering interiors are all more or less instructive, from a picturesque as well as from a professional point of view, and hence the adjacent Plate will no doubt prove acceptable, as it illustrates a small portion of Messrs. Galloway's works where the machinery we are

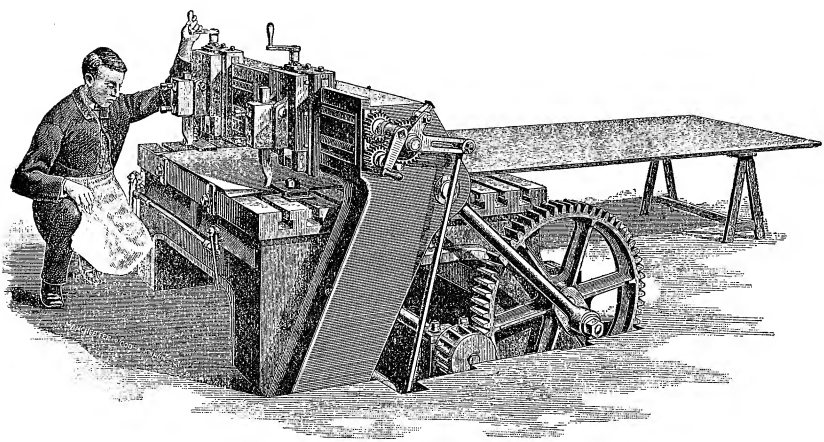
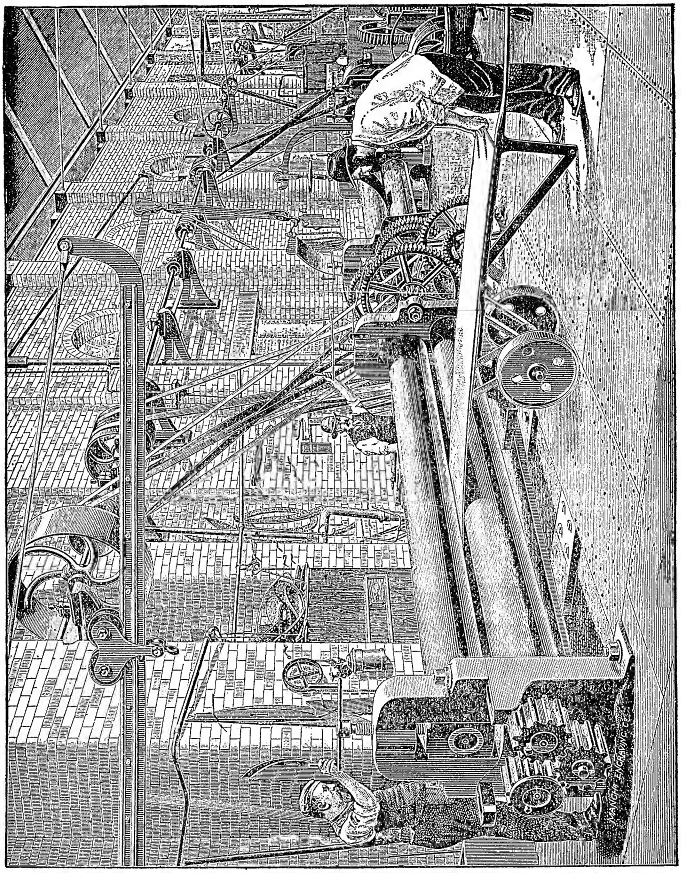


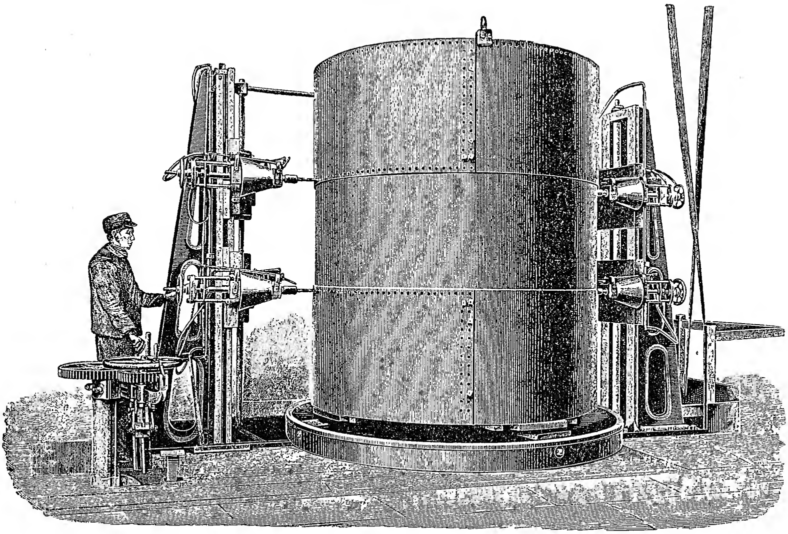
PLATE CORNER THINNING MACHINE.

describing is fully employed. The curvature of the plates depends upon the distance of the top roller from the two lower ones, and this is regulated by screw gear at each end of the machine, which is under the control of two men as delineated. At the same time, the plate itself is guided backwards and forwards by another "hand," between the alternately revolving rollers, until the segment of the circle is completed.



WORKSHOP INTERIOR—PLATE BENDING MACHINERY.

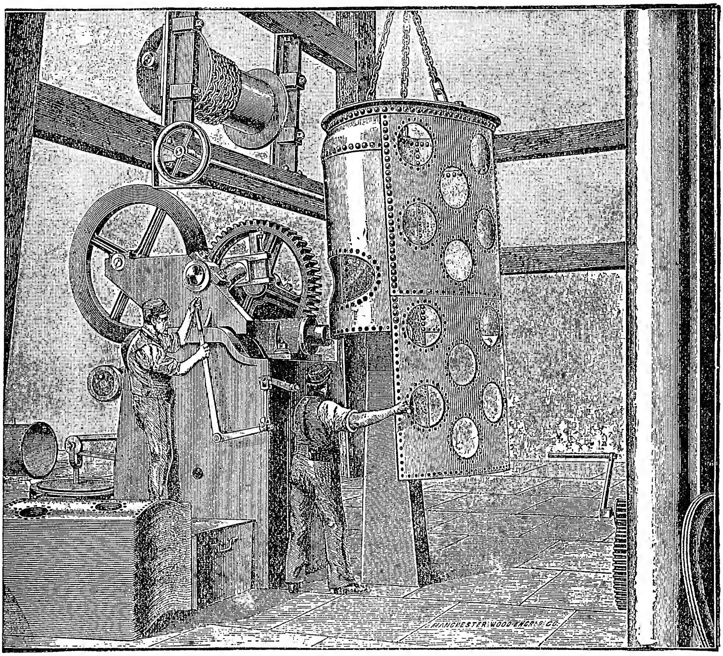
After the shell plates have been suitable curved, these complete rings are temporarily fixed in position on a revolving table, and brought under the action of *Special Drilling Machines*, arranged as shown in the adjacent engraving. These machines are capable of boring with great accuracy all the rivet-holes in the longitudinal and transverse seams. This is accomplished by means of self-acting motions which cause these holes to be divided



BOILER SHELL DRILLING MACHINE.

with the utmost regularity throughout, thus avoiding all the evils incidental to the old system of punching, and producing work of the highest excellence.

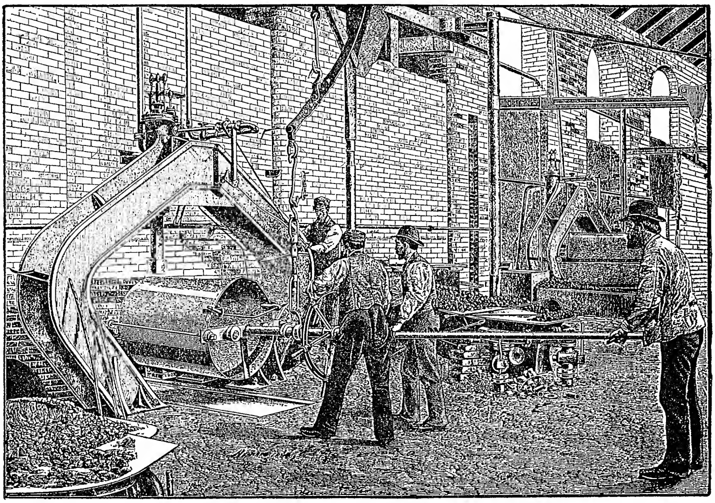
The next movement consists in bringing the above segments and also those for the Flues under the action of *Steam Riveting Machines* by means of an overhead crane, and here we at once come into contact with the two totally distinct systems of steam and water power. Messrs. Galloway, however, adopt the former, because it is more suitable for their particular kind of work. The machines they employ are worked by an arrangement of gearing which is designed to produce a definite amount of pressure upon every rivet during its formation. This is



STEAM RIVETING MACHINE.

obtained by means of levers and weights, the pressure being adjusted according to the diameters of the rivet; hence, even in this little matter, as will be clearly seen, everything is kept under the most perfect control.

After the *Internal Furnace Plates* have been curved at the bending rolls, their ends are brought together ready for *welding*. Each cylinder is then secured by a long porter bar, as shewn in the annexed view, and the two edges of the plate in contact with each other, are placed in the adjacent smith's fire, and brought up to the proper heat. The cylinder is now swung quickly round by means of an overhead crane, and brought under the action of a rapidly moving self-acting steam hammer,

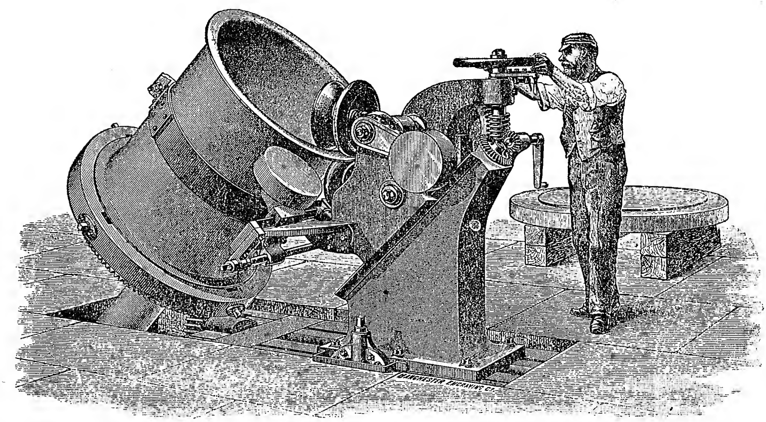


WORKSHOP INTERIOR—WELDING HAMMERS.

which makes a longitudinal weld extending the full length of the plate. All the apparatus employed is of special construction, and the great experience acquired by the men insures thoroughly sound and perfect workmanship.

We have thus six welded segments for each Lancashire boiler that require fixing at the ends in such a way as to enable them to form two continuous furnaces, and possess at the same time the greatest strength to resist the collapsing pressure of the steam outside of them. They must also have a certain amount of longitudinal elasticity to allow for expansion in length when heated. These objects are attained by means of a special *Flanging Machine*, clearly delineated in the accompanying illustration.

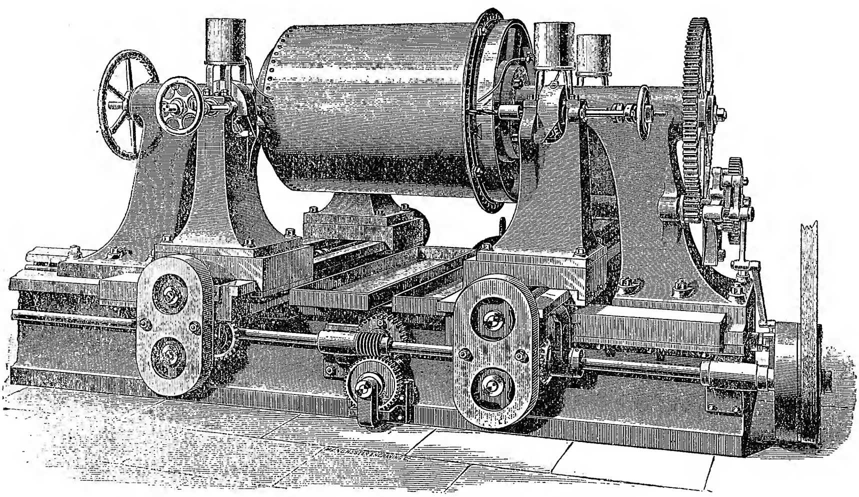
The flanges of the ordinary furnace rings are formed by this machine upon a face plate placed at an angle of about 45°. One end of the ring is first heated, then



FLANGING MACHINE.

rotated at high speed upon the face-plate to which the other end is fixed, and as a grooved roller is brought to bear upon the heated edge, as it rests upon guide rollers underneath it, a perfectly formed flange is the result. Caulking rings are generally inserted between the two flanges, which are afterwards riveted together. Transverse joints are very generally made by this process, but solid rolled hoops of various sections are sometimes used instead, thus allowing, in every case, a certain amount of expansion and contraction in a boiler, without throwing an undue strain upon the ends. Besides this, it is well known that these encircling rings strengthen the furnaces so enormously that one of them, which of itself would not be suitable for a pressure of 20 pounds per square inch, can, by means of a sufficient number of rings, be made to work safely at 150 to 200 pounds.

When the furnace segments or rings have been so far



FURNACE DRILLING MACHINE.

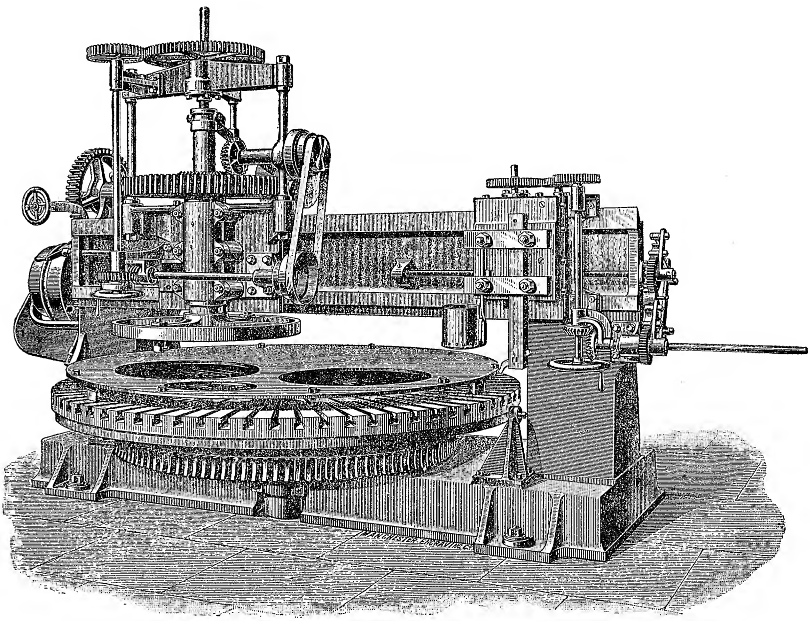
completed, they are taken to the patent *Furnace Drilling Machine*, illustrated above, the action of which can be clearly understood. It may only be added that the gearing is reversible, and that both sets of drills are suited for working either parallel with, or at right angles to the axis of the machine, which is self-acting in all its parts, and capable of dividing off the holes with the accuracy of a wheel-cutting engine.

The final operation in finishing the complete sets of furnaces previous to putting them into a boiler, is the attachment of the various rings to each other so as to form a continuous length. This is effected by means of a *Furnace Riveting Machine*, in which the power is given out by the direct pressure of steam on a piston whilst being multiplied many times by the intervention of toggle-jointed levers, thus closing the rivet in a ready and efficient manner.

In addition to this, we have a separate *Flue Riveting Machine* for finishing the peculiarly shaped parts of the flues containing the Galloway tubes that form the distinguishing feature of these boilers as shown in the Plate of *Sections*. Here, however, the jointing is of the ordinary "lap" formation, instead of the aforesaid external flanges, which, for reasons already given, are so necessary for the cylindrical furnaces.

The view on page 65 clearly shows how the operation is performed, and illustrates the method of riveting boiler shells in general, even of the heaviest marine sizes. On account of the large dimensions and great thickness of plates, however, in the latter, hydraulic machinery is preferred, and in many cases special riveters are used having a 12 feet gap, and a capability of exerting a pressure of 150 to 200 tons on a rivet. In boiler shells, such as those made at Ardwick, the above steam machinery has however proved highly satisfactory in every respect.

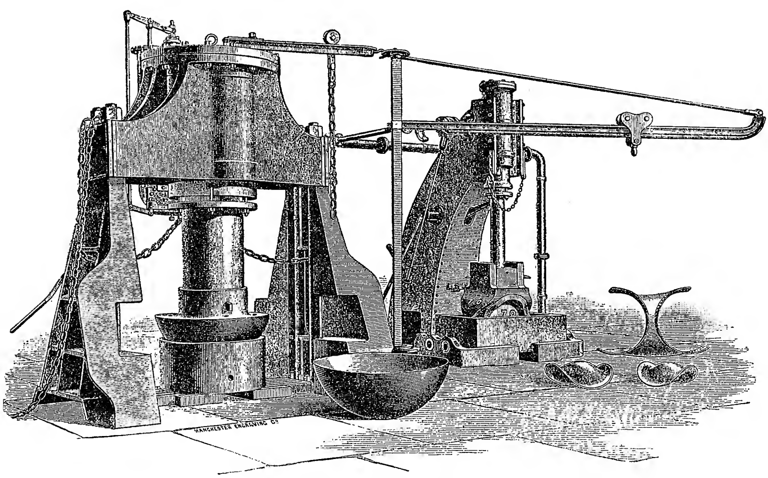
Amongst the various machines used at this establishment, is the *Horizontal Lathe*, or *Circular Planer and Special Borer* shown in the annexed illustration, and here it may be said that in this, as well as in other views, the introduction of the work to be operated upon, and in some cases, the men who conduct these operations, give an unusual freshness and interest to mere technical art productions that is much to be desired. The machine referred to has been specially designed for turning the end plates of boiler shells and the angle irons attached to them, thus producing better and more finished workmanship than could otherwise be obtained. While the front



HORIZONTAL LATHE.

end plate is on the machine, a vertical boring disc cuts out of the solid the two holes for receiving the furnaces. The table is then revolved by worm-wheel gear, and the end slide rest tool turns up the periphery to the exact diameter. After being thus prepared, the necessary holes are separately drilled for the attachment of various fittings, the shell, flues, furnaces, gusset stays, etc., are brought together, and the whole securely riveted up into a complete boiler.

Besides the engines we have mentioned, there are others of a more or less important nature which have also their part to take on an extensive scale. These include machinery for making and flanging the Galloway tapered tubes that so greatly strengthen the flues, and increase their steam raising efficiency—hydraulic presses for



STAMPING PRESS.

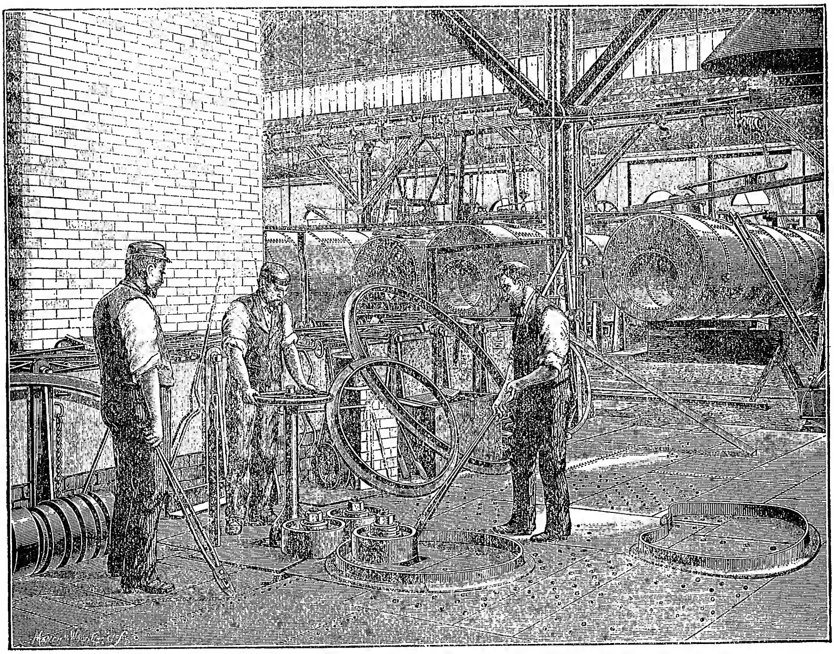
punching tube holes in the flue plates—machines for angle iron bending, etc.—and also those for performing the various stamping operations which in this, and other branches of engineering, have now become so popular.

The accompanying view clearly illustrates the process and indicates the method of action. These *Stamping Presses* are employed in shaping special plates into boiler details after being heated in a furnace to a proper temperature to enable them to bear the necessary pressure without injury. It may be added, that a much more accurate form can thus be obtained than by the old fashioned style of hand-finishing, which was costly as well as imperfect. Some of the stamped pieces are shown in the foreground of the picture, and these may be varied according to requirements, by simply changing the dies and their connections, the whole of the operations being completely controlled by means of the attendant jib cranes and hand gear.

The *Angle Iron Bending Machines* are very simple in construction and have all their gearing placed underneath a perforated iron floor on which the angles rest while being operated upon. The only things visible about them are three shallow vertical iron rollers, arranged similarly to those used in the already described Plate Bending Machines; hence the imagination must supply what the eye fails to discover. The view not only gives a fair idea of the process but illustrates a portion of the interior of the Erecting Shop, and also the position of angle iron heating furnaces, which are most convenient for the workmen.

The boilers upon being completed by the aforesaid machinery, and tested to one-and-half times their working pressure, are removed by the overhead travelling cranes in the erecting shop to the store where they are kept ready for sending off. To provide, however, against serious delays owing to a large influx of orders, from forty to fifty boilers of different sizes are kept in stock, so that clients may at once be provided with what they require.

Having described the manufacture of the above boilers, which have received the highest awards at no less than nine International Exhibitions since 1873, including that of Paris in 1889, we now illustrate their *Construction, and Setting in brickwork*, by giving three clearly defined views of them. These consist of two transverse sections, one showing the old style, and the other the new style of flue construction. The longitudinal section shows the stop valve, safety valves, manhole, and general

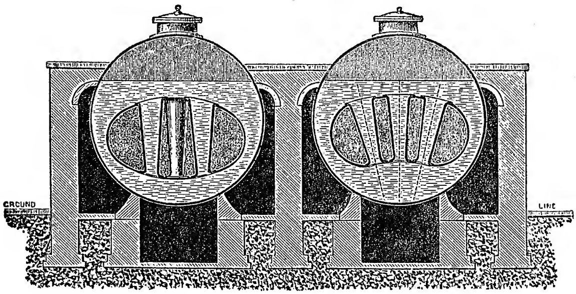


WORKS INTERIOR—ANGLE IRON BENDING MACHINE.

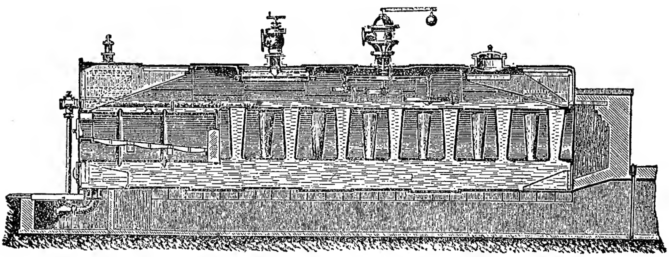
fittings, as well as the arrangement of conical flue tubes, etc., which are also given in the plan.

In the brickwork, six inches is generally allowed for the width of opening between the outside of boiler, at greatest diameter of shell, and the inside of the flues, as

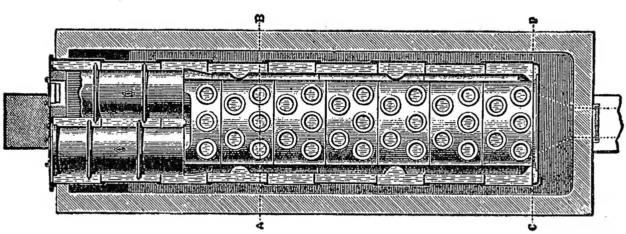
THE GALLOWAY BOILER.



AS FORMERLY MADE. | THE LATEST PATENT.



LONGITUDINAL SECTION, SHOWING FLUES AND FITTINGS.



PLAN.

shown in transverse section. The other parts, however, must be made large enough to enable a man to get all round for cleaning and examination purposes. The man-hole on the top of the shell allows the same operation to be performed in the interior, and thus, as will be clearly seen, the boilers are accessible in every direction, so that their heat-absorbing powers and durability may be sustained to the utmost.

These few remarks upon the system of manufacture adopted by Messrs. Galloway will show that nothing has been omitted that can in any way facilitate the progress of the work in all its stages. It is indeed a most excellent series of mechanical operations, the object of which is to produce the highest class of workmanship, combined with the strictest economy in every detail, and, it may be added, that a similar system, variously modified, is used in the construction of marine boilers, even of the largest size, with the very best results.

As everything that tends to reduce the labour of engineering calculations is of great importance, we give the following table, taken from the practice of the firm, which will be found useful. Its object is to enable one to ascertain with ease the number of pounds of water required for supplying steam to cylinders from 20″ to 60″ diameter, direct from the boilers, and at pressures ranging from 100 to 200 lbs. per square inch.

The co-efficients, multiplied by the piston-travel in feet during which the steam is admitted, indicate the exact number of pounds of water to be evaporated per hour, which agrees very closely with the well-known, but more elaborate rule. For example:—A cylinder 30″ diameter, 4′ 0″ stroke, at 100 revolutions per minute with 100 pounds of steam, and cutting off at half-stroke, requires 400′ × 77·7 = 31,080 pounds of water per hour, whereas, by the old rule, 31,062 pounds would be sufficient, exclusive of allowances. The advantage, therefore, of using the above simple formula will be at once apparent.

Diameter of Cylinder	Boiler Pressure.					
	100	120	140	160	180	200
20	32·8	38·2	43·6	48·79	53·98	59·17
2	41·79	48·67	55·54	62·16	68·77	75·38
4	49·74	57·92	66·11	73·98	81·85	89·72
6	58·36	67·97	77·57	86·81	96·04	105·28
8	67·69	78·82	89·96	100·67	111·38	122·1
30	77·70	90·49	103·28	115·57	127·87	140·16
2	88·32	102·97	117·52	131·51	145·5	159·49
4	99·71	116·12	132·53	148·31	164·09	179·86
6	111·89	130·31	148·72	166·43	184·13	201·84
8	124·66	145·18	165·69	185·41	205·14	224·86
40	138·44	160·87	183·60	205·46	227·32	249·18
2	152·3	177·36	202·42	226·52	250·61	274·71
4	167·15	194·65	222·16	248·61	275·05	301·5
6	182·68	212·74	242·8	271·71	300·61	329·52
8	198·92	231·66	263·39	295·86	327·34	358·81
50	215·84	251·36	268·88	321·03	355·19	389·34
2	233·46	271·88	310·3	347·24	384·18	421·12
4	251·76	293·18	334·61	374·45	414·28	454·12
6	270·76	315·32	359·88	402·72	455·56	488·40
8	290·44	338·23	386·02	431·98	477·93	523·89
60	310·82	361·96	413·11	462·29	511·47	560·65

For the opportunity of acquiring the information upon which this chapter is based, I am indebted to the kindness of Messrs. Galloway, and especially to Mr. Beckwith, one of the Managing Directors, who most courteously showed me all over the works, and explained every operation from first to last.

CHAPTER VI.

MANUFACTURE OF STEEL FOR SHIPBUILDING, ETC., PURPOSES.

Works of the Steel Company of Scotland, Glasgow—Plan of Departments—Plate Mills — Initial Process of Steel Making — Ingot Casting—Cogging Mill Process—Powerful Machinery—Its severe treatment—System of Preliminary Testing—Method of Rolling Finished Shafts—Cold Steel Sawing Operation—Peculiarities of Steel Castings—Other Departments of the Works—Steel of the past and present.

PERHAPS the best method of describing engineering operations of any kind is to begin at the foundation and work upwards, just as architects do while erecting a building. It may, therefore, be advisable to commence this chapter by explaining how the rough materials are produced that are now universally employed in shipyards.

With this in view, we shall describe the Works of the Steel Company of Scotland, which I had the pleasure of visiting with the object of learning how their well-known steel plates and bars of different kinds, as well as steel castings and forgings for general purposes, are primarily operated upon. Having made the *Hallside Works* of the above firm, at Newton, near Glasgow, a point of observation, I was placed by Mr. James Riley, the courteous General Manager, in the hands of Mr. F. W. Dick, the Works Manager, who conducted me over the establishment in regular order, as we shall explain further on.

The above Company was formed in 1872, for the production of steel by the Siemens' process, and the first rails were rolled in 1873. Since that period, the whole of the works have been extended until they now contain, at Hallside alone, twenty melting furnaces, capable of producing 140,000 tons of ingots yearly. There are also various steam hammers on the premises, ranging from 4 to 10 tons, mills of different kinds for cogging purposes, and for rolling plates, angle, tee, *Z*, square, round, and other bars, rails of all descriptions, and a variety of irregular sections too numerous to mention.

The machinery for performing the various cutting operations in the *Mill Department*, as well as the engines for driving it, are of a powerful character, and include massive punching and shearing machines, hot steel sawing machines, and other gear. There is also a large *Foundry*, fitted with every appliance for producing the heaviest and most intricate steel castings used in ships and marine engines, or indeed in any other branch of engineering.

In addition to this, there is an extensive *Heavy Turnery*, filled with machines that are capable of finishing all the above when required. There are also extensive *Repairing Shops* similarly well stocked, and a complete *Laboratory*, and *Testing Houses* where every piece of steel made on the premises is tested to the satisfaction of the Board of Trade or other surveyors. Besides these, there is a large shop where patterns can be made, when required, from drawings sent from any part of the world.

The Blochairn Works of the same firm are able to produce fully 140,000 tons of steel ingots yearly, but these are chiefly used in the manufacture of plates for ship, boiler, and bridge building purposes. To meet the latest requirements of engineers, a complete set of machinery has been provided for flanging boiler plates by hydraulic power, and for machining the edges of the same, as well as for ripping all plates above 1½″ thick, thus avoiding the serious injury that may be done to the metal by shearing.

The Company has carried out most important contracts for various governments, and also for mercantile firms at home and abroad, the most important of all their undertakings being the execution of the largest contract for the steel employed in the construction of the Forth Bridge, amounting in the aggregate to 35,000 tons, out of a total of 54,000 tons, which was distributed amongst eight famous firms. So far, however, as the Steel Company of Scotland is concerned, it was the skilled efforts of Mr. Riley and Mr. Dick that contributed in no small degree to produce a material eminently adapted to fulfil the stringent requirements of the Bridge engineers. Indeed, it may be said that it was through the persevering exertions of the Company and of Mr. Riley that the value of *mild* steel for shipbuilding and boiler making, as well as for bridge building, was forced upon the attention of shipowners and constructors.

The Association is well known as the pioneer Steel Company in Scotland, and has been all along under the guidance of Mr. Riley, who had previously occupied the position of General Manager at the Landore Works in South Wales. And it is to this gentleman that the Institute of Naval Architects are indebted for the first paper introducing mild steel, as supplied to the Admiralty, for the consideration of its members, and for the discussions on the same subject in which he frequently took part. It was on account of his identification with the introduction of the above material that he was some years ago presented with the Bessemer gold medal of the Iron and Steel Institute of Great Britain—the highest honour that can be conferred on a member. And it was the distinction achieved by the Company and its manager which gave them the large contract for the Forth Bridge material, to which reference has been made.

Without giving a detailed list of manufactures by the above firm, we may broadly state that it undertakes everything in cast or wrought steel, that can be made in wrought or cast iron, or gunmetal, from anchors and armour-plates to propeller blades, and the smallest bars. The maximum finished dimensions of plates $\frac{1}{16}''$ thick are 14′ 0″ in length, and 4′ 0″ in width, but the total area must not exceed 30 square feet. At $1\frac{1}{2}''$ thick these proportions become respectively 60, 10, and 250; that is, the area divided by the length, will give the extreme breadth, and by the breadth, the maximum length that is usually rolled. By special arrangement, however, larger and thicker plates may be supplied when desired. The bars or rails of various sections are usually made to suit the market; but, in this respect, there is practically no limit, when special sizes or sections are asked for.

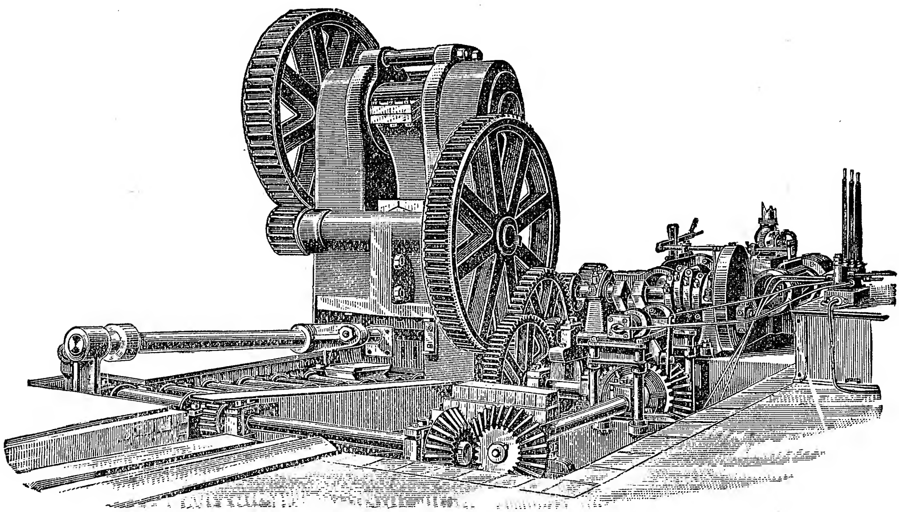
On arrival at the Works, Mr. Dick shewed me in the first place the producers, where the gaseous fuel is made for heating the melting furnaces; then the furnaces themselves, the door of one of which was opened to show its interior. Those who gaze upon this fiery scene with the naked eye will find it quite as dazzling as the sun at noonday, on account of the intensely glowing heat required to boil the steel in course of formation. When, however, dulled spectacles are used, the process can be clearly seen, as the bubbling up of impurities becomes visible.

The ingredients used in the preparation of the metal are, firstly, a quantity of pig iron of special quality, which is thrown into the furnace, and upon which is piled a certain amount of scrap steel, thus using up all the waste cuttings of the establishment in a profitable manner. After the scum referred to has risen to the surface, a specified quantity of ferro-manganese is added, which changes the bubbling fluid into pure steel. In this state it is now run into ladles, which are automatically swung by hydraulic machinery into position for filling the moulds. When sufficiently consolidated, the ingots are taken out of the casting pit by hydraulic cranes and landed upon a live roller path that quickly carries them forward, until they are tilted on end into the re-heating furnaces.

After being re-heated, the ingots are taken out and passed on to the cogging mill, which roughly shapes them into slabs or billets according as the finished productions are to be plates or bars. To insure thorough solidity in every case, the scrap portion of each end is cut off by a powerful shearing machine, and the rest is similarly divided into lengths suitable to the bar, etc., into which it is to be rolled. This latter process is effectually accomplished in the rolling mill, which, by means of diminishing grooves gradually reduces the billet to the exact section. The lengths, however, are kept sufficiently in excess to allow for cutting to the precise dimensions by means of quick running circular saws.

Plates of all kinds are similarly finished by means of guillotine shearing machines, which for $1\frac{1}{2}''$ thicknesses are capable of taking a cut about 10 feet long at one stroke. The framing and gearing of these machines are of immense strength, and in the larger sizes sometimes require an 18″ by 20″ cylinder engine to drive them. The annexed illustration of *Bloom Shearing Machinery*, by Messrs. H. Berry and Co., of Leeds, for cutting hot slabs 22″ × 6″, or 11″ square, will give some idea of what is required for the purpose.

On the left of the engraving a few live rollers are to be

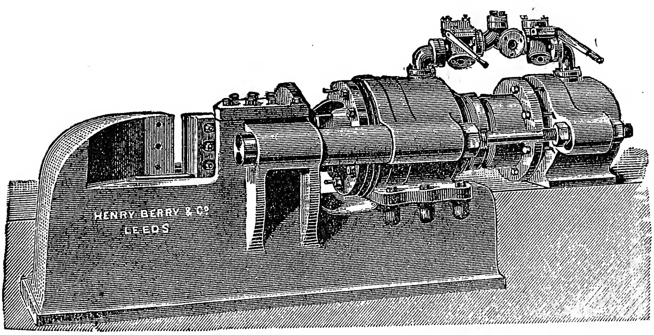


BLOOM SHEARING MACHINERY.

seen, each of which is revolved by bevel gear at the back, worked from the main engines, having 15″ by 18″ cylinders, and these, as well as everything else, are kept under instantaneous control by means of hand gear. In Steel and Iron Works, the live roller system is invaluable, as it automatically and rapidly transports masses of hot metal from the casting pits, &c., to any desired spot, thus saving much unnecessary labour.

In still heavier machines than the above, by the same firm, these rollers are driven by a separate engine, and the whole of the details are made strong enough to sever slabs 30″ by 12″, through the gear-transmitted energy of a pair of 28″ by 30″ engines. It may be added, that the enormous massiveness of this machinery is rendered necessary by the fact that it has to operate upon slabs that occasionally lose so much of their heat as to endanger the whole fabric unless it is able to withstand the greatest strains that can possibly come upon it.

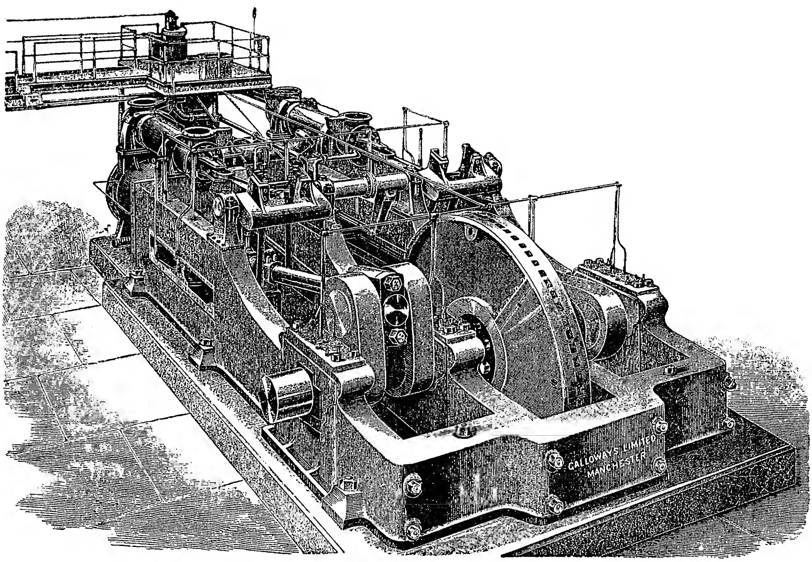
When hydraulic power is used, great simplicity of



HORIZONTAL SHEARING MACHINE.

detail is obtained, as may be seen by the annexed view of Messrs. Berry's patent *Horizontal Shearing Machine* for cutting slabs 18″ by 4″, or 8″ square. In this instance, the power is used with great economy, as it can easily be modified to suit the work in hand by means of two cylinders, the front one alone being used for small billets, and, when necessary, as an intensifier, through the differential ram action of the other cylinder.

In works such as those at Hallside, the mills employed in cogging, rolling, &c., are subject to very heavy and irregular strains. The main engines themselves have not only to bear all this, but in many cases continuously sudden reverses from go ahead to go astern, as the bars are taken successively from one groove to another in the rolls; consequently, there is perhaps no class of machinery that is so roughly treated as the one now under consideration, whilst preparing for ship-builders and engineers the raw material upon which they are so entirely dependent. The adjoining illustration is of a *pair of Engines* by Messrs. Galloway, for driving mill



MILL ENGINE.

trains direct. The cylinders are each 56″ diameter by 6′ 0″ stroke, and the total weight is about 270 tons. The piston valves above the cylinders are actuated by Joy's patent valve gear, which is highly suitable as a reversing motion for this type of machinery.

One of the pieces cut off the finished bar or plate when it leaves the rolls, as well as the production itself, is stamped with consecutive numbers, that are recommenced each month. These specimens are then variously tested in accordance with the engineer's specification, and any faulty piece that may be found will cause the rejection of the plate or bar to which it belongs. This, as will be shown further on, is an absolute necessity when we have to deal with such a peculiar metal as steel has sometimes shown itself to be. So thoroughly, however, is its manufacture and future manipulation now understood, that not only do the tests very rarely fail, but a material is produced that may be employed with the utmost confidence even in the most important undertakings, such, for instance, as the Forth Bridge previously mentioned.

The process of *rolling highly finished shafting* is beautifully simple. The round bars are first taken through the rolls in the usual way for ordinary work. They are next passed while hot between two rapidly revolving conoidal rollers over which water is allowed to flow, and as a man on each side of the machine guides the shaft through them as it spins round, it comes out eventually with a high finish, and almost as true and straight as if it had been turned in a lathe. It is finally run over a number of level rail bearing surfaces, on which it is kept slowly in motion for a time, and thus prevented from irregular cooling, and perhaps warping out of line.

Whilst meandering zigzaggily, but very pleasantly, over the premises, noting everything we saw, and speculating upon what we could not discover, we came to a place where a few foundations were being somewhat extensively excavated.

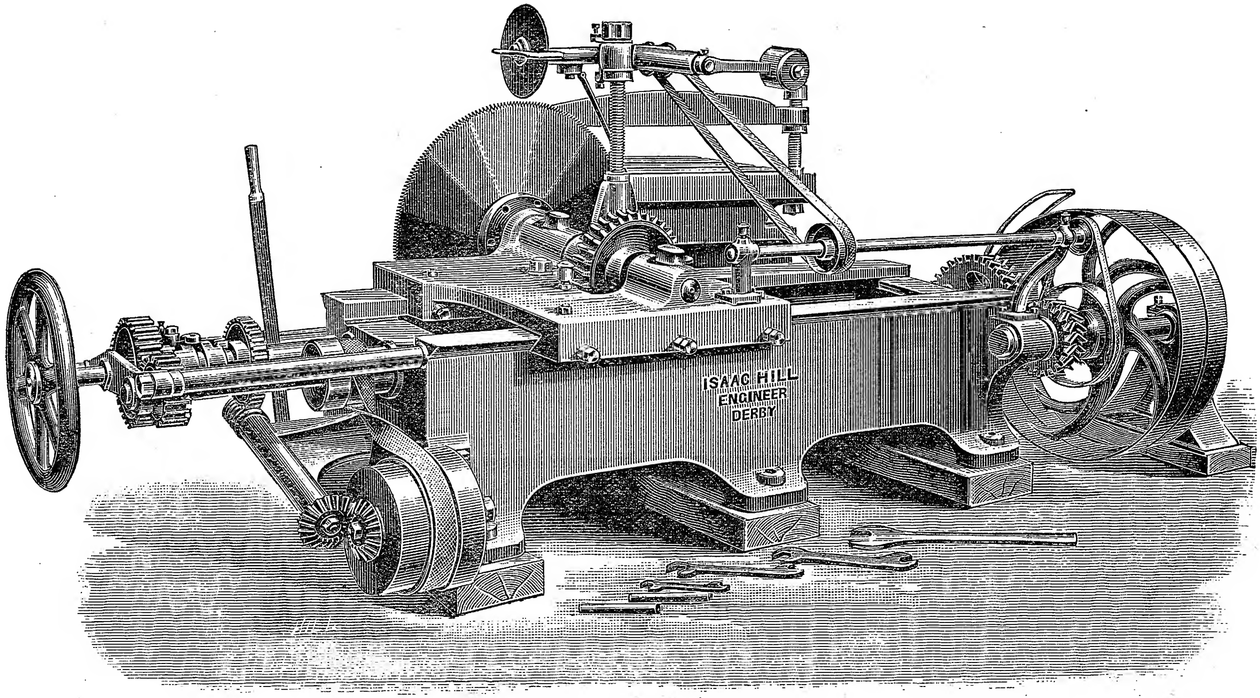
"*More* new machinery ?" I remarked.

"Yes," said my friend, "we have been much troubled of late with strikes amongst the workmen, and as we have just got out of one of them, we are doing our best to introduce new labour saving appliances."

"The old story over again ! Napier did it very successfully in a similar way forty years ago. Indeed some of our best inventions owe their origin to unnecessary strikes—strikes, which instead of really benefitting those who thus acted, produced wide-spread loss to all concerned."

Mr. Dick seemed to think my last observation somewhat felicitous, and I was glad he did so, because up to this point, he had been treated rather inquisitorially. He, however, kindly gave me every opportunity of learning all I wished to know in a systematic and most interesting manner.

As we went along examining the powerful engines and machinery that usefully occupied the various buildings, we, at last, entered the heavy *Machine Shops*, containing lathes for turning the heaviest crank shafts for triple marine engines, and also a most powerful slotter of the newest design, as well as numerous drillers, planers, etc., of the usual type. Messrs. Isaac Hill & Son's patent *Cold Steel Sawing Machines* were amongst the most recent additions, one of which is shewn in the annexed view. As will be seen in the example, the table, and also the longitudinal movement of the saw, are under the most perfect control, and when required, the saw can, in some instances, be removed from the spindle, and a cutter head, or milling cutter, employed effectually instead. There are several special varieties of these machines made by the same firm, but for heavy work the above is



COLD STEEL SAWING MACHINE.

very suitable. The success of the operation, however, depends upon the peculiar shape of the saw teeth, the excellent temper of the metal, and also the circumferential speed, which is about 50 feet per minute. The Emery Wheel Apparatus is so arranged as to enable the saw to be sharpened without being disconnected.

After visiting the spacious and well arranged *Foundry*, which was very similar to others of the same class, we had a few turns in the *Yard*, which contained a large assortment of steel castings for engineers and ship builders, including pistons, cylinder covers, bed plates, propeller blades, stems for ironclads, rudder and stern posts, and a great variety of other gear. Here, too, we found out the cause of the roughness and rustiness that disfigures this kind of work, especially when contrasted with the beautifully smooth surface of iron castings of similar details.

As Mr. Dick pointed out to me, one of the former when it leaves the sand, has the usual grey colour, and is quite clean and smooth when trimmed. The annealing process, however, to which it is now subjected destroys all this, but at the same time it improves the quality of the metal, and makes it easier to machine. It also greatly reduces any internal strains that were perhaps originated by unequal contraction in cooling, and that may afterwards become destructively developed. The operation referred to consists in placing the article to be annealed in a furnace until sufficiently heated, and then allowing it to cool slowly. This has the effect of roughening the skin of the metal, which is finally washed with a solution to improve its appearance, but which eventually produces the aforesaid rusty exterior.

Besides the various departments to which reference has been already made, there is a *Forge* fully equipped with all the most modern appliances. And to this may be added, a complete *Chemical laboratory* and *Testing houses*, and every possible engine, machine, or instrument that can in any way conduce to the economical and successful production of high-class steel.

From the above references to these Works the reader will have a general idea of the processes required in the preparation of the material upon which the safety, economy, and excellence of ships and engines now so much depend. Formerly, the application of steel in important structures was hedged about with difficulties owing to the want of a thoroughly developed system of manufacture. This produced irregularities in the texture of the metal which occasionally showed themselves in the most unaccountable manner in the plating of ships, and especially of boilers, but which the rapid advances of practical science have abolished so completely, that it may now be used with the utmost confidence, owing firstly, to improved methods of manipulation, and secondly, to the rigid tests applied to every piece of steel that is made.

To the non-professional, the amount of waste, or "scrap" metal, usually to be found in such places as Hallside, may appear surprising. This, however, is melted over again with fresh material, recast into ingots as already described, and in an improved state rolled or forged in endless variety.

The great advantage that steel possesses over wrought or cast iron in the construction of ships and engines, lies in its superior strength, which allows a reduction in weight of about one-fourth, thus enabling a vessel to carry so much more cargo. And as every ton thus saved produces an additional revenue to the owner of about £10 per annum, the commercial aspect of the question will at once be seen. Besides this, the superior toughness of the metal has sometimes prevented a ship from filling with water after grounding, because the plates on the bottom were more or less harmlessly bulged inwards, instead of being torn open as they might have been if made of wrought iron.

Hence, it may be added, that everyone connected with ocean navigation has reason to be satisfied with the highly trustworthy material now produced by the Steel Companies in general, including the very famous firm to which the foregoing remarks refer, and to which we are indebted for a very pleasant and instructive visit.

CHAPTER VII.

MANUFACTURE OF IRON AT THE DALLAM FORGE, WARRINGTON.

Extent and varied nature of the Works—Evening Ramble over the Premises—Manufacture of Iron—Puddling Process—Effects of Unskilful Treatment—Peculiarities of Red Short and Cold Short Iron—Shingling Process—Grand Night Effects—Rolling Mill Operations—Hydraulic Forging Machinery.

THE material so extensively manufactured by the Pearson and Knowles Coal and Iron Company Limited, at the Dallam Forge, has played many important parts in the history of the world from the earliest ages, and as it still retains its leading position amongst the constructive metals, a few remarks upon its initial manipulative processes may be interesting to many, especially when the information upon which the following notes are based has been derived from the above establishment, to which I received a kind invitation from my old and esteemed friend, Mr. Thomas Morris, the Works manager.

Besides the usual machinery for rolling, forging, etc., in all departments, similar to that described in the last chapter, these works employ 123 puddling furnaces, 5 scrap furnaces, 37 mill furnaces, and 5 for annealing purposes, the united efforts of which produce about 110,000 tons of finished bars, hoops, plates, sheets, and wire rods, per annum.

In addition to this, there is a fully equipped *Foundry*, and an *Engineering* department, where constructional iron work of every description is extensively manufactured, as well as railway wheels and axles, bridges, and tanks for petroleum or water up to 100 feet in diameter and 30 feet in depth. Also, engines, boilers, steam hammers, general mill and forge machinery, pumping machinery, blast furnace plant, etc., the whole of the immense works thus requiring very many driving engines, and about 112 Lancashire, Cornish, and vertical boilers, to supply the necessary motive power, which is most extensively and effectively distributed all over the premises. Besides the above, the Company possesses a branch establishment at Wigan, for puddling, coal mining, and other operations.

Mr. Morris is quite a Master of Arts in his own line, and is greatly pleased to tell, with modest simplicity and good humour, as much of what he knows as his enquirers can comprehend, and as a keenly observant and practical scientist for very many years, the information he supplies cannot be surpassed. His vast experience is due to industriously studious habits, combined with long sustained association in different capacities with similar establishments in the Wolverhampton district, until he was eventually promoted to the rank of technical Commander-in-Chief at Dallam. I was therefore fortunate in being able to secure his services for the above object.

To enable me to accomplish this, I paid a visit one fine evening to Warrington, as that was the best time to see the whole performance, on account of the establishment being kept almost continually going, so that the furnaces once heated up to the proper temperature, could be maintained in order without loss through cooling down. The shades of night were falling fast, as through the noble works we passed, and no sooner did the evening shades prevail, than the FORGE took up its wondrous tale—of engineering enterprise. The fresh hands were in possession of the place, which was in full swing, and it was quite evident that we had entered upon a most interesting entertainment in the Regions of Fire, whose glare, and striking contrasts, and noise were all the more remarkable on account of the surrounding darkness and gloom.

Up to this period of my existence I had successfully avoided being run over by erratic locomotives and trains, even when crossing numerous lines of rails in the dark. Now, however, the adjacent concert of steam hammers in a thump! *bang!* SMASH! sort of style, completely drowned the noise of approaching rolling stock as we passed from one building to another. Hence my good friend occasionally took me by the arm, as he shouted in my ear, "Mind the engine!" "*Take care of the waggons!*" "LOOK OUT!" and so on. I was similarly protected from falling over platforms, stepping into dangerous places, tramping on hot metal, and getting in the way of the men engaged in the various processes.

Truly the Dallam Forge by night is a strangely *striking* sight, since the absence quite of light, makes glowing furnaces more bright, whilst those around in garb so slight, develop all their skill and might. It may here be observed that the manufacture of iron was at one time hedged about with many difficulties, notwithstanding its apparent simplicity. In reality, however, the chemical and mechanical treatment of this metal is very complicated, and requires the most careful attention owing to its great value as a constructive material. The processes employed may be described as follows.

The ore is, in the first place, smelted in the usual way at the blast furnaces, and cast into crude "pigs," that vary in quality according to the mineralogical nature of the locality from which it is taken. These pigs are subsequently sent to works such as those we are describing, for the purpose of being so operated upon as to eventually produce the finished iron suitable for engineering and shipbuilding purposes.

The next process is termed "puddling," by means of which the crude cast iron is converted into malleable or puddled iron. This most interesting operation cannot be performed without mechanical treatment and the introduction of important chemical changes, whose object has been to perfect the system of manufacture, and to relieve the workmen of much of their arduous labour. It is this initial movement that lays the very foundation of all future virtues in the rolled or forged material, and produces iron that is absolutely worthless, or of the highest quality, according to the methods employed.

The present almost universal system of puddling was invented by an ironmaster named Cort, about the year 1780, and afterwards improved by Joseph Hall, and as this system has been thoroughly tested in the gradually increasing practice of at least a century, we may conclude that its excellence has been fully established. The puddling furnace of the present consists of two chambers separated from each other by a bridge 12″ thick and 14″ high, one of which is termed the "grate," the other the "working chamber," which is charged with about 170 pounds of hammer slag, 14 pounds of scales from the rolls, and at least 448 pounds of pig iron.

Before these substances, however, can be exposed to the melting process, the cast iron bottom and sides of the furnace in which they are to be thus treated, are protectively lined with slag, scale, scrap, cinders, etc., from two to three inches in depth. When these are fused by preliminary heating, and consolidated into a refractory coating, the working chamber is ready to receive its first charge, as mentioned above, and then it has its apertures closed air-tight. The grate also receives a proper supply of coal for melting the charge, the waste heat from which is led away to generate steam in the main boilers throughout the Works.

In about half-an-hour after the heat is thus applied to the mass, the pig iron will be found lying in a liquid state about $1\frac{1}{2}''$ in depth upon the bottom of the furnace, and covered with a layer of melted slag nearly $\frac{3}{4}''$ thick. The puddler's assistant now takes a "rabble," or special kind of rake, and stirs with it every part of the iron from front to back, and from side to side. In a few minutes the carbon of the metal begins to combine with the oxygen of the slags, or silicates, and as the carbon is emitted, the atoms of the iron expand until its specific gravity is no greater than that of the silicates, and the whole attains a thickness of nine or ten inches. At this stage a sort of boiling goes on, the carbonic oxide is thrown off, and the master puddler now smartly stirs the mass, taking care at the same time, that every atom of iron gets a sufficient quantity of purifying oxygen from the silicates.

In a short period the metal is so much decarbonised that the atoms begin to agglutinate and adhere together, and also acquire a somewhat spongy consistency. As the operation proceeds, the silicates that were once the lightest become the heaviest, and fall to the bottom, while the iron at the same time rises to the surface. It is at this stage that the puddler collects the easy yielding metal and forms it into balls for conveniently taking out of the furnace and sending to the steam-hammer to undergo the " shingling" process.

These last-named chemical changes have to be watched with the utmost care by the chief operator, with the object of producing good, clean, tough iron. If, on the other hand, however, there has been any carelessness or want of skill displayed, no future manipulation will be able to rectify the evils thus engendered. Indeed, we might just as well expect a piece of choice, but overheated cast steel to make good tools, as first-class metal to be made out of iron that has been improperly treated before removal from the puddling furnace. If this is not prevented, the iron may afterwards become either " red short," or " cold short." The former tempts the smith to think or speak unparliamentarily when the work he is engaged upon breaks off suddenly at red heat while being finished on the anvil. Whereas the other grieves the contractor when a twenty ton load destructively comes down with a run, because one of the links in the lifting chain was of *cold* short iron, which snapped with the slightest jerk.

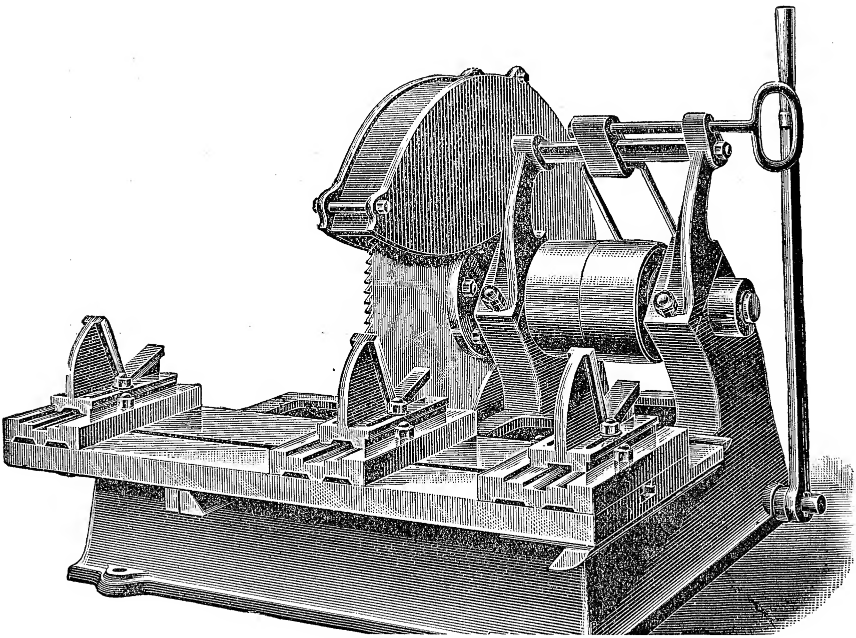
Another peculiarity of red short iron is, that although it cracks at a glowing heat when being punched or bent, it is sufficiently tenacious when cold. Cold short iron, on the other hand, can be worked with ease while hot, but possesses the aforesaid ineradicable and dangerous evil in the ordinary state, hence the necessity for extreme carefulness on the part of the puddler from first to last.

When the puddled ball has reached the neighbouring steam hammer in a highly plastic state, it is " shingled," or beaten into the required " bloom " form, to enable it to undergo the next operations of cogging and finally rolling into finished bars, plates, &c., as previously described. During the shingling process a great quantity of red hot scale and slag is thrown off all round, thus endangering the parade costumes of ladies and gentlemen who may be too closely surveying the scene. The hammerman himself, being directly exposed to the horizontal shower of fire, is dressed in strong leather around the lower part of his body, his legs being also covered with sheet iron, and in addition to this he wears a fine wire gauze mask to protect his face from the sparks. Thus equipped, he is enabled rapidly to prepare the bloom for the aforesaid future manipulations and sawing to length, which run much upon the same lines as those for the manufacture of steel when it reaches the same point.

The manner in which the last named operation is performed may be gathered from the annexed view of a *Hot Iron Sawing Machine* by Messrs. Isaac Hill & Co., for cutting bars and rods of all kinds. These are placed in rests fixed to the sliding table, and pressed by means of the hand lever against the saw, whose diameter is 30″, and velocity 1,400 revolutions per minute, and whose lower part is immersed in water for cooling purposes.

At the time of my visit to the works, the whole strength of the company appeared to have been called into requisition. The various sixty ton flywheels, with their attendant engines, shafting, drums, pullies, belts, and machinery of every description, were in full operation. We also noted that Mr. Morris, with the sanction of the directors, has adopted throughout the establishment a system of ventilation that proves most effective. This consists of a number of two-armed fans or paddles, fixed to the overhead quick running shafting, thus producing excellent cooling results, and giving at the same time a picturesquely unique appearance to the various interiors, under strikingly intensified lights and shades.

One of the most beautiful sights in the establishment was the manufacture of wire rods in a mill that was invented by Mr. J. J. Bleckly, one of the Directors of the Company. From the moment the billet enters the first groove of the rolls, until it leaves the last at about

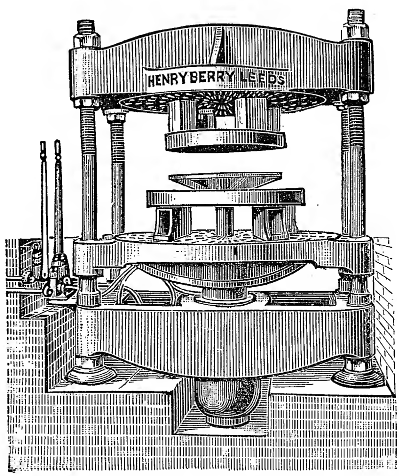


HOT IRON SAWING MACHINE.

No. 5 B.W.G., or ·22″ diameter, and over 1,000 feet long, it is kept in rapid and perpetual motion. Firstly, in and out in serpentine fashion, and then wriggling like a fiery snake on an iron floor as an attendant seizes the free end and attaches it to a swiftly revolving pulley that coils the wire into bundles ready for use.

"*Plate*" iron ranges from $\frac{1}{8}''$ to at least 1$''$ in thickness, and may be made to weigh either so many pounds per square foot, or regulated in thickness to suit the new Birmingham Wire Gauge. Thin "*sheets*" are rolled in the usual way down to $\frac{1}{16}''$ thick, they are then doubled, heated to redness and rolled again, then quadrupled, heated and rolled as before, if necessary, until the required gauge is attained.

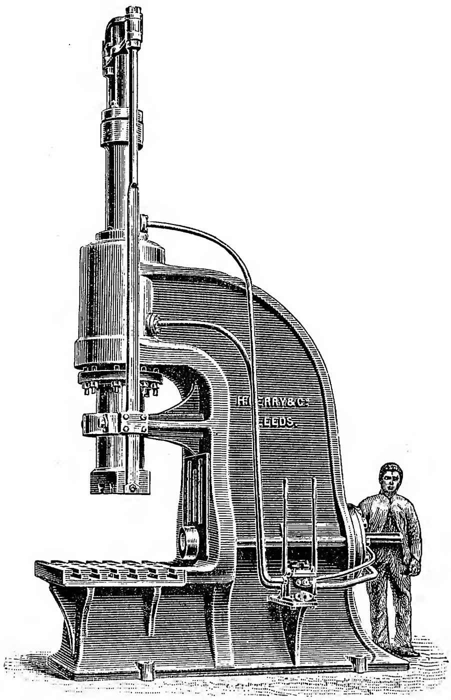
In forges, especially those for very heavy work, the



HYDRAULIC FLANGING AND FORGING PRESS.

Hydraulic Press has now attained a most important position owing to its peculiarities, which have been already described in Chapter IV. We shall therefore only refer to two well known and useful specimens of this class of machinery by Messrs Henry Berry & Co., of Leeds.

The annexed view represents one of these for giving a dead pressure of 130 tons, which may be employed for boiler flanging as well as for ordinary forging, whilst the larger sizes are capable of taking in plates 11′ 0″ diameter by $1\frac{1}{4}$″ thick, with a greatly increased working load. The usual four column fixings are clearly indicated, each having sufficient length of screw for vertical adjustment. This machine can also be used for stamping purposes, and for punching out of the solid



HYDRAULIC FORGING PRESS.

much that formerly had to be done by slower and more expensive methods.

The other specimen of *Forging Press*, for general use, by the same firm, is adjacently illustrated. Here we have the steam hammer type of framing, fixed table, overhead ram—whose lower end may be variously arranged—pull back gear, and a horizontal ram for side pressure operations. Engines of this description can be modified to suit ever-varying circumstances, and under a pressure of 1500 lbs. per square inch, are made to exert a force of 200 and 85 tons respectively. They are also most conveniently controlled in every movement by means of the hand levers shown in front. In addition to the above, Messrs. Berry make presses in other styles up to 2000 ton power for gun forging and other purposes.

From the samples we saw of manufactured iron on the premises, we could only conclude that the highest finish, as well as general excellence, is aimed at in every department by means of a first rate system and good machinery, the advantages of which have already been referred to in connection with other spheres of labour.

For the benefits derived from the aforesaid evening ramble over the Dallam Forge, I am indebted firstly, to the Managing Director of the Company, and secondly, to Mr. Morris, who so successfully and pleasantly "bossed the show," and so generously aided me in my investigations. It may only be added that as the steel and iron *manufacturing* processes have now been described, we shall in the chapters that follow show how these materials are applied in shipbuilding and marine engineering, and for this purpose will primarily introduce a few remarks in our next upon the Fairfield establishment on the Clyde, as one of the best examples that could be selected.

CHAPTER VIII.

THE FAIRFIELD WORKS, GLASGOW.

Shipbuilding on the most improved principle — Building Yards generally—Origin of the Fairfield Works — Early recollections of Mr. John Elder and his productions—Rapid building of S.S. *Normannia*—Resources of the establishment—New Extensions—Moulding Loft — Method of Drawing Ships full size — "Off-set Book" of dimensions—Ship Yard Machine Shop—Frame Bending Floor—Frame Bevelling Process—Cause of extreme variety in Ships—Initial Operations in Drawing Office—Paper Working Drawings—Example of Practical Application—Working Model, and its uses—Laying the Keel of a Ship.

The portion of an Engineering establishment set aside for Naval Architecture differs materially from the other parts of the premises where the more exact mechanical operations are conducted, and as the description of Boiler Works, given in a former chapter, is only a step in this direction, we shall now proceed with the survey of a Shipyard and its surroundings. Here we at once come in for a series of operations that are admirably adapted to a different class of work. The labour-saving machines and appliances in this branch of science are just as carefully studied and arranged as in the others previously referred to, and although a somewhat changed order of practice prevails, nothing is neglected that can in any way further the end in view.

"The *Building Yard*" is a somewhat elastic phrase, and may mean, on the one hand, a gigantic establishment, or, on the other hand, a miniature work for yacht building. It may have several graving docks on the premises, or perhaps none at all, as the river side, or some neighbouring water space, may be considered quite sufficient for the purpose. This, however, depends upon circumstances too varied to be dealt with here.

In large places, a "fitting-up basin" is generally attached for conveniently erecting the machinery on board, but in others, an adjacent quay does very well if the water is deep enough. Formerly, the engineering and shipbuilding departments were often miles away from each other, as indeed they sometimes still are, or perhaps worked by different firms. For instance, Napier made many sets of naval engines, which were sent to ships building at Portsmouth, or Plymouth, and elsewhere. Elder did the same, and Caird & Co. made all Denny's marine machinery up to the year 1850, when the latter erected their present engineering establishment, which has since been very greatly extended.

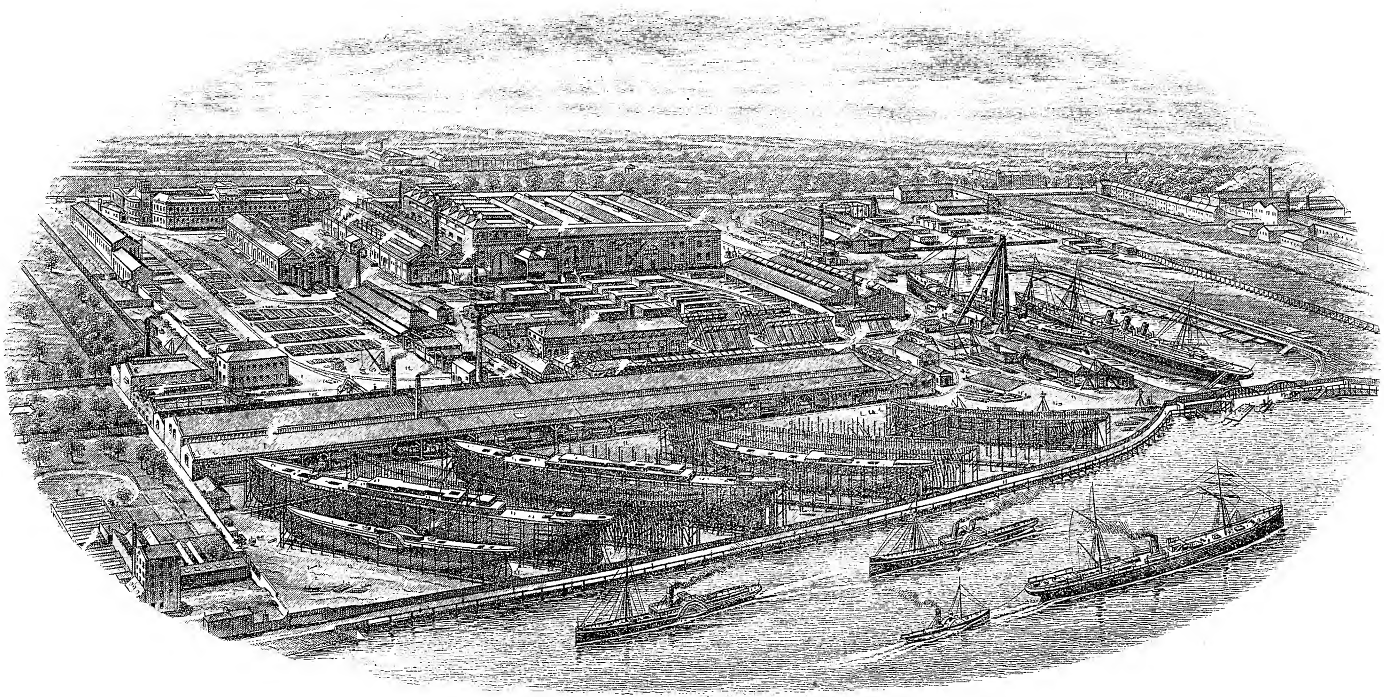
Now, however, both operations are almost invariably conducted on the same premises, but, to some extent at least, in an independent manner, as each department has its own office, special staff, and machinery. It must, nevertheless, be understood that the executives on both sides work together most harmoniously under a highly developed system, and this, it may be added, will account for the rapidity with which 10,000 and 12,000 tonners are now built, engined, and sent to sea.

It is curious to note that while for about the last sixty or seventy years Maudslay and Field, Napier, Denny, Caird, and others, have retained their original title, the present Fairfield Company has had many changes, the history of which may be compressed into the traditional nutshell form, as follows.

In the year 1834, Messrs. Randolph & Cunliff commenced business together as millwrights in very small premises in Glasgow. These, however, gradually expanded, and, in 1837, Mr. Elliot joined the firm, which now became Randolph, Elliot & Co., who soon acquired a great reputation for wheel gearing, shafts, pulleys, and a large variety of similar work.

In 1852, the introduction of Mr. John Elder, as a partner of the firm, caused the name to be changed to Randolph, Elder & Co. This gentleman had been educated under the care of his father at the Lancefield Works of Mr. Robert Napier, and also in some English establishments, in all of which he was a diligent observer. When, however, in 1858, he patented his arrangement of Compound engines, and had them successfully tried in practice, millwork was gradually superseded by the more profitable business of marine engineering, which the firm rapidly improved, chiefly under the auspices of the Pacific Steam Navigation Co., until, in time, the new machinery became universally popular.

The success that attended the firm was almost unprecedented, and in 1860 it entered upon a shipbuilding career which rapidly increased until, in 1868, Mr. Elder became sole proprietor and technical Commander-in-chief of both establishments up to the time of his death in 1869. After this, the business was carried on for a few months under the title of John Elder & Co. Then Mr. J. F. Ure, Mr. J. L. K. Jamieson, and Mr. — afterwards Sir — William Pearce, became sole partners; and in 1878 the last named assumed the sole proprietorship of these vast Works, in



WORKS OF THE FAIRFIELD SHIPBUILDING & ENGINEERING COMPANY,
GOVAN, GLASGOW.

which he brought his most extensive government and other experience to bear with great effect.

In 1885, he admitted Mr. Richard Barnwell as a partner, and in the following year the title of the firm was changed into the "Fairfield Shipbuilding and Engineering Company Limited." On the death of Sir William, in 1888, his son, Sir W. G. Pearce, became Chairman of the Company, whilst at the same time, Mr. Barnwell remained as Managing Director, and under this new arrangement the Works are now carried on with a prestige that has never been diminished during all the aforesaid changes.

Returning to Mr. Elder, it may be added that his engines were remarkable for exquisite beauty of design and finish, as we had often to note during a residence on the Clyde from 1852 to 1862. He was a very genial and enthusiastic worker in the field of practical science, and one whose expression indicated the closely sustained thoughtfulness which was so fully confirmed by his numerous productions. In 1860, I was just on the point of becoming one of the Drawing office Staff, but as Messrs. Tod and Macgregor had just received orders for the first Inman S.S. *City of New York*, and other vessels in succession, after a period of depression, I remained with that firm on the invitation of Mr. William Tod, and was thus prevented from acquiring a more intimate knowledge of the establishment now under consideration.

As it may be interesting to readers to see the exact spot where the S.S. *Umbria*, *Etruria*, *Normannia*, *Dunottar Castle*, the new 14,000 ton Cunarders, and many other famous ocean racers and naval ships have been built, we give in the accompanying Plate a bird's eye view of the whole of the Fairfield establishment with its surroundings.

As will be clearly seen, the Works are bounded on the left by a factory. In the far back ground, by the new offices and engineering buildings skirting the Govan road. On the right, by the *Fitting-out Basin*, containing the two mail steamers *Normannia* and *Dunottar Castle*, lying within easy reach of the 130 ton sheer legs. In front, by the river, where two swift steamers can be seen paddling home, say from Rothesay and the Gare Loch, and also a large ocean liner slowly screwing her way down, with an attendant tug to help her in steering round the bends.

The Works themselves comprise the aforesaid *Offices*, with the *Pattern Shop* in front of them. Upon crossing the adjacent yard-space we come to the *Forge*, 300 feet long, by 100 feet wide, containing 40 fires, 8 steam hammers, and all other appliances. Next in order is the *Boiler Shop*, 300′ 0″ by 68′ 0″ by 65′ 0″ in height to the top of the walls, which has recently been added to a magnificent building 300′ 0″ square, containing a splendidly equipped *Engine Constructive* department, consisting of the *Machine and Erecting* shops, which must very greatly interest all who visit them.

At the head of the dock is placed the *Boat Building Shed*, and towards the centre of the Plate may be seen the *Timber Stores and Racks*, *Iron Working Shed*, *Coppersmith*, *Brassfounding*, and *Pipe Bending* shops, also the *Ship Yard Smithy* and *Turning Shop*, *Wood Working* departments, etc., and above all, the great *Shipbuilding Machine* shop, 1,000′ 0″ long, by 140′ 0″ broad, which very appropriately adjoins the *Slips*, where at least twelve steamers may be constructed at the same time. These vessels are built angularly to the river to gain water space in launching; and when everything is ready for the event, the movable roadway at the waterside is opened out to let the ship free.

The resources of the establishment, from every point of view, are of a very extensive nature, and are capable of rapidly and efficiently carrying out the most advanced operations upon ships and engines of every kind and size. This is owing to the use of the best machinery, but chiefly to recent innovations of a somewhat unique character, which are, therefore, all the more worthy of note.

Some idea may be formed of the capabilities of the Fairfield Works when it is known that in 1884, whilst the Cunard steamships *Umbria* and *Etruria*, each of 15,000 horse power, and various other large vessels were being built, the first-named ship was completed in what was then considered the unprecedentedly short space of fifteen months from the time the keel was laid. In 1890, however, the twin S.S. *Normannia*, of the Hamburg-American line, was constructed and finished in *ten* months, and was delivered to the owners on the very day she became due under the contract. This magnificent ship is 500′ 0″ long, 57′ 6″ beam, and 8,500 tons gross tonnage. Her propelling machinery consists of two sets of triple engines, collectively of 16,000 indicated horse power on trial, while her speed, at the same time, was 21 knots an hour. As the vessel is shown in the Plate, it will be seen that she has three funnels, and two pole masts of the simplest type, without yards, which are now considered unnecessary appendages. The extreme rapidity in the building of this vessel, as well as others of later date, is due to the admirably organised system of management at the works, and also to the excellence of their general arrangements, to which reference will be made as we proceed.

Another cause is to be found in the completeness, and elaboration, and systematic manner, in which working drawings are now prepared, and which gives them an easy adaptability to the requirements of engines that may be a little larger or a little smaller than those they were originally designed for.

The Fairfield establishment covers an area of 50 acres, and may be considered a model of its kind in every respect, as it had from the beginning the advantage of Mr. Elder's valuable experience derived from his very extensive practice in the old works.

The first thing that attracts the attention of visitors is a very handsome and spacious new building in the Italian style of architecture, containing the seat of government, the finished model room, and the offices for the commercial and scientific staffs, the latter of which includes separate accommodation for the shipbuilding and engineering draughtsmen, and also for the young ladies who trace the drawings for both departments. The new offices are constructed of red sandstone in a large two-storey block 335 feet in length, the centre of which is adorned with Corinthian columns and pediment. The ends of the edifice are of more simple design, and one of them is embellished with a square tower.

Passing onwards, we reach the *Moulding Loft*, 320 feet long by 50 feet broad, whose smooth and black-painted floor is suited in every way for the intended purpose. When the small scale paper drawings, and numerous complicated calculations connected with a ship have been sufficiently matured in the drawing office, the preliminary model submitted by the builders and approved of by the owners, and when the quarter-inch scale working model is completed, the lines are transferred full size to the floor just mentioned. This is done by marking upon it a sufficient number of points, through which these lines are drawn by the aid of flexible wooden battens, and then run over with chalk to make them sufficiently distinct. Thus it comes about that the half breadth plan of the ship gives the exact horizontal shape of the vessel at different levels from the keel upwards, and the half sections show the curvature of the frames or ribs in every position, forward and aft of the midship section.

At the same time, the graceful fore and aft curve of the sides at the deck line are also given in the longitudinal, or "sheer plan," and hence the proper shape of the ever-varying frames can be finally determined.

It may be asked how a vessel 500 feet long can be drawn on a floor only 320 feet in length? Well, this, like a good many more of our beautifully simple operations, can easily be accomplished when you know how to do it. As previously observed, a ship consists of a "fore body," and an "after body"—taking the midship section as the point of division. All that has therefore to be done is to draw each half by itself in any convenient part of the floor, thus leaving sufficient space for the other views, which may be made to cross each other when necessary. On the office drawings, however, all this complication is avoided by the use of specially-prepared drawing boards, and *web* paper. For distinguishing marks, each frame aft of midship is numbered 1, 2, 3, etc., ending with the stern post, whereas those going forward to the stem are marked A, B, C, etc., until the alphabet is exhausted; then it is repeated thus: AA, BB, and so on to the end. Frequently, however, the numbers are used throughout, but this system is not so expressive.

After the aforesaid mould loft lines are made fair with each other, they are carefully measured along numerous offsets, as in land surveying, and then entered in the

"Offset book" for future reference, so that they can be reproduced at any time either full size, or to any other scale. In addition to this, numerous long measuring staffs are scored upon their sides with the exact dimensions and other particulars of every frame, for transference to a somewhat similar floor in the frame bending shop.

When these outlines have been carefully reproduced in this manner, iron bars, say $1\frac{1}{2}'' \times \frac{1}{4}''$, are bent to suit the shape of the different frames, each of which is used as a templet for accurately curving the hot angle irons whilst being manipulated on the levelling plates. After this is done, the frames are allowed to cool previous to removal to the vicinity of the intended vessel, whose keel has already been laid in the yard. It may be added, that *before* the angle or Z irons for the above are bent as described, they are variously bevelled in a patent machine, by Messrs. Davis and Primrose, of Leith, to suit the ever-varying fore and aft shape of the vessel. This allows the plating to lie solidly upon the frames, and conduces in no small degree to the elegance and strength of the structure.

The above machine is mounted on rails in front of a special furnace, and when required it is brought up to the door of the heating *chamber* so that it can draw the straight bar out of the fire, and at the same time perform all the bevelling, and smoothing of the rough edges of rivet holes during one heat, without injury to the metal. By means of an index that is graduated from 45° to 90°, any intermediate amount of angling can be accomplished with great simplicity and economy.

One of the most important departments at Fairfield, is the *Shipyard Machine Shop*, which covers an area of one hundred and forty thousand square feet. In this portion of the premises, all the multifarious operations connected with the iron, and steel, and woodwork of vessels in progress, are conducted by means of special machinery, some of which is of a very powerful character. Here we find arranged in pavement style the large metal levelling plates, perforated all over with holes about $1\frac{1}{2}''$ diameter, and $6''$ pitch, upon which the frames for every ship are bent while hot to the required shape. Close to this is the wooden floor for containing their outlines, after transference from the mould loft, as previously described. In the immediate vicinity will also be found the *Bevelling Machines*, hence this portion of the premises may be said to initiate the practical operations of Shipbuilding, which will be explained as we proceed.

Some people have thought that there should be less variety in the size and design of ships and engines for the sake of economy in manufacture. A few may also have fancied that the existing complications in the construction of a steamer's hull may be greatly simplified by making its outlines more regular, and more capable of easy reproduction on a large scale, as in other branches of engineering. No doubt this *could* be done, but its attendant evils would be insurmountable, except in special and somewhat unusual cases. From this it will be seen that in shipbuilding, uniformity of design and construction cannot generally be obtained without making sacrifices of some kind or other. The highest skill of the professional is, therefore, best displayed in the selection of what is really good out of much that only appears so, and this is pre-eminently observable in the productions of the firm to which reference is now being made.

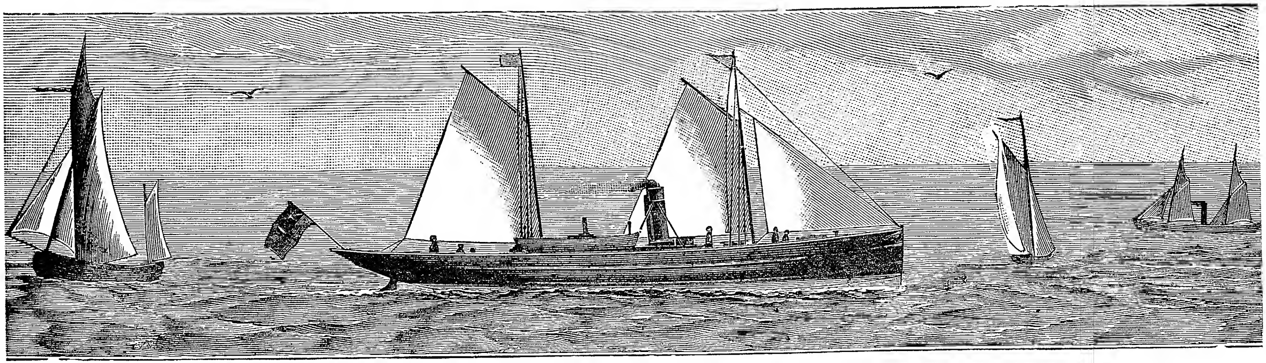
The preliminary paper drawings that originate the full size "lines" of a ship, consist of Sheer Plan, Body Plan, and Half-breadth Plans. The first-named is simply a longitudinal view of the vessel, showing the spacing of the frames, and their varying heights, due to the gradual rise of the deck from the centre to the ends. It also gives the outlines of the stem and stern-posts, as well as the stern itself, etc.

The Half-Breadth Plan only gives one side of a ship, because the other side is exactly the same, and does not need reproduction. It clearly shows, however, the curvature of the lines at different water levels, which may be either fine, or full, according as the ship is intended to be a lightning racer or a slow speed cargo vessel, a cut-through-anything sort of clipper or a tub. This, we may add, lies entirely with the owners; but so anxious are the builders to please their clients in every respect, that they will do all that they are requested to perform, subject, of course, to their own scientifically matured judgment.

The Body Plan, or Half Sections of fore and after bodies, at various frames, have already been described, and these are drawn upon the same vertical centre line, as both sides of the ship are precisely alike.

These "line drawings" are not by any means artistic for obvious reasons; the general plans, however, are often elaborately handsome and costly productions, on account of so much of the interior and exterior work being shown upon them. This includes engines, boilers, main shafting, auxiliary machinery of every description for pumping, electric lighting, refrigerating, hoisting, etc., and all the fittings and constructional details in every department, below and on deck.

The accompanying Plate clearly gives all the above general views, except the transverse sections, of a 70 ton steam yacht, built by Messrs. Simpson, Strickland & Co., of Dartmouth. And although these views are necessarily



SEVENTY-TON STEAM-YACHT, WITH KINGDON'S TANDEM QUADRUPLE ENGINES—SPEED 11 KNOTS, AND COAL BUNKER CAPACITY FOR 2,000 MILES' STEAMING.

simple on account of her small size, they nevertheless clearly indicate the method adopted, while delineating on drawings the very much more elaborate and extensive interiors of naval ships, royal mail liners, and other vessels.

The *Deck Plan* shows everything that is visible in that region, when looked at from the masthead, which, in the present instance, is not much.

The *Sectional Plan* gives the Kingdon engine and boiler arrangement, coal bunker spaces, saloons, berths, etc., while the longitudinal section, or *Sheer plan*, illustrates the same from another point of observation. In this case, the screw shaft, propeller, load draught line, and general outline of the ship, with the position of all the frames marked just above the keel, are clearly seen.

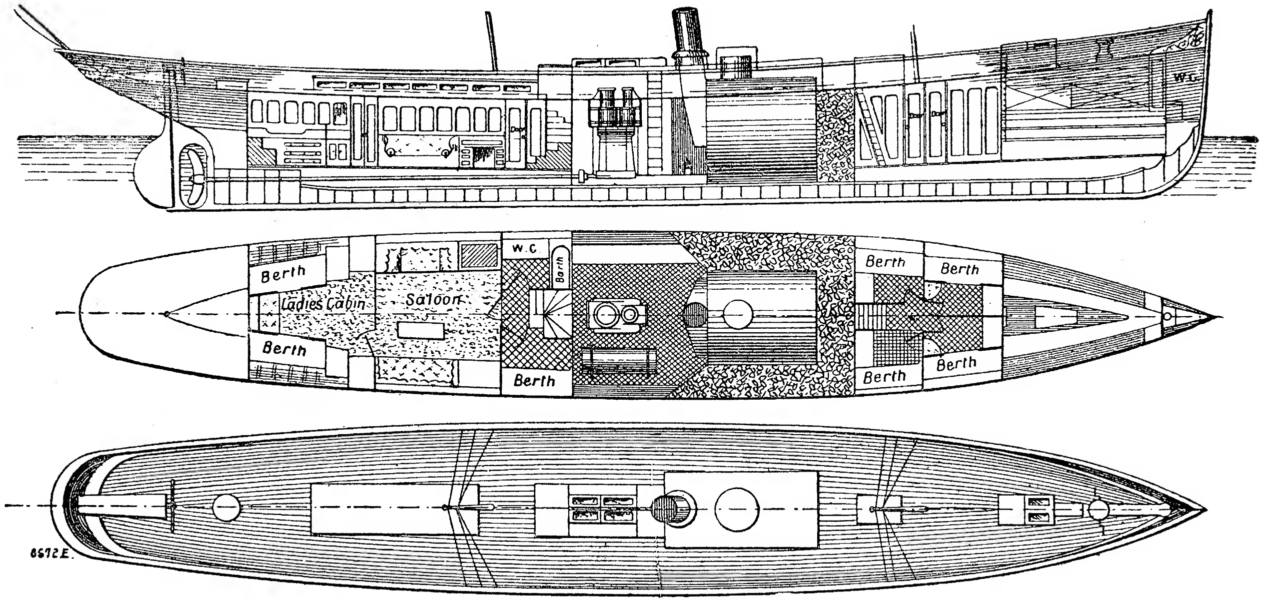
In large steamers, these views become most extensive affairs, as there is so much to be shown upon them. A plan, too, is required for every deck, just as in drawings for a large mansion or public building; and, besides this, there are numerous full transverse sections, which, like all the rest, are indispensable. From these drawings very many working details are prepared, so that the general construction of the ship in the yard may go on smoothly and rapidly. The engines, however, have *their* important share in the performances behind the scenes, and thus it happens that the systematic and harmonious action of two distinct classes of professionals, unitedly sustained from first to last, produce in the end those splendid results the public occasionally read about, without knowing exactly how they are attained.

The uppermost view in the Plate will do very well for a *Masting or Rigging Plan*, notwithstanding the picturesque nature of its surroundings, which in drawing offices are always omitted, as they are quite unnecessary. Here we have the outside aspect of the ship, with funnel, lifeboat, spars, rigging, sails, and even the national, house, and name flags, in their respective positions. In modern steamers this Plan is very simple, as the masts have now become mere poles, but in sailing ships it makes a splendid show for obvious reasons.

All these illustrations form good examples of the style of yacht construction adopted by the builders, and may also be considered fair specimens of the usual style of ship plans of this nature in any establishment. These little vessels can be built of iron, or steel, or timber, and, as in the present instance, of light draught, to enable them to enter small harbours with safety. The yacht referred to has a speed of about eleven knots, upon an extremely small consumption of coal, a sufficient quantity of which can be carried in her bunkers for about two thousand miles steaming. It may be added that, although the foregoing remarks directly refer only to a very simple ship, they are intended to exemplify certain leading principles that permeate the whole domain of naval architecture.

The *Working Model* is of great importance, as it gives, to a scale of quarter-inch to one foot, the exact shape of the hull, with the positions of all the frames, etc., marked upon it. It also similarly gives the lengths, breadths, and thicknesses of all the outside plates, the latter of which vary according to position, and from these dimensions the rolling mill people can be supplied with the requirements in full.

Besides this, all the transverse joints of the longitudinal plating are shown where they are intended to be, which enables the seacocks, valves, and other connections, to be arranged so that they will not foul anything, and thus



SEVENTY-TON YACHT—LONGITUDINAL SECTION, LOWER DECK PLAN, AND UPPER DECK PLAN

cause, perhaps, much trouble and expense to rectify. Models of this kind are eminently useful, and should be considered by visitors as valuable aids to shipbuilding, instead of so many semi-demi-tattooed and unattractive logs of timber, as no doubt they often are. When we come, however, to full-rigged specimens such as those that are so greatly admired at exhibitions, we become at once associated with works of the highest finish, even in the most minute details, which, in their own way, are as instructive as they are artistically beautiful.

Whilst the frames of a steamer are being shaped on the levelling floor previously mentioned, the keel blocks are being laid at the building slip in a manner suited to the size of the intended vessel, and raising her sufficiently above the ground to enable the men to work underneath. When these are ready, the keel, stem, and stern posts—drilled throughout for plate rivetting—are placed in position. Owing, however, to the great length of the keel, it is made in pieces, which are scarph-jointed, and then securely fastened to each other. The frames are now erected in their proper places, and kept in position by temporary fixings until the outside plating binds them all together. This, we may add, is the *visible* opening of a scene which becomes more animated as the work proceeds, and gradually creates employment for many hundreds of men on one ship alone.

CHAPTER IX.

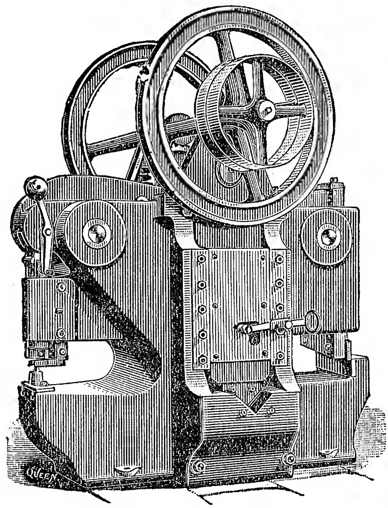
APPLICATION OF SHIPBUILDING MACHINERY AT FAIRFIELD, AND OTHER WORKS.

Punching and Shearing Processes—Experiments upon power required—Enormous Crushing Strength of Hardened Steel—Recent Improvements in Constructive Machinery—Beam Curving Process—Method of Bending Heavy Ship Plates—System of Straightening Irregular Plates—Heavy Plate Edge Planing—Keel Plate Bending Process—Tank Plate Flanging and Stamping Operations—Countersinking Process—Rapid Method of Drilling Keel Bars—Jointing the same in lengths—Deck Plating of Ships—Shell, &c., Plating—System in Shipbuilding.

THE machinery which in a general way facilitates the construction of ordinary ships is much the same in all similar establishments. In places like Fairfield, however, we meet with specimens of an extremely interesting and sometimes unusual character, to which reference will now be made.

Perhaps the most powerfully represented class of machines is the well-known Puncher and Shearer, and this is owing to the fact that while the Driller has largely abolished the former process in modern boiler works, for the reasons already given, it is not so necessary in the preparation of ship plates, etc., where properly punched holes are not only quite sufficient for the purpose, but much more economical.

A good example of a very popular and improved type of *Punching and Shearing Machine*, by Messrs. Henry Berry & Co., is shown in the adjacent view. These machines are fitted with angle iron shears in the centre, and one of their most important features is the working of the slides by means of levers operated by cams in such a way as to



PUNCHING MACHINE.

enable the punch slide to pause at its highest point for one half of the cam's revolution, the stroke being given by the other half. This arrangement allows ample time for setting the plate accurately before punching the hole, and also enables the machines to be run at a higher speed than is usual with ordinary eccentric gear.

The four standard sizes in general use by different makers, are respectively able to perforate holes $\frac{3}{4}''$, $1''$, $1\frac{1}{4}''$, and $1\frac{1}{2}''$ diameter through plates $\frac{3}{4}''$ to $1\frac{1}{2}''$ in thickness. The shears have the same range of power for plates, and for angle irons, from $3'' \times 3'' \times \frac{1}{2}''$ to $6'' \times 6'' \times 1''$, and the driving gear in the largest sizes may be arranged either for being worked by belt or by an engine attached to the framing. For heavy operations, these machines have light iron jib cranes attached to them, that lift, and lower, and slide large plates into any required position, but for the smaller sizes, the attendants themselves do all that is required without such aid.

Some years ago an extended series of experiments was made to ascertain the actual dead load in tons required to cut bolts in single and double shear, and also to punch holes from $\frac{1}{8}''$ to $1''$ diameter through iron plates of the same thickness as the diameter of the punch, an abstract from the results of which is given as follows :—

SHEARING AND PUNCHING STRAINS.

Diameter of Bolt or Punch.	Actual D. L. Single Shear.	Sg. Stn. per square inch.	Actual D. L. Double Shear.	Sg. Stn. in tons per square inch.	Actual Punching loads in Iron Plates	Sg. Stn. on area of cut surface.
$\frac{1}{2}''$	$4\frac{1}{8}$	$19\frac{3}{4}$	$7\frac{1}{2}$	$18\frac{1}{4}$	22	28·
$\frac{5}{8}''$	$5\frac{3}{4}$	$17\frac{1}{2}$	11	$17\frac{1}{4}$	$33\frac{1}{2}$	27·4
$\frac{3}{4}''$	$8\frac{1}{2}$	$17\frac{5}{8}$	$16\frac{3}{4}$	$17\frac{3}{4}$	$47\frac{1}{4}$	27·
$\frac{7}{8}''$	12	$18\frac{1}{2}$	$22\frac{1}{4}$	17	$62\frac{3}{4}$	26·1
$1''$	$15\frac{1}{4}$	18	$28\frac{1}{4}$	$16\frac{3}{4}$	80	25·5

An ordinary punch may be regarded as a circular shearing blade whose length is equal to its circumference, and whose whole power must be put forth at once, instead of by the angular, or scissor-like action of a machine shearing blade, which is usually angled from 1 in 8, to about 1 in 12. The shearing strength of good iron or steel is generally allowed to be equal to about four-fifths of their tensile strengths, but in punching a hole out of a solid plate a little more pressure is needed. Hence we find by the above experiments that the strain per square inch of sheared area of punched holes ranges from $25\frac{1}{2}$ to 28 tons, instead of 18 to $19\frac{3}{4}$ tons for single, and $16\frac{3}{4}$ to $18\frac{1}{4}$ tons for double shear, as in the bolts.

If, for example, we now suppose a shearing blade 20″ broad to come down flatly upon a $1\frac{1}{2}''$ plate, it will have to put forth a power of $20'' \times 1\frac{1}{2}''$, multiplied by say 18 tons = 540 tons, before the plate can be severed. If, however, the blade is so angled as to allow 5″ of the plate to be cut through before another 5″ is entered upon, only one-fourth of the above, or 135 tons pressure, will be required to do the work. If, on the other hand, we take a punch having a circumference of 5″, we shall have, say, $5'' \times 1\frac{1}{2}'' \times 25\frac{1}{2} = 191$ tons, for perforating an iron plate $1\frac{1}{2}''$ thick.

This will clearly show the difference between the circumferential shearing power of a punch when acting upon a plate, and that of a shear blade whilst cutting a bar, or indeed anything else that produces similar strains upon the pin and bolt joints that ramify in every direction the details of machinery. From the above, and other experiments, we also discover the enormous resistance of hardened steel to crushing. The mean ultimate crushing resistance of wrought iron is allowed, by the best authorities, to be about 18 tons per square inch, cast iron 43 tons, and wrought steel 52 tons, but when we come to hardened tool steel there is a very great increase, as indicated by the fact that a punch 1″ diameter bears safely in *ordinary* work a constant pressure of about 80 tons.

Experiments upon the strength of materials will never be reduced to an exact science, from causes over which we have no control, but so far as punching and shearing are concerned, perhaps the available knowledge is sufficient for the purpose. The extent of that knowledge may be gathered from the fact that, since Fairbairn experimented for himself, the subject has been taken up by others in endless fashion. Hence the enormous amount of literature that has been published by learned societies and individuals upon the *Strength of Riveted Joints*—so enormous, indeed, as to lead us to wonder that so much could have been said and written upon such an apparently simple subject. It must be remembered, however, that the shearing powers of rivets in various combinations so permeate the whole domain of Mechanical Engineering, that the most complete information on this point is an absolute necessity.

These remarks are only intended to act as pointers to the scientific investigations of others, but simple as they are, they fairly indicate the basis upon which general practice is founded.

With the object of lightening the structure of steel clads and large steamers, without reducing their strength, and also of allowing their double bottoms to be cleaned and examined all over, numerous oval and circular holes are pierced in the frame plates, &c. Here, the Tweddell puncher of the Hydraulic Engineering Company, of Chester, with its prodigious power, becomes valuable, since by employing specially prepared dies, apertures up to 30″ by 21″ can be cut through 1″ steel plates at the rate of about seven per minute, the scrap pieces being worked up again in the forge.

None but those who have closely watched the progress of engineering events during the last few years can have any idea of the great advances that have been made in the Constructive Machinery of ship yards. This, however, is only natural when we consider the position now occupied by naval architecture through the building of gigantic war vessels costing about £1,000,000, and also of 10,000, 12,000, or even 14,000 ton steel built lightning racers of the ocean. All of which clearly indicate the necessity for employing machines of an extremely massive and costly description.

Punching and shearing machines are used in great variety, including those on wheels, or without wheels—Washer and manhole punching machines—Self-acting table machines, and Multiple punching for as many as 78 holes, $\frac{7}{16}''$ diameter, at one stroke, for ship and other tanks.

Besides the above, there are various "*Combination*" *Machines* for bending deck beams at least 10″ in depth, punching inch holes through 1″ plates, &c., and shearing $6'' \times 6'' \times \frac{3}{4}''$ angle irons, one of which, by Messrs. James Bennie & Sons, of Glasgow, has proved very useful. Larger sizes are sometimes used, either belt-driven or engine-driven, according to circumstances, and with most excellent results.

The machines, perhaps, of next importance in ship-yards, are those for bending, flattening, and otherwise setting the plates that form the shell as well as the other parts of a ship. This—like everything else—requires to be done to perfection to insure accuracy of workmanship, and suitable finish. As the aforesaid plates are bent *cold*, great power is necessary, hence the colossal bending machines that are now to be seen in some of the great establishments.

Not so long ago, about 12 feet was considered a good length for the rolls of such machinery, but now we are not content with even 30 feet, and, only recently, Messrs. Shanks supplied two machines, having rolls 32′ 2″ in length to Messrs. Harland & Wolff, for bending plates $1\frac{1}{4}''$ thick. We also saw one of about the same size at the Fairfield Works, which was fitted with an amount of heavy helical and other gearing that gave it a very massive appearance. For shipyards, as well as boiler works, such appliances are absolutely indispensable, since even the largest boilers are made cylindrical, and the shape of the outside plating of a ship is almost constantly changing from keel to upper deck, and from stem to stern.

A good example of a large *Plate Bending Machine*, by Messrs. Craig & Donald, of Johnstone, is shown in the adjacent Plate, which gives an excellent idea of what is needed for such purposes. The rolls are 22′ 6″ long, and are stayed in two places underneath to prevent them from springing when operating upon heavy work. The main driving engines have cylinders 12″ diameter, and the small engine, fixed to the framing for working the elevating gear of top roller, has an 8″ cylinder. It will thus be observed that the machine is under the most perfect control by steam power, and that as the top roller of 30½″ diameter is placed nearer, or further apart from the two lower ones, each of 19″ diameter, so will the radius of the curve in the plates be made smaller or greater.

Machines of this class perform an immense quantity of excellent work that cannot be accomplished in any other way, both in plate bending and angle iron curving, when required. They can be driven by belt-power in the medium sizes, or by hand-power in those of still lesser degree, or by hydraulic agency as in the peculiarly shaped keel plate, or garboard strake benders. They can be made to produce skewed curves in plates, especially for the ends of ships where the lines rapidly become finer. They can also be enabled to produce tubes for masts, &c., of different sizes if one of the standards is made movable. In this case, however, the end elevating gear must be driven by independent hand wheels, instead of by simultaneous lifting screws. For the heaviest boiler

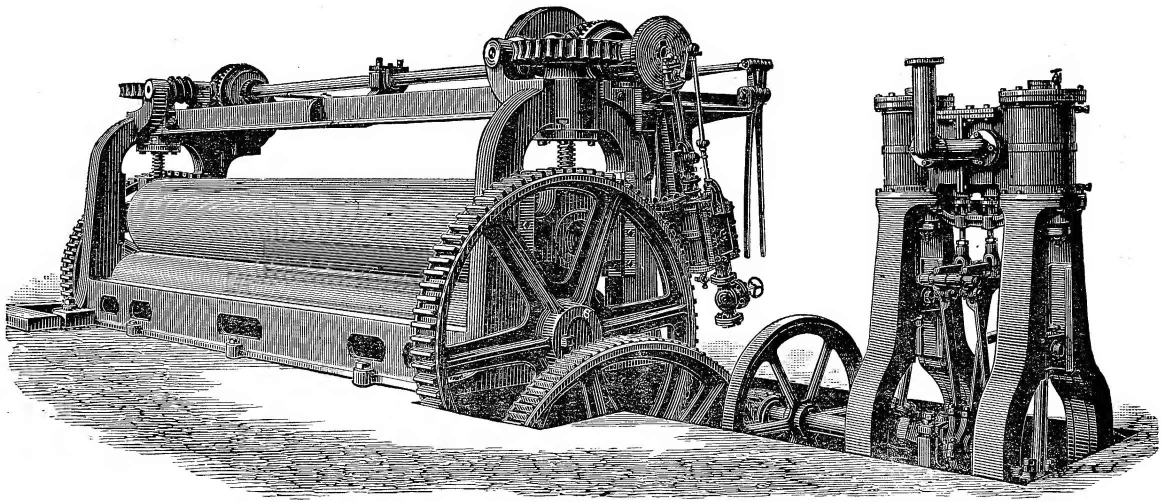


PLATE BENDING MACHINE.

plate bending operations the above firm considers it preferable to place the rolls *vertically*, and work them by means of separate engines, with suitable gearing on the bed plate, and also above. When this is the case, the machine is triple-geared, and has two different speeds to suit the manipulation of light and heavy plates. It will thus be seen that the most modern innovations of this class have a range of power and general usefulness that, until recently, it was not necessary for them to possess.

A well known branch of the same family, though not employed in the same way, is the *Plate Flattening Machine*, which also serves a very useful purpose. Everyone who knows the difficulty of making large and thick plates true and fair by the hammering process, after being warped perhaps by harsh usage in transit or otherwise, will recognise the value of the Patent Five-roller Plate-straightening Machine, made by Messrs. Craig & Donald for the Fairfield Works, which is shown on the opposite page.

In this case steel plates up to 8′ 0″ wide and $1\frac{1}{2}''$ thick are passed between two sets of rollers, the upper of which can be vertically adjusted, and both together made capable of levelling down all irregularities that may exist. It is this feature that constitutes the true value of the operation, especially when it so greatly facilitates the building of vessels of all kinds whose upper sides amidships have no curves, and whose bulkheads, tanks, and decks, employ a very large quantity of similar plating.

In the works we are now describing, the next points of interest are the *Plate-edge Planing Machines*, which occupy a conspicuous position. As previously remarked, the Rolling mill people shear their plates to the sizes sent to them by the builders, to allow for the trueing up process that is so effectually performed by machines

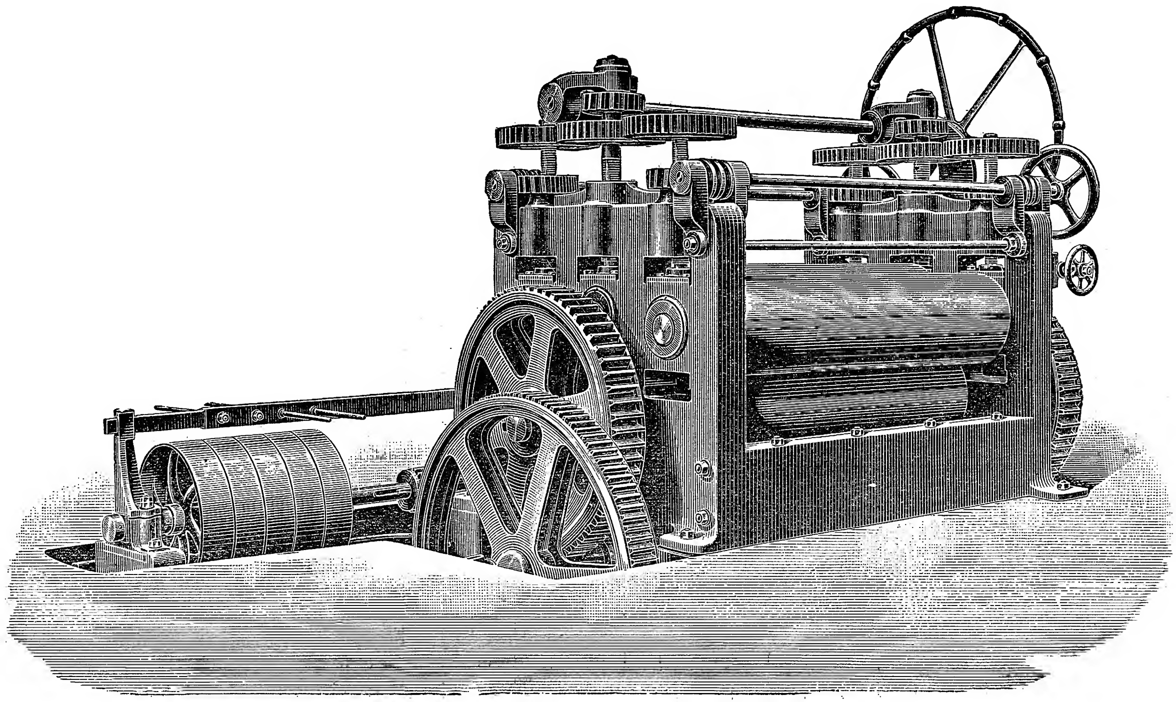


PLATE FLATTENING MACHINE.

similar to, but much larger than, the one illustrated in the chapter upon Messrs. Galloway's establishment.

The top girder of one of these machines carries $2\frac{1}{2}''$ diameter steel screws, with enlarged lower ends for fixing the plates that may be laid on the table. This contains rows of small square holes, so that similarly shaped wedges may be driven into them, thus giving an immovable lateral support to resist the heavy strain of the cutting tool. A much quicker method of effectually fastening the work when water power is at hand, is to substitute small hydraulic rams instead of the above, as at Fairfield, and other establishments, where the latest improvements have been recently introduced.

The square threaded steel guide screw $4\frac{3}{4}''$ diameter, is driven by the end gearing at a speed to suit the cutting tool. And as the latter is placed in a revolving, and variously adjustable holder, it is not only enabled to act during the return stroke, but to produce bevelled as well as square edged plates when required. The tool itself is at the same time so formed with a broad and strong flat edge as to take a cut each way the whole depth of the plate, even if it should be 2″ thick. The reversal of the driving gear is effected by means of a self-acting arrangement, which also enables the workman on the travelling platform attached to the tool slide to reverse the cut at any point without previous adjustment.

These machines are sometimes fitted with a right angled extension, so that the *ends* of a plate can be planed simultaneously with the sides, and although the main longitudinal traverse of cutting tool may be as much as 40 feet, a travel of about 24 feet is the ordinary limit.

Another popular machine employed in shipyards is that for *Scarph Planing* the ends or corners of the plating, so that the joints may overlap each other with the greatest smoothness. As this machine, however, bears a strong resemblance to the large Shapers previously referred to, nothing more need be said about it.

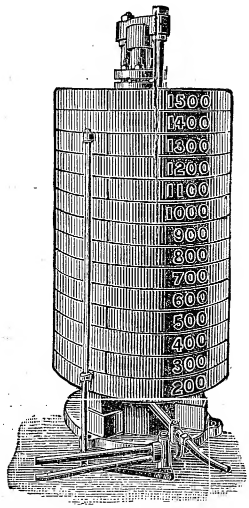
For Keel plate bending, and Tank plate flanging, and also for a few stamping operations, a great amount of labour is saved by the use of special *Plate Flanging Machines*, such as those used in many works. These appliances are very simple and effective, and are much employed for flanging the plating of tanks previous to riveting, instead of securing the sides, tops, and bottoms to each other by angle irons.

A most powerful bender of the latest design, by Messrs. Hugh Smith & Co., of Glasgow, has recently been added to the Fairfield collection, for the purpose of bending cold steel keel plates up to 31′ 6″ long, by 5′ 6″ broad, and $1\frac{1}{8}$″ thick. The machine is worked by hydraulic power, and is fitted with separate engine, pumps, accumulator, and jib crane, whilst its total weight is about 150 tons.

With the object of showing how this power is generated for ordinary purposes, we give an illustration of a *Self-Contained Accumulator*, by Messrs. H. Berry & Co. The guides for the sliding pullies are cast on the ram cylinder, the crosshead of which is seen above, and thus the weights are prevented from turning round. Automatic engine starting and stopping gear is also fitted for regulating the supply of water to the ram in working.

Suppose, for example, that the plunger of a vertical pump has a sectional area of 100 square inches, and that its weight is 2,000 pounds. It is evident that before the plunger can move upwards, a pressure of, say 20 pounds per square inch must be given to it. If its top end is now loaded progressively with weights of 1,000, 2,000, 3,000 pounds, and so on, the pressure will be correspondingly increased to 30, 40, 50, etc., pounds per square inch in the ram cylinder.

This principle is applied to the aforesaid *Accumulator*, but with so great an increase in the loads that its plunger may be enabled to give any desired pressure in the pipes leading from it, such, for instance, as 1,500 pounds, which

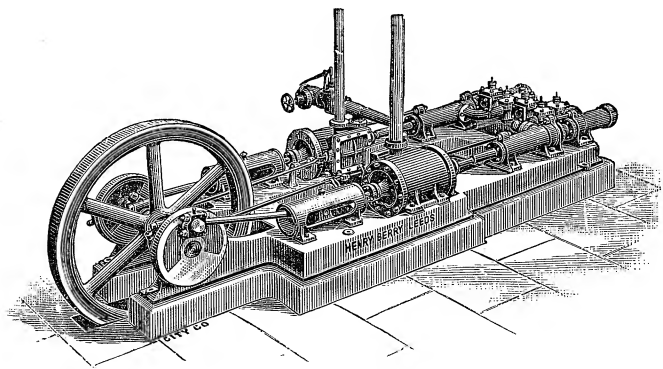


SELF-CONTAINED ACCUMULATOR.

is generally used for shipyard machinery. For special purposes, however, from 3,000 to about 8,000 pounds is sometimes allowed, but in these cases the working parts must be of immense strength. Cold drawn seamless steel tubes are here very usefully employed, and according to tests by Sir Joseph Whitworth & Co., for the Credenda Company, of Birmingham, we find that while tubes as above, $1\frac{1}{8}''$ outside, and $1''$ inside diameter, burst with 4·6 tons pressure per square inch, others similarly, $1\frac{1}{16}''$ and $1\frac{7}{16}''$ diameter, gave way with 5·3 tons.

It will be noticed that each layer of weights is so marked, that by removing them from the top the remaining pressure can be at once known.

The annexed view forms a good example of a popular type of *Hydraulic Pumping Engine*, by Messrs. Henry



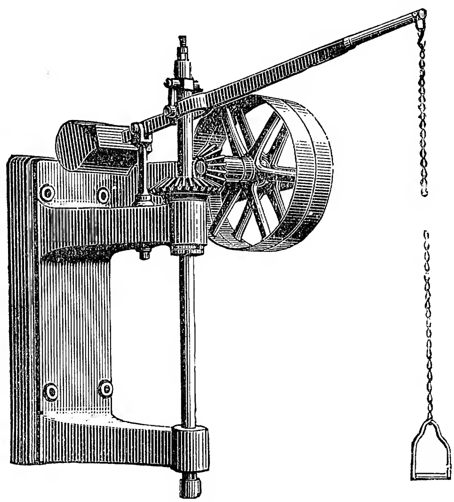
PUMPING ENGINE.

Berry & Co., having steam cylinders 20″ diameter by 24″ stroke, and rams $6\frac{1}{2}''$ and $4\frac{1}{2}''$ diameter. It may be observed that when the accumulator barrel is fully charged, the engines stop of their own accord, until some of the water is drawn off in working the various machines of the system, but after the limit is reached, they start again with more or less rapidity, according to circumstances.

Thus far, we have proceeded with the constructional details of a steel built ship. We have laid the keel, and punched, bent, and set up the frames in position. We have planed and punched the plates, and sheared everything that required shearing, and now we wish to prepare the holes for the rivets that are intended to fill them—internally with their heads exposed, but externally flush with the plating, to enable the future vessel to pass through the water with the least resistance.

Another reason for this is the ease with which a ship's bottom so treated can be cleaned and painted after a long voyage. Various compositions are used for the purpose of protecting the plates from corrosion, and also from the fouling properties of different kinds of animal and vegetable life existing in the sea, that sometimes greatly reduce a ship's speed. These must all be carefully scraped off previous to painting when a ship is in the dry dock, and hence it will be seen that projecting rivet heads would be most objectionable.

This flush riveting is easily attained by the simple process of *countersinking*, through the use of a *Wall Drilling* apparatus such as that by Messrs. Francis Berry & Sons, shown in the annexed view, which is employed



WALL DRILLER.

in externally tapering the rivet holes of the shell plates. The machine may be fixed vertically to any suitable support or beam. The diameter of the spindle is 2½″; the depth of feed 8″; and distance from centre of spindle to wall 3′ 6″. The rise and fall of the drill spindle can be actuated by treadle levers below when required, thus allowing the workman the free use of both hands, and also by the simple hand lever as shown. Amongst recent innovations may be mentioned an improved method of countersinking, by means of which the labour of shifting heavy plates at each hole is abolished.

The engineer's drilling machine is but little used in shipyards, as the Puncher is so all-powerful, but even at the best it cannot manage keel bars, or stem and stern posts, because they are too thick for a punch to cut through. The holes in these for securing the plating must therefore be bored, and here Messrs. Craig & Donald's *Keel Bar Drilling Machines* become useful.

As we have described and illustrated the Radial drillers in a former chapter, they need not be reproduced here, even in an altered form. Perhaps, therefore, it will be sufficient for the reader to imagine three of Messrs. F. Berry's Wall Radials placed in a row, with their swinging arms pivoted on strong cast iron columns, bolted to a bed-plate to which three rollers are attached, and over which the keel bar is easily moved. The above arms and their spindles are adjustable in every direction, and although independent of each other, they are nevertheless actuated by one main shaft driven by a belt as usual. These machines have no great range of size, but they can be variously modified by increasing or decreasing the number of radial arms. The table may also be altered, so that extra thick ship plates up to 24 feet by 6 feet can be drilled at one setting.

The keel bars referred to are made in lengths as great as circumstances will admit, to reduce the number of joints, which are of the "scarph" description. These are planed and adjusted carefully to each other, so that when the keel is laid in position on the blocks, and the lengths riveted together, it will be perfectly straight from end to end. When this is done, the frames are set up, and the growth of a steel-clad to cost, perhaps, £1,000,000, or a colossal ocean racer, at once begins.

It may not be generally known that beneath the beautifully white deck planks of a Royal ship, there lies an immense quantity of thick plating, which acts primarily as a protection from shot, and secondarily as a means of binding the structure of the vessel in the strongest possible manner. In mail liners, a similar system is employed, though with necessarily much thinner plates, but in many cargo ships the deck plating is used alone without the timber covering. This, we may observe, is an economical arrangement, and for rough usage perhaps better than the former, but for other reasons it is much to be regretted. It is unsightly and uncomfortable, especially in the tropics. It is rusty, and difficult to keep clean. It is a very cold or a very hot covering for those below, and in every respect the *naked* iron or steel deck might well be dispensed with.

The external plating of a ship is put on in longitudinal strakes of different thicknesses according to their position, and the butt straps are invariably on the *inside*, so that the outside may be smooth and true. In some of the latest steamers, however, lap joints are very successfully employed, as they can be made to present no resistance to the water.

When we consider that not only the above, but the plating for the deck, and the ironwork for bulkheads, stringers, keelsons, tanks of all kinds, etc., have to be carefully machined in some form or other, and put together and riveted up, we shall have a good idea of the enormous amount of high-class work that has to be performed in a short time, and also of the gigantic resources of establishments such as the Fairfield Works.

When large contracts are in hand, involving the construction of ten or twelve ships of various sizes, including a few mail and other liners of six, eight, or ten thousand tons, two or three ironclads with all their massive complications, and one or two swift river steamers to fill up the corners of the yard, there is a great strain thrown on the whole establishment. And were it not for the machines we have described, as well as others to be mentioned later on, aided by a thorough system of management in every department, the execution of extensive orders would at once become quite an early nineteenth century performance, instead of what it is.

Many of the machines now so well known were in a very imperfect state forty years ago. Their present excellence, however, is due to the vigilance with which engineers have continuously noted every new invention and *real* "improvement," no matter how small, and evolved something that would effectually meet the requirements of changing practice. This has been accomplished, firstly, by the practical or trial and error process, and secondly, by the blending of practice with advanced science, so as to produce the happiest results in the most extended form, and on the most colossal scale.

CHAPTER X.

SHIPYARD MACHINERY—*continued.*

Origin of Hydraulic Shipyard Machinery—Hydraulic Riveting—Its various Applications—Fixed and Portable Machines—Punching and Shearing—Boiler Flanging, &c.—The System as a whole—Hydraulic Engines—Ship Side Drilling—Flexible Shaft Gearing—Applications of Hydraulic System to Steelclads—Rivet Manufacture—Steam Hammer and its Improvements—Its numerous varieties—Compound Steam Forging Press—Forgings to be Machined—Stamping and Smithing Processes for Finished Forgings.

Since the introduction of the Steam Hammer, nothing has so much altered the conditions under which iron and steel structures are put together as the *Hydraulic Machine Tools* invented by Mr. Ralph Hart Tweddell, C.E., of London, which are now universally known. It has been well said of this system, that its riveting machinery revolutionised the conditions under which ships, boilers, bridges, and similar engineering undertakings were formerly constructed, thus saving immensely the cost of labour, and greatly improving the quality of the work.

It was steamships and their machinery that twenty-five years ago drew the attention of Mr. Tweddell—then a pupil of Messrs. R. & W. Hawthorn, of Newcastle—to hydraulic machines, and the first of these he designed was a portable one for rapidly and efficiently fixing marine boiler tubes in their places, under a water pressure of 1½ tons per square inch, which was conveyed to it in unique fashion through a spiral and flexible copper pipe.

Upon the introduction of high pressure steam, much difficulty was experienced in making the riveted joints of marine boilers sufficiently tight, as the plates had become too thick even for the steam riveting machines in general use. Mr. Tweddell was, therefore, led to consider the practicability of using *hydraulic* power for the purpose of overcoming the difficulty, and, in 1865, he designed his first stationary hydraulic riveting machine, which was at once adopted by Messrs. Thompson, Boyd & Co., of Newcastle, who soon found that it produced absolutely perfect work at one-seventh of the cost of hand labour. This encouraged the inventor to design other kinds of riveting machinery, and, eventually, special hydraulic tools for forging, flanging, punching, shearing, and drilling, also many labour-saving appliances, such as cranes, etc.

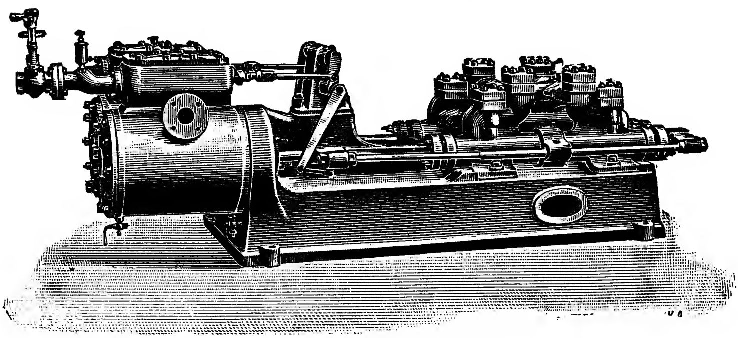
When these stationary riveters were first used by Penn, Humphrys, Maudslay, Elder, and others, their maximum pressure of 40 tons was exerted six or seven times a minute. But as ship-builders, bridge-builders, and others discovered that when work was ready for riveting it was too heavy to be taken to the machine, Mr. Tweddell invented, in 1871, the *Portable Riveter*, which has proved invaluable, as its weight of only three or four hundredweight enables it to be easily carried about, and yet its power is sufficient to exert a pressure of 50 tons nearly ten times per minute. By means of a system of articulated pipes, the water is transmitted from the mains at pressures of 1,500 to 2,200 lbs. per square inch, without disturbing a single joint, whilst the machines can be applied at any desired point in a space of 30,000 to 40,000 cubic feet.

About sixteen years ago many well known people adapted this system to the riveting of frames, keels, sheer strakes, beams, engine seatings, etc.—there is, however, much still to be done, but experience subsequently showed that the extended success of the system greatly depends upon the manner in which the overhead lifting gear of shipyards is arranged. This suggestion has been utilised on a very complete scale by one of the leading American firms, and partially by many others.

Bridge construction has some features common to shipbuilding, and, therefore, since the first bridge was riveted together *in situ* by Mr. Tweddell, in 1873, all those of most importance on the Continent, and in India, America, and Australia, have been similarly treated by his hydraulic machinery. To no one were these advantages more prospectively visible than to Messrs. Fielding & Platt, of Gloucester, who, in 1871, undertook the manufacture of the *Portable Riveter*, after others had declined to do so, although installations of the various *Stationary* machines referred to had already been extensively introduced into many of the leading engineering and Government dockyard establishments at home and abroad. Since that time, the above firm and Mr. Tweddell have unitedly developed improvements which have now almost perfected this class of machinery.

The general principles which govern the transmission of hydraulic power are so well known that no reference need here be made to them. So far, however, as the pumps are concerned, it may be said that for small applications they are usually of the two or three throw description, driven by ordinary belting; but for large installations it is found more convenient to employ *Steam driven Pumps*, of the Duplex type, similar to those adjacently shown. Each working barrel is divided by a diaphragm, so that there are really *four* plungers, thus insuring a very steady delivery of water to the *Accumulator*.

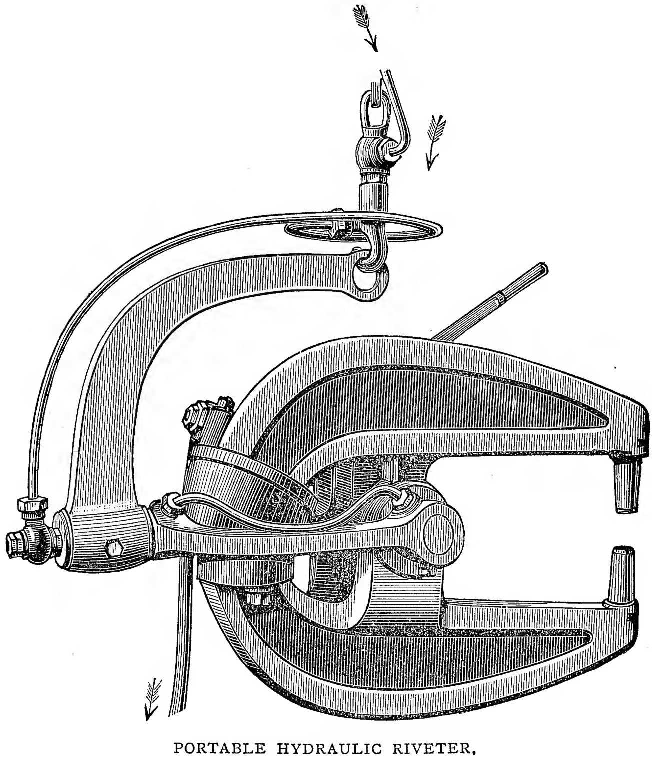
This last-named appliance is most essential; firstly, as a means of efficiently storing high pressure water to be drawn upon at any moment for driving purposes, without waiting for the required supply from the pumps direct. And, secondly, as a means of securing a uniform pressure



DUPLEX STEAM PUMPING ENGINE.

which can easily be reduced at any time if desired, by simply removing some of the weights with which the ram is loaded. From this point a suitable main pipe is led, having branches conveniently attached for working the various machines of a system, even if they should be miles apart.

For marine purposes, *Stationary Riveters* sometimes assume colossal proportions, as may be expected when boiler shells have become so large and so thick as to require the application even of 150-ton force before good work can be obtained. At present, however, these machines are quite equal to any demand that may be made upon them, but as a means of economising water in such large tools, *Intensifiers* are employed which have proved most beneficial. As a rule, these machines are made with three separate powers, so that by simply

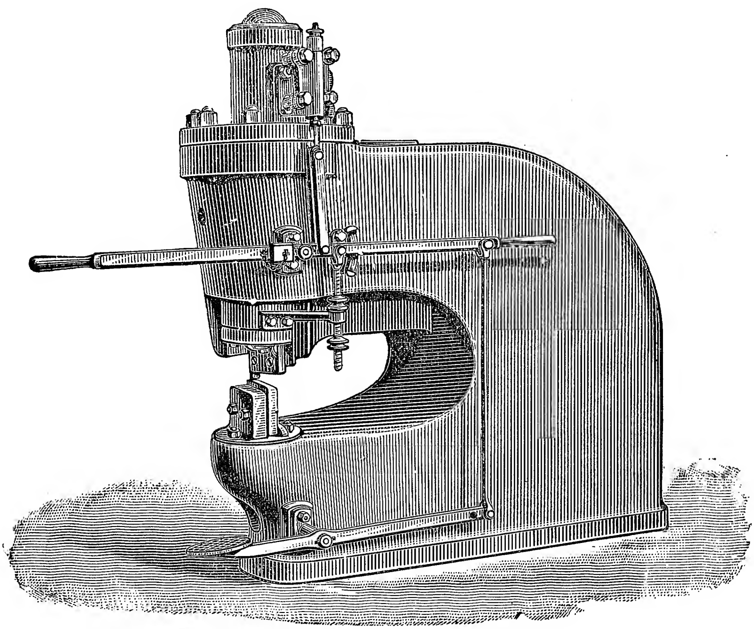


PORTABLE HYDRAULIC RIVETER.

shutting off the pressure from different areas, plates of various thicknesses can be operated upon with a proportionate expenditure of water.

The chief difference between these riveters and others is the application of hydraulic power direct, in place of steam, with its attendant gearing, as mentioned in the

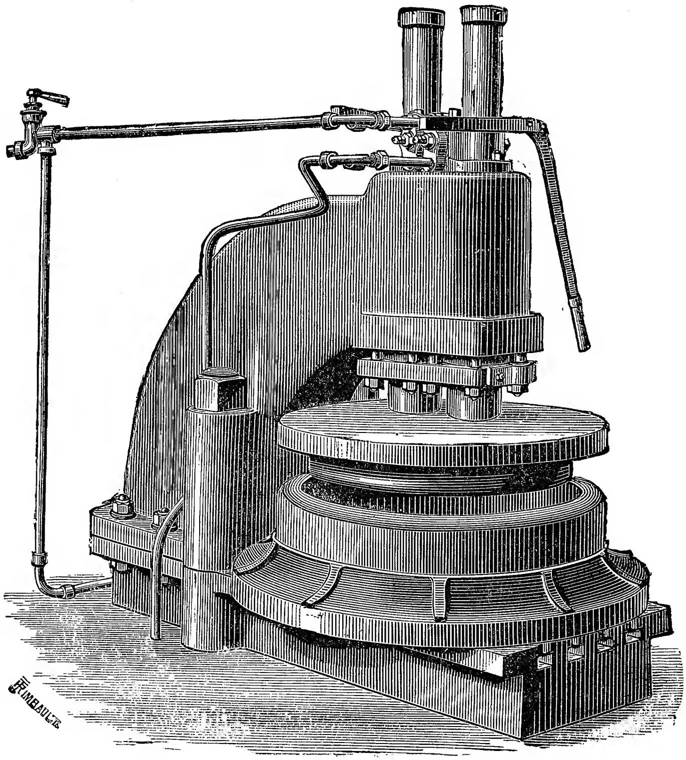
"Galloway" chapter. In those of the *Portable* class, however, an entirely new departure was made, involving the application of many novel mechanical devices, which are only partially shown in the annexed illustration. These last-named riveters have enabled a large amount of work to be done *in situ*, and can also be provided with double or treble power, as previously mentioned, which adds



HYDRAULIC SHEARING MACHINE.

greatly to their usefulness. As will be seen in the view, this riveter is not only capable of being swivelled in every direction, but by means of its suspending gear can be traversed all over a large area by a light overhead travelling crane, or by a jib-crane on wheels, or otherwise; whilst the lifting and lowering of the apparatus is provided for by the flexibility of the spiral copper tubes conveying the water power. Hence the frames, keel, and other parts of a ship, or any other work, can be finished off with ease in almost any position.

In *Punching and Shearing* machinery the hydraulic system has proved most useful, on account of its great



HYDRAULIC FLANGING PRESS.

simplicity, and the ease with which concentrated pressures of great intensity may be delivered without the aid of cumbrous gearing. This will be to some extent understood on reference to the adjacent engraving of one of Mr. Tweddell's single-ended machines, which does not need description. It may be added, however, that those of the double-ended design are preferred, as they can be used for punching, angle iron and plate cutting, or, when slightly modified, to the perforation, at one stroke, of manholes up to at least 30″ diameter, and ovals 27″ by 22″ in steel plates ½″ to 1″ thick.

For minor flanging purposes machines have been variously designed; the annexed view, however, gives a good idea of what is required for marine boiler furnace mouths. The *Progressive Flanger* is another type very extensively adopted. In it the bending dies and blocks usually employed in other presses have been discarded, as so many of them were required to meet the different sizes of boilers, and also on account of their great weight and general unhandiness. This press imitates as closely as possible the action of hand flanging, and produces excellent work. It is therefore largely used as a rapid and most efficient *Boiler-end Plate Flanger*, and is considered one of the greatest novelties. We may further state that Mr. Tweddell has recently introduced a very successful hydraulic *Bender* for curving the thickest boiler-plates, and that his *Hydraulic Forging Presses*, of the single frame steam hammer type, are extremely popular.

The origin, and development of this system from its initial stages, its storage of power, and distribution of the same, also some of the machines actuated by it, and their effect upon shipyard and engine constructing economy, have thus been very briefly sketched out. Much more might be added if space permitted, but what has been said will clearly indicate the immense value of a system that has proved so universally beneficial, and won for its inventor the most distinguished success at home and abroad.

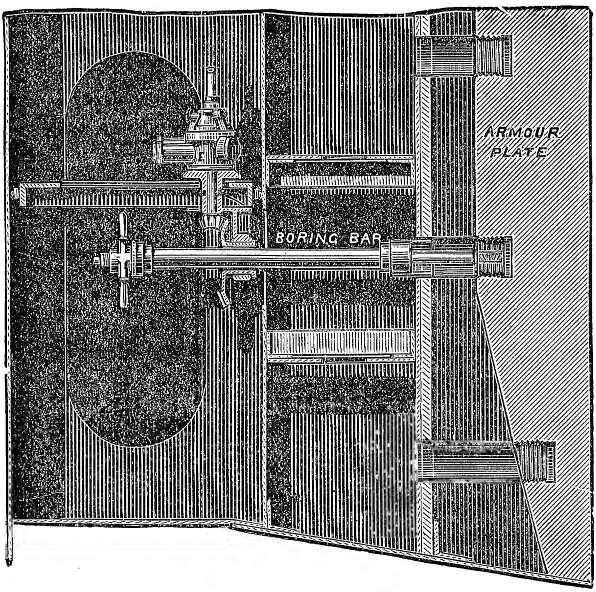
For some years past a large amount of drilling and hole cutting in ship's plating has been done in ship and boiler yards, and elsewhere, by means of portable machines, made by the Hydraulic Engineering Co., of Chester, in which a three cylinder engine is employed for driving the drill direct. The whole apparatus only weighs from 60 to 70 pounds, and can be used in connection with an ordinary ratchet drill head. There is therefore no difficulty in attaching the gear to a ship's side, while the speed of working, on the average, is nearly 10 to 1 in favour of hydraulic boring. The stability of the machine, when in operation, depends only upon two bolts, by means of which it can easily be secured in any required position.

In the other application of the gear, the drill head is still lighter, as the power is transmitted from a separate engine by a "Stow" flexible shaft, which is capable of working in the most out of the way places, such for instance, as the inside of a boiler, or the interiors of the numerous crevices that are to be found in ships. It can also be used most effectively upon the outside plating, whilst being held in position by very rough and ready supports of the most temporary nature.

In addition to the advantages obtained by the more accurate execution of work by the above system, especially when several thicknesses of metal have to be bored in position, there is the great saving in labour by not having the plates, &c., to mark off, take to the shop, and return when drilled. And it may be added, that the experience gained by the use of these machines in large ships built on the cellular principle, including those supplied by Mr. Tweddell to the Elswick Works for iron-clad construction, leads us to infer that no shipyard should be without them.

The little drilling machines mentioned above were designed and patented by M. Berrier-Fontaine, and are now extensively used in the dockyards of Brest, Toulon, and Cherbourg, and by different Governments, and numerous private firms.

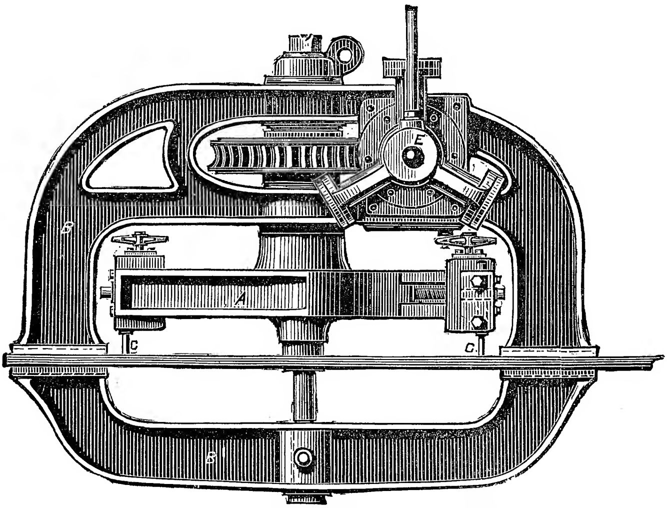
A still further application of the system is exhibited in the adjacent view of a small portion of the side of *H.M.S. Victoria*, while building at the Elswick yard. The



ARMOUR-PLATE DRILLING ON SHIP'S SIDE.

engraving shows the armour in position, and a portion of its interior backing, etc., which, although greatly limiting the space for practical operations, did not prevent the hydraulic apparatus from performing all that was required with great ease and efficiency.

The other view represents a machine for cutting out circular openings in ships' decks, also side lights, etc., from 15″ to 30″ diameter. All the gearing is self-contained, and of easy adjustment, and, if desired, can be arranged to cut oval as well as circular holes, not only on board ships, but in the plates themselves in any part of the yard, thus saving much room in the shops, and also unnecessary transport of heavy material. For similar purposes a very simple portable machine by Mr. Lyall, of Glasgow, has long been popular. It can be driven either



HYDRAULIC MANHOLE CUTTING MACHINE.

by hand, or by belt, or by rope power, and is made in sizes capable of cutting holes from $7\frac{1}{2}''$ to $36''$ diameter, and oval openings from $9\frac{3}{4}''$ by $5\frac{3}{4}''$ to $39''$ by $33''$.

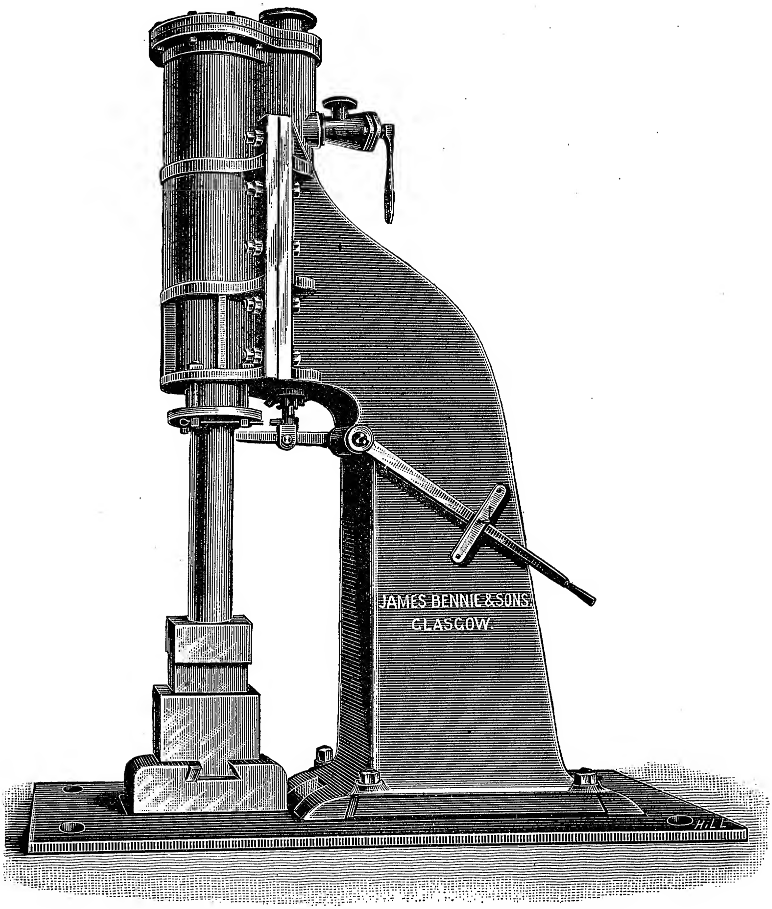
The sides and interior of a ship before the plating is finished have so many punched holes in them that they resemble gigantic sheets of perforated postage stamps. To bind the whole structure securely together, enormous quantities of rivets have therefore to be used, the manufacture of which forms an important branch of industry. In works such, for instance, as those of the Clyde Rivet Company, of Glasgow, rivets of all sizes are made in millions by special machinery, which enables large Admiralty and other contracts to be executed with great rapidity. These rivets are made of steel and iron of the best quality, and have to undergo the usual rigid tests before being officially "passed." Immense quantities of bolts and nuts are also made by the same firm, and these, too, enter most extensively into Shipbuilding and Engineering work of an infinitely varied character.

Whilst the steamer "Great Western" was being built at Bristol, in 1838, the manager of the works endeavoured to get her enormous paddle shaft forged by various firms, but without success. Upon pointing out this to Mr. Nasmyth, that gentleman pensively pondered over the peculiar phases of the perplexing position, and rapidly evolved a rough design for the famous *Steam Hammer*, which has rendered practicable things that were previously impossible. In the early hammers, the double framing limited the operations of the workmen, the moving block and piston were raised by steam, but allowed to fall by gravity alone, and, finally, the valve gear was complicated and heavy.

Practical men noted these defects, and in 1854 Mr. Rigby, of the Parkhead Forge, Glasgow, invented and patented an arrangement embodying several important improvements, the rights to which he transferred to Messrs. Glen & Ross, of the same city. This firm designed and applied to the above hammer an equilibrium piston valve, which, by means of a simple hand lever, not only intensified the force of the blow, but put any size of hammer under the most easy and perfect control of the operator, by taking the steam from the under side of the piston after it had been lifted, and using its full pressure above it to increase the rapidity of the blows, and at least quadruple their energy. This valuable modification quickly secured the general introduction of the engine to the forge and smith departments of engineering and shipbuilding establishments.

The above mentioned firm also introduced the system of fixing the cylinder of the hammer to a single box column, instead of the bridge framing previously in use. This made the engine so compact, and accessible to the workmen, as to increase very greatly its popularity. The Rigby steam hammer, of various designs, has been most extensively employed by the British and Foreign Governments, and by numerous private firms for many purposes, including ordinary forging, shingling, wheel-bossing, steel-working, etc.; whilst in its smaller sizes, it has been largely applied to stamping, general smith's work, and boiler flanging.

Amongst the various firms who now undertake the manufacture of similar hammers are Messrs. James Bennie & Sons, one of whose productions is shown on the opposite page. The head is of cast steel securely fixed to the piston rod, but when required it can be forged on. The sizes range from three to forty hundred weight, which is about the largest used by shipbuilders, and when it is considered that the weights given only represent those of the piston, piston rod and hammer head, it will be seen that the force of the blow is enormously increased by the steam pressure previously referred to. From this it will be evident that the concussion caused by the working of heavy hammers must be very great, so great, indeed, that the Woolwich Titan is said to shake the ground for a considerable distance all round.



STEAM HAMMER.

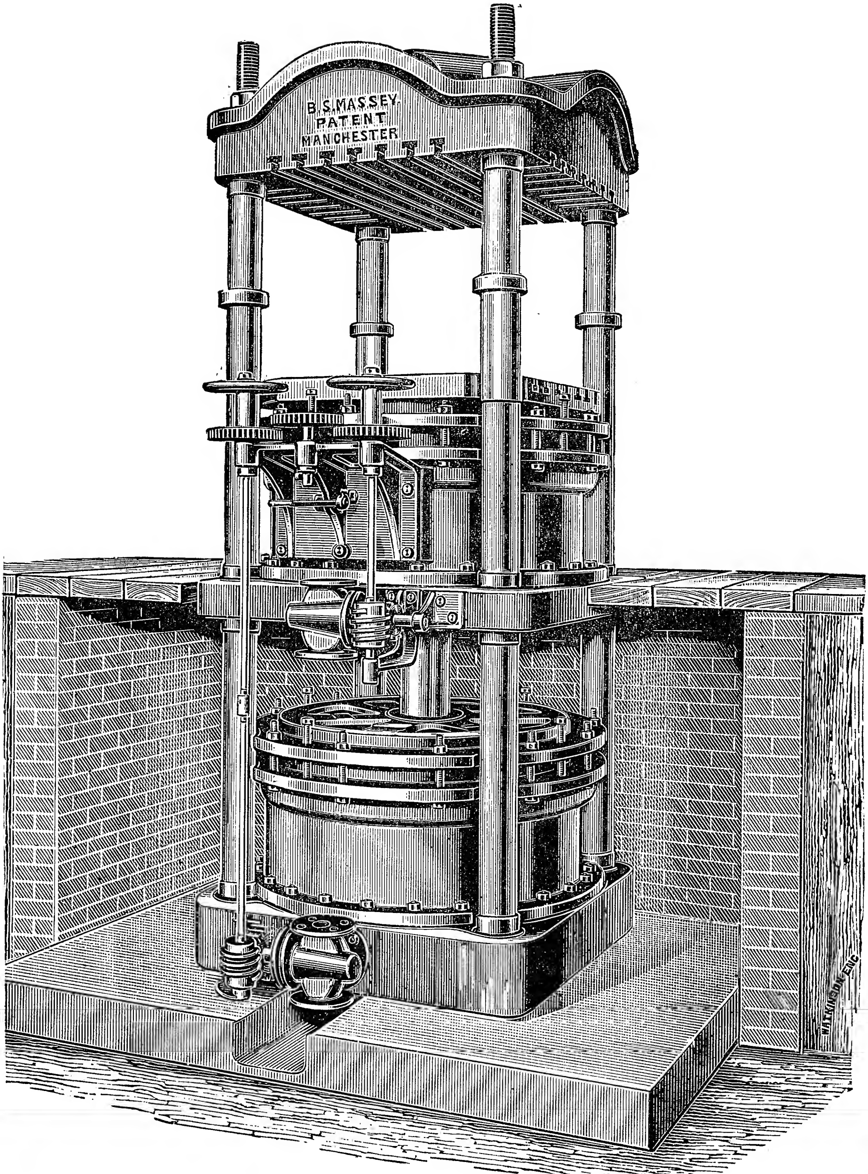
The special and other kinds at present in use are multitudinous. There are hammers with, and without slides; heads that are fixed or movable; anvil blocks with similar variations; machines that are either hand or foot lever geared; B. & S. Massey's "Improved Rigby;" hammers with speeds varying from the stately movements of the Demon Crushers, to 300 or 400 strokes per minute in those of small dimensions. Then we come down amongst the stamping or forging appliances driven by belts at the rate of 500 to 800 strokes per minute, and here we approach a class that is absolutely invaluable for performing with great rapidity an enormous amount of small repetition work. In short, the range of power and application of this description of machinery is now so great as to be almost beyond belief. Some idea may be formed of the dimensions of the new engine at Bethlehem Iron Works, Pennsylvania, from the fact that the total weight of the steel and iron used in the anvil block and its foundations is about 1800 tons; whilst the piston-rod, piston, and hammer head alone contain 125 tons of metal, having a total fall or blow of 16′ 6″.

In conclusion, it may be said that the Steam hammer owes its present state of perfection to a series of fortuitous circumstances. A practical engineer in Bristol discovered a need for it. Another at least equally practical at Patricroft, originated the design for it which he developed with the utmost success. The commander-in-chief of a great Forge in Glasgow made valuable improvements which, in connection with those of an engineering firm of the same city, perfected the engine, and made it so beautifully simple and efficient as to cause indirectly the enormous extension of the manufacturing and travelling resources of the world, and through them, unlimited benefits to the human race.

After everything had been done to develop the steam hammer to the utmost, it still proved incapable of making the heaviest forgings sufficiently sound internally. Hence its percussive action has in some cases been superseded by the more powerful and steady force of six, eight, and ten thousand-ton hydraulic presses.

These gigantic engines have proved very acceptable in many ways, but when comparatively moderate squeezing force is needed, an admirably arranged *Patent Compound Steam Forging Press* by Messrs. B. & S. Massey, of Manchester, will be found useful. In this machine, which is shown on the following page, there are two cylinders of 49⅛″ bore placed one above the other, the lower one having its piston rod working through the upper one, and when both are in operation with 60 pound steam, the pressure given out is equal to 100 tons. This, however, may be doubled or trebled if required by simply increasing the steam pressure. The table has a vertical travel of 12″, and is provided with T grooves for fixing dies, and other appliances.

One of the main objects of this press has been to introduce a comparatively inexpensive arrangement possessing the advantages of the more elaborate hydraulic machinery, while saving at the same time the cost of engines, shafting, pumps, and specially strong water pipes. For general purposes it is capable of rapidly producing a variety of details, including large bolts, levers, joints, handles, &c., and also flanged work in steel or iron, such as steam hammer standards, base plates, cylinder covers, &c., in the most perfect manner. The valves are so arranged as to allow either one or both pistons to be worked at the same time, thus enabling single or double power to be exerted as required. And although the table and top frame are shown without any die blocks, these



COMPOUND STEAM FORGING PRESS.

can be variously applied according to circumstances for either light or heavy forging.

It is frequently unnecessary to put much expensive labour upon smiths' work, on account of the powerful lathes, etc., now used in finishing what may only have been roughly allowed for in the forge. But when such details are not to be tool finished, the highly developed powers of the rolling mill and steam hammer will make everything accurate enough for the purposes intended. Frequently, too, it happens that some things are partially stamped either by steam or by hydraulic pressure, and the finishing touches put in by the smith without any allowance being made for turning, planing, etc. This, however, chiefly refers to work for the rougher parts of engineering structures.

Smithies, or Forges, prove invaluable acquisitions to any establishment, but, unlike the pattern making, machining, and erecting departments, the apprentices are not allowed to practice in them, nor indeed is it necessary to do so. A good knowledge of such work, however, incidentally obtained, is most desirable, as it enables the engineer to avoid unnecessary costliness in design, and other defects too numerous to mention.

CHAPTER XI.

WOOD-WORKING MACHINERY OF SHIPYARDS.

Conversion of Timber from Rough to Finished State—Ancient and Modern Machines Compared—Complete Set for a Shipyard—Monarch Machines—Log Sawing Process—Band Sawing of Heavy Timber—Circular Sawing Machinery—Log Trueing-up and Planing Machines—Mortising and Tenoning Machines—Universal Advantages of Good Wood-working Machinery—Economy of Standard Sizes in Timber—Utilisation of Waste Cuttings—Motive Power of the Works—Fairfield Works as a whole—Colossal Sheer Legs.

THE conversion of timber from the rough state into finished material ready for fitting into the interior of vessels forms a considerable part of the daily work of shipyards. Not only is this the case with the ordinary woods used for constructional purposes, but also to a great degree with those of a more valuable character for internal embellishments. To enable the various operations to be carried out, a considerable portion of the works is occupied with sawmills, and joinery and cabinet making shops, in all of which *Wood-working Machinery* of the best description is all important.

In some of the famous establishments bearing the stamp of modern antiquity, there are still to be found a few specimens of very old-fashioned machines, that show by their architectural framings, and other similar but most inappropriate adornments, that they belong to a by-gone age, and form a striking contrast to the elegantly designed and massively constructed gear of the present. Only recently, whilst visiting one of the above, I saw two or three specimens of these good old faithful servants who had been in the employ of the firm for something like fifty years, and had helped their proprietors on to fame and fortune.

A large lathe especially attracted my attention, as it was one of the most interesting relics of ancient times I had ever seen, and this was all the more marked as close beside it they were planting a new and splendid specimen of one of Messrs. Harvey's powerful turning and boring machines. In many of these grand establishments that were perhaps originated amongst the "thirties" or "forties," we find similar remnants of machines that have been gradually weeded out, until probably only one or two remain to serve as landmarks in history, which it would be ungrateful to part with.

To wood-working mechanisms these remarks are quite as applicable, as so many new labour-saving appliances of this description have been introduced during recent years, that skilled manual labour has threatened to become in time a lost art. And while the greatly extended use of other machines has brought about sweeping changes in the iron departments, it is equally true that some of the most revolutionary innovations of modern times have been connected with the conversion of timber, and the working of wood into the multitudinous forms in daily use all over the world.

This will be apparent to every one who clearly understands the nature of the machines that, in endless variety, permeate this most extensive province of engineering; and especially is this the case when, with the light of early days around me, I see once again the very slow and tedious process of timber cutting as it used to be in Australia. For land clearing purposes, the stately primeval gum trees had to be felled with the axe alone. Their cross cutting into lengths for splitting into roof shingles, or paddock rails, or posts, or ripping into planks for housebuilding, were all performed in a style worthy of the ancients. And even now, in out of the way places, the very same methods must be employed unless modern tools and appliances are utilised. Leaving aside altogether the one thousand and one phases of timber working in general use, we shall briefly describe those which affect shipbuilding and engineering operations alone. To enable this to be accomplished, we have selected as a basis the productions of well known firms.

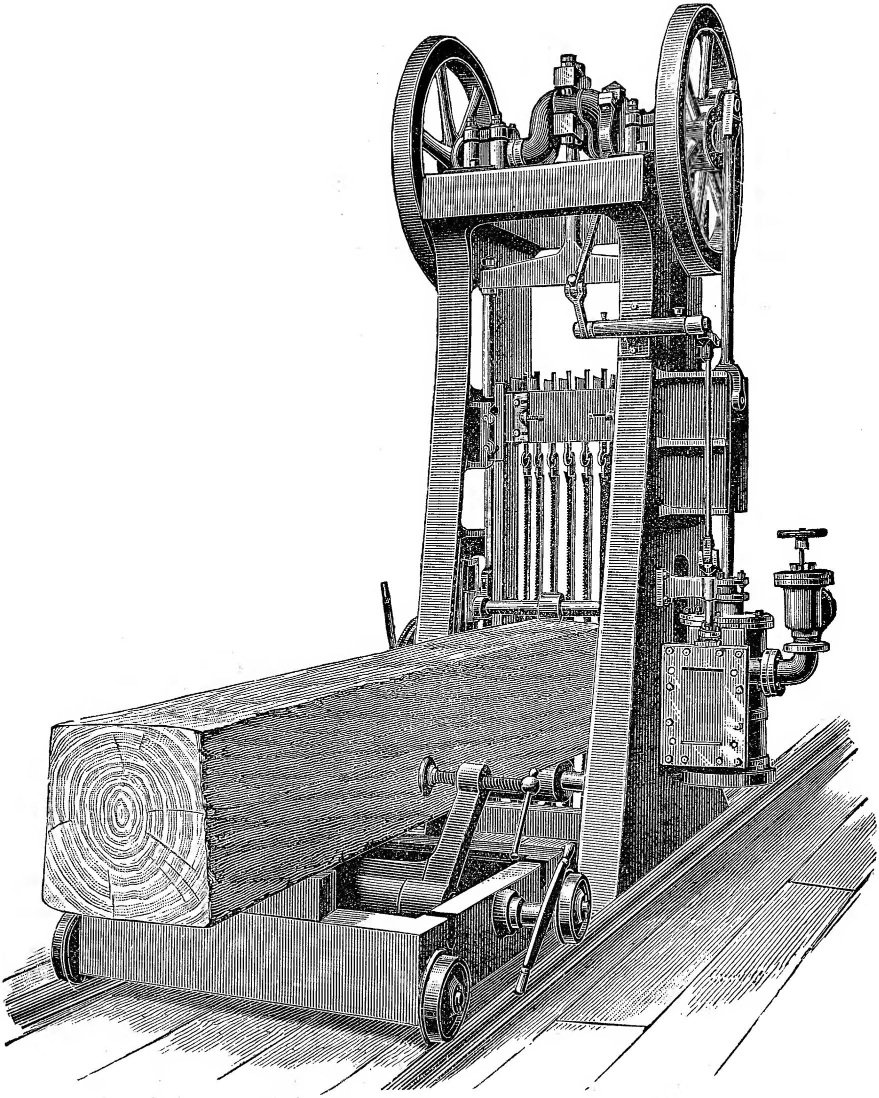
According to a complete list of machines supplied by Messrs. Robinson, of Rochdale, to a few shipbuilding firms, we find that the set includes circular saw benches; band sawing, and fret sawing, and pendulum cross-cutting machines, variously arranged; planing, moulding, and trying-up machines; mortising and boring machines; tenoning machines; wood turning lathes; planing and sand-papering machines; saw sharpening machines, etc. It must not be supposed, however, that the above are *only* to be used in shipbuilding yards, because they are equally applicable to all similar operations, no matter where. Allowance must also be made for the varying opinions of those who use them, which are governed more or less by circumstances. Hence, the list only gives an approximate indication of what may be required in other cases.

The position occupied by the lathe in the iron departments is exactly similar to that of the wood *Sawing*

Machine in his own particular sphere. In other words, the latter is quite as much the monarch of his own race as the other is of *his*, because he most lavishly provides the material upon which all the rest of his tribe depend for subsistence. The Heavy Band Sawing Machine is no doubt a refined modern improvement of great value, but for very many years past, the most of the heavy cross-cutting, and plank and beam ripping, and other similar work, has been performed by the Circular Saw and the Vertical Log Frame, of which there are now many varieties.

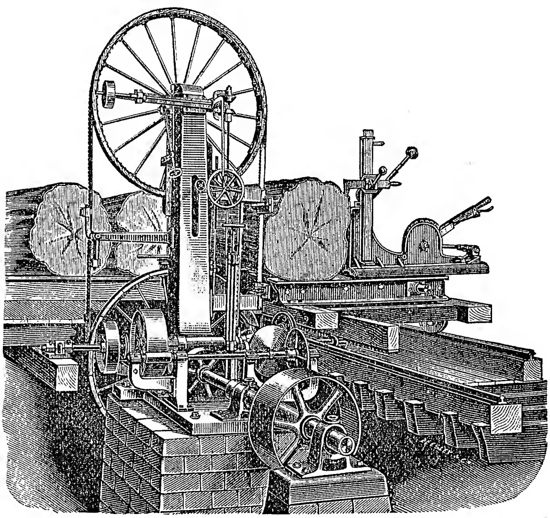
An excellent example of an *Improved Self-contained Timber Frame* by the above firm is shown on the next page. This is a very useful type of machine, suitable for erection in almost any locality, and, on account of the driving gear being overhead, it requires very little depth of foundation. As the engine is directly coupled to the crank-shaft, and all the working parts are in sight and easily accessible for cleaning and lubricating, etc., it cannot easily get out of repair. The size of the logs to be operated upon range from 16″ to 48″ square, by 30′ long, but in every case the strength of the parts is made to suit the maximum strain when working.

These sawing machines seem to be extremely popular, judging by the varieties of them that are now made. For heavy cutting, however, in the hardest timber, Messrs. Ransome, of Chelsea, manufacture a very powerful and massively constructed arrangement for operating upon logs from 20″ to 48″ square, and from 25′ to 40′ in length. The greatest number of saws in use at one time ranges from twenty-five to sixty, but the spacing of these, as in all other cases, depends entirely upon the required thickness of the timber when cut.



IMPROVED SELF-CONTAINED TIMBER FRAME.

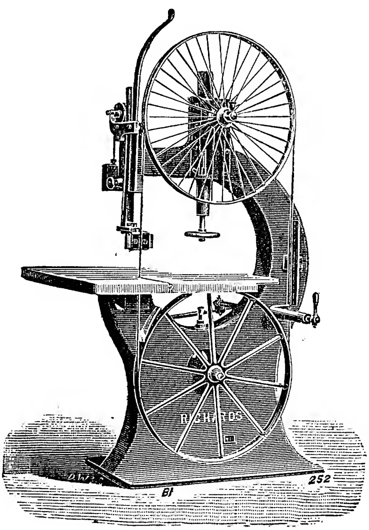
Many will no doubt remember the *Band Saw* of early days, which was only suitable for genteel carving on a small scale; it is, therefore, surprising to find such an enormous expansion of the uses to which it can now be applied. Who would have thought, thirty years ago, of employing a *Band* Saw for cutting through massive blocks of iron and hard steel? And yet such has been the march of progress, that both of these operations are of continual



LOG BAND SAWING MACHINE.

occurrence in many of the largest establishments. With a desire to still further extend its sphere of action, Messrs. Ransome supply a colossal and specially designed machine of the above type, for performing the very heaviest work in hard as well as soft timber. And it is now an accepted fact that in America the band saw will soon be generally adopted for log cutting in place of the large circular saw or vertical frame previously described, as the waste is much less, and at the same time a smoother cut is produced with half the power required for the former, and a greatly increased production when compared with the latter.

A good example of the above class of machines by Messrs. Richards, for cutting logs 5′ square, or 6′ diameter, is shown with all its surroundings, on previous page. The wheels are 8′ diameter, and the feeding, controlling, sawing, and all other gear are capable of adjustment in



BAND SAWING MACHINE.

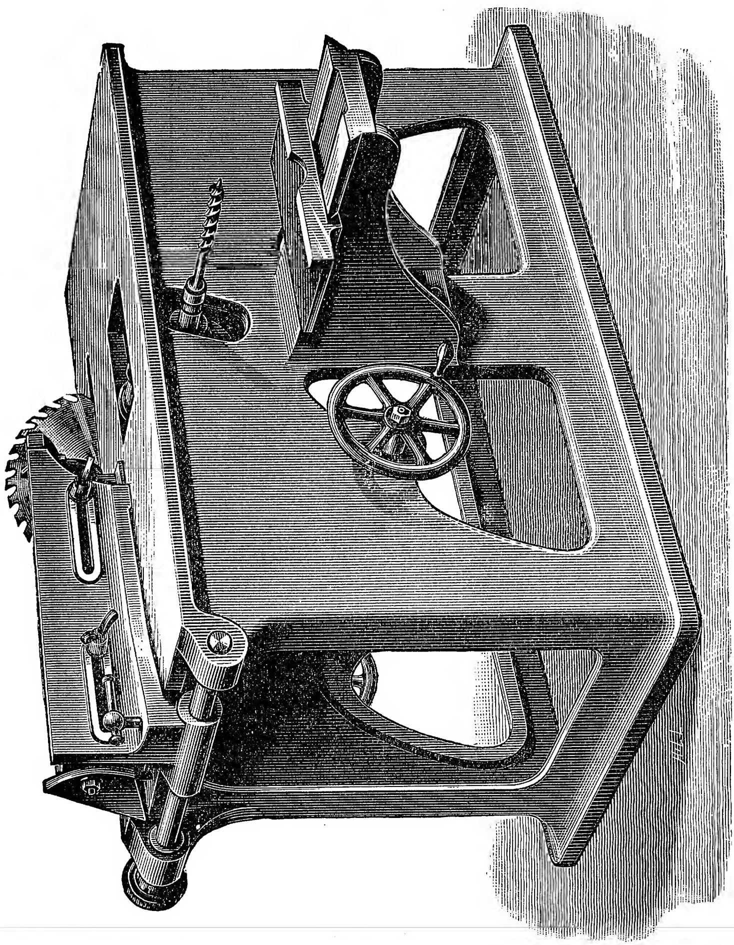
every direction. The above Illustration will also give a clear idea of a very popular *Band Sawing Machine* by the same firm for general purposes. The upper wheel, which makes 400 revolutions per minute, is 36″ in diameter, whilst the table can be set at various angles for bevel sawing when required. This machine forms a very good example of its class when used for pattern making, or for the joinery, etc., work of shipyards, and, indeed, does not differ much from the very slow-speeded steel cutters, where gearing is employed to give a feed motion to the table.

The best known of all the sawing machines is the "Circular," of which there are many varieties, simple as well as compound, large as well as small. Simple as its arrangement of details may often appear, it is nevertheless capable of numerous combinations of great importance. Hence, a *Circular Sawing Machine* may also be a planer, moulder, tenoner, mortiser, borer, etc., or otherwise, to suit the views of purchasers.

A very useful and specially designed shipyard type, by Messrs. Robinson, is shown on the following page. It has a rising and falling spindle, and is intended for sawing, tongueing, grooving, rebating, boring, and cross-cutting, all of which can be performed with little trouble. When, for instance, the 36″ saw is removed, a circular block, fitted with suitably shaped cutters, can be put in its place, and thus the operations of tongueing and grooving, beading and rebating, can be at once performed. The other end of the spindle is used for boring purposes while the timber rests on a sliding table as shown, and the adjustable fence can easily be removed to allow for cross-cutting. Hence, it will be observed that, by a series of simple movements a machine that appears only capable of doing two things, can be made to perform several.

Circular saws range from 4″ to 84″ in diameter, and great experience is required in shaping their teeth to suit all kinds of hard and soft timber. When properly made, however, they work most satisfactorily.

In Government dockyards, arsenals, and shipbuilding yards generally, there is a considerable quantity of heavy timber that requires to be roughly squared previous



CIRCULAR SAWING MACHINE.

to being otherwise worked. This used to be done by passing the logs, under a rapidly revolving horizontal disc containing a roughing, and also a smoothing tool—

the former being in advance of the latter. To meet the requirements of the best modern practice, however, Messrs. Ransome employ their own *Improved Planing and Trying-up Machine*, which not only does its special work with great rapidity and efficiency, but also cuts mouldings, beads, or rebates if required. This is accomplished by means of a steel adze block fitted with suitable cutters, and revolving at high speed in a vertically adjustable carriage. The table is furnished with the necessary screw cramps for timber-fixing purposes, and the rate of forward travel can be varied from 15 to 30 feet per minute, as desired, the return motion being 80 feet in the same period.

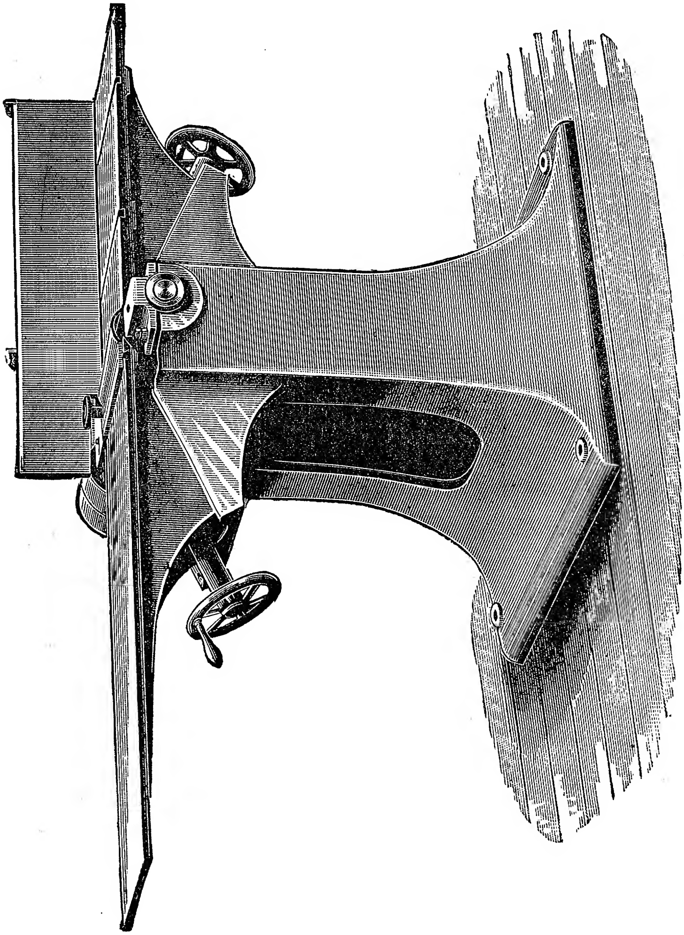
Machines of this description are made to true up timber from 14″ to 20″ thick, from 14″ to 24″ in width, and from 7′ to 25′ in length, and by means of a little extra gear, can be made to perform *side* planing or moulding when necessary.

For ordinary light *Hand-feed Planing*, up to 12″ in width, Messrs. Robinson provide the very simple machine which is shown on the next page. It is also used for surfacing, jointing, trying-up, rebating, and chamfering, according to the manner in which the cutter block is treated. The tables, and improved canting-fences for angular cutting, are adjustable; and, by means of a little extra gear, other operations can be performed with ease.

In the carpentry and joinery departments of a ship, there is an enormous amount of *Mortising and Tenoning* to be performed, and therefore the machines that can execute this kind of work satisfactorily must prove invaluable.

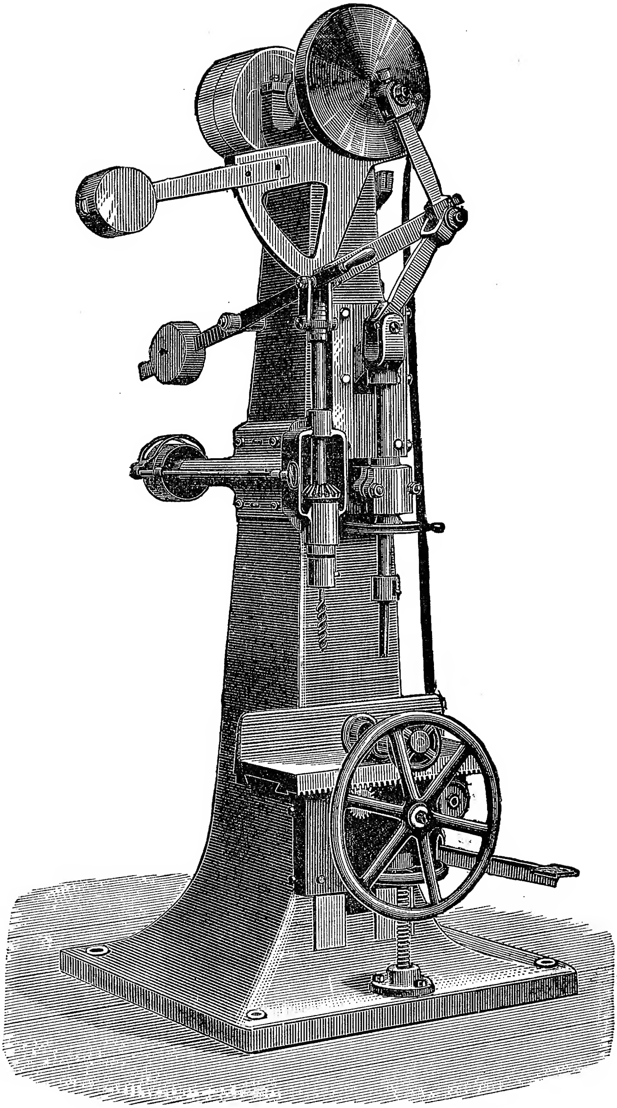
The Plate on page 163 illustrates the manner in which the hand labour system of mortising has been overcome by

Messrs. Robinson. Here we have a simple and substantial machine, fitted with a boring spindle having sufficient vertical range to enable augers to pass through timber



HAND-FEED PLANING AND SURFACING MACHINE.

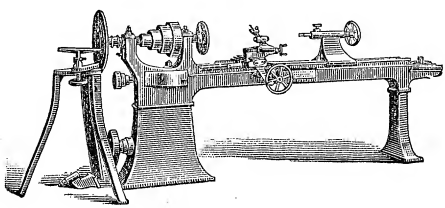
12″ deep by 8″ wide. When this has been effected, the reciprocating chisel is brought into play until the hole, say $1\frac{1}{2}$″ in breadth, is completed. By means of the rocking



MORTISING MACHINE.

levers and side treadle, the stroke of the chisel can at any moment be varied, or stopped altogether, and the table can be raised or lowered to suit different thicknesses of timber. It is also fitted with a longitudinal slide, and thus the work can be adjusted with ease in every direction.

Tenoning Machines may be simple or complex in construction, according to circumstances. On the one hand, a "drunken," or wriggling, circular saw may be good enough for the purpose; and, on the other hand, various elaborate arrangements of adjustable cutter blocks, and a saw as well, may be required. All this, however, depends greatly upon the size and quality of the timber,



10″ CENTRE WOOD LATHE.

and the speed and accuracy with which the work is to be executed.

As the *Lathe* is an indispensable machine in iron and steel working, so also is it in the timber-working portions of engineering establishments. We therefore give an illustration of Messrs. G. Richards' 10″ centre lathe for the latter purpose, which will sufficiently indicate the nature of the wood turning process. Besides the usual head-stocks and slide rest, the outer end of the cone spindle is fitted with face-plates of various sizes to which work can be attached. The movable tripod is also supplied with adjustable hand tool rests, so that patterns of large diameter, such as cylinder covers, etc., can be manipulated with ease, whilst those for rods, spindles, etc., can be turned at a very high speed between the centres.

With the object of facilitating the surface finish of woodwork in shipyards, etc., Messrs. Robinson have introduced an arrangement that far excels previous efforts of this nature. Their machine has three rollers, which are progressively covered with coarse, medium, and fine sandpaper, each of which in turn acts rapidly and efficiently on the surface of the timber, and finally imparts to it a very high polish. Several important improvements have recently been made, by means of which the paper can be fixed with great rapidity, and a saving of twenty-five per cent. effected in the material. This machine is variously modified, and, like many other American inventions, is most ingeniously designed.

So far as shipyards are concerned, the plates and descriptions given in this chapter are sufficient to indicate how the principal wood-working operations are performed in them. Much more might be added; enough, perhaps, has been said upon this point; since, with a few leading ideas as a guide, aided by critical observation, much may be learnt in a general way about timber working in these establishments, and especially in places such as Woolwich Arsenal, and also in the great railway carriage and wagon works, where the most modern improvements have reduced the art of wood-cutting to the utmost precision, and "whizz" and "whirr" rapidity of execution.

The subject is most important and far-reaching on account of the infinite variety of machines in use, and their application in manufacturing industries, from that of matchboxes to the very heaviest constructional work.

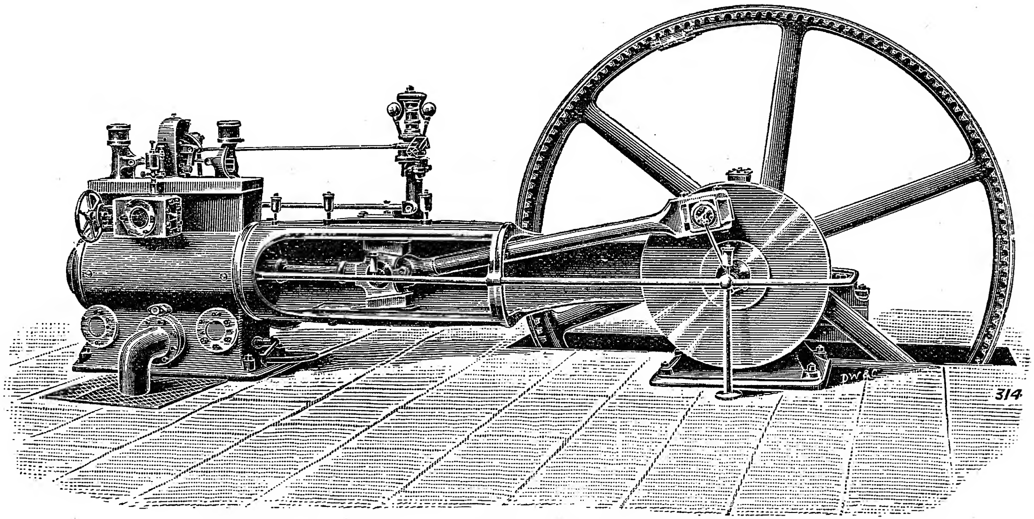
And here it may be added that our talented colleagues in the sister branch of engineering deserve the highest praise for the elegance and simplicity of design, excellence of workmanship, and general suitability to the end in view, that so fully characterises all their productions.

There is more system in *commercial* timber working than many would suppose. Deck planks, for instance, are usually about 5″ × 4″ or 3″ in thickness, according to circumstances. Flooring joists for all kinds of buildings throughout the realms of architecture are cut to standard sizes of 11″ × 3″, 9″ × 3″, and 7″ × 3″; and as the distance between each joist is usually fixed at 11″, the planking that covers them is 9″, or 7″ wide by 1″, 1¼″, or 1½″ thick, according as it is required for domestic or public hall uses, or for carrying heavy warehouse loads. By these means, timber sawn in Transatlantic or Continental forests is sent to this country in whole shiploads for the above purposes, at very low rates, and ready for use without any more extra work being required than that of cutting to the length, and mortising, tenoning, etc., and boring for bolt holes when necessary.

In Wagon Works, where the amount of shavings, sawdust, and waste cuttings, is so enormous as to fire the main boilers for the driving engines, almost without the aid of coal, a special apparatus is provided, so that they can be deposited automatically on the boiler room floor. Messrs. Ransome provide for this through the use of their *Pneumatic Cyclone Dust Collectors*, which effectually remove the refuse from the different machines, and deposit it where desired, thereby saving labour, keeping the shops clean, and much reducing the danger of fire.

Notwithstanding the numerous changes that have arisen in recent times, and the improved systems of driving machinery that are now in operation, it does not at present appear likely that the steam engine will be superseded by any other motive power in shipbuilding and engineering establishments. Water, compressed air, gas, and electricity, are admirable enough in their own way, and, within certain limits, are very suitable and economical. The first named is certainly the least expensive and most convenient where a plentiful and steady supply can be obtained, as in some parts of the Continent and in America, where it is employed on the most colossal scale.

In the north of Europe, and especially in Sweden, the millowners frequently use steam even when a river flows past them, which may be frozen up at one time, and nearly dried up at another. Hence, they naturally prefer this power to all others, and so also must the great shipbuilding and engineering firms of the world in places where coal is cheap or wood fuel plentiful. The selection of the "*Best Engines*" for driving purposes is sometimes perplexing, as there are now so many who claim the honour of turning out machinery bearing this title. One of them, by Messrs. Marshall, of Gainsborough, illustrated on the next page, can be used either in single or coupled high pressure, or in coupled or tandem compound form, with steam from 100 to 125 pounds per square inch. The single engine can be as shown, or with a condenser and air pump of "tail end," or "downstairs" description, according to requirements. One of its most important features, however, is the adoption of the Proell two-valve releasing gear, and Corliss exhaust valves, the former actuating in the most perfect and economical manner equilibrium double beat admission valves, and the



HORIZONTAL ENGINE.

Indicated Horse-power 210, *without Condenser.*

" " 265, *with* "

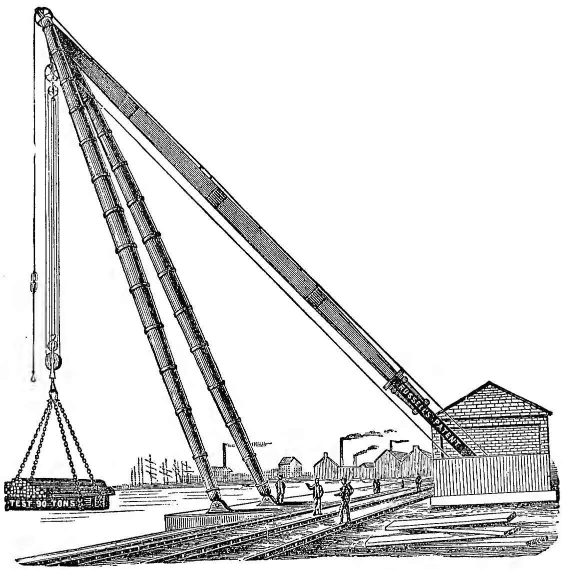
latter being so designed as to drain the cylinder of any water that may be in it at each stroke of the piston.

It may be added that the horizontal land type of engine, variously modified, is much used abroad in stern wheel shallow draught river steamers, for which it is so well adapted, and that the excellent superposed Compounds of Messrs. Galloway have the small cylinder placed over the large one, as in some of the latest and most powerful long stroke diagonal paddle engines of mail racers, thus occupying little room and enabling both piston rods to work the same crank.

In the *Fairfield Works*, where specimens of wood-working machines of latest design are to be found, everything has been planned on the most liberal scale in all departments, including those of a minor character not specially mentioned. The buildings are handsome and spacious, and the available ground area quite sufficient for more extensive operations in the future. Indeed, as a vast establishment completely organised in every respect, it is a model of excellence throughout. Besides the indoor gear to which we have referred, there are many outside appliances of great importance, including numerous cranes and other lifting tackle, railways, etc., that greatly facilitate the operations in the yard. And, last, but not least, may be mentioned the new 130-ton steel built *Sheer Legs*, shown in the Plate of the establishment, which have superseded the previous ones owing to the great increase in the weight of boilers, etc., during recent years.

This hoisting apparatus is capable of taking in the above weight as a working load, and is also arranged to lift smaller loads at increased speed, when required. The back leg is worked by a horizontal steel screw, 10″ diameter and 70 feet long, whilst the travel of the nut that regulates the overhang of the front legs is 61 feet. This system is admirably adapted for lifting heavy weights into their places on board a ship, indeed, for work such as described, it has become indispensable.

Its advantages may be gathered from the following view of the 80-ton *Hydraulic Sheers*, made by Messrs. G. Russell & Co., of Motherwell, near Glasgow, for West Hartlepool, which are remarkable for the introduction of



SHEER LEGS.

novel features. The front legs are 106 feet in height, and instead of the main screw being placed in a horizontal position, it is arranged inside the back leg. The traversing movement is obtained by the telescopic action of the latter, and on its highest point there is a single chain pulley having separate hoisting gear for masting and other light purposes. Two pairs of special driving engines are employed, and these are so arranged that either of them or both together can be used. The sheers were tested with a 90-ton load, as shown, and this was traversed inwards and outwards the full range of 50 feet each way most satisfactorily.

We may now conclude our remarks upon the establishment where so many magnificent specimens of Naval architecture have been built, and, although the spacious and handsome engineering portions of the premises have not been touched upon, it is because they are stocked with so many of the splendid machines described in other chapters. What has been said about them, however, may perhaps prove additionally interesting because they have been treated not as *isolated* examples, but as links in a chain of the most modern engineering operations in the largest as well as in the smallest works of the present day.

CHAPTER XII.

ATLAS WORKS OF SIR JOHN BROWN AND CO., SHEFFIELD.

Changes in Naval Ships—Sir J. Whitworth's Improved Ordnance—Sir J. Brown's Initial Movements—His Successes—Marvellous Extension of the Works—Whitworth's later Improvements—Brown's Steel-faced Armour—Atlas Works of the present—Stupendous Machinery—Sawing Hot Steel Armour Plates—Ribbed Flue Manufacture—Forging, and other Departments—Armour Rolling Department—How Steel-faced Plates are Made—And Machined—And Fitted to Ship's Side—Hydraulic Bending Process—Rolling a Gigantic Armour Plate—Attendant Dangers—Magnificent Scene—Latest Improved Plates.

At no part of the nineteenth century were so many rapid changes made in the general appearance of Royal ships as during the "seventies" and "eighties," so much so, indeed, that those who inspect high art plates of some of the finest specimens of past war vessels, can only feel that in one sense, at least, an unwelcome change has come over the spirit of the times, and, although the latest steel-clads appear like huge rafts, with lofty deck house, and other constructions in the middle, and masts that are only signal posts, and machine gun batteries, they must nevertheless be considered excellent specimens of the most advanced practice in naval architecture.

We have noted the gradual rise of the modern system ever since Messrs. R. Napier & Sons constructed the first "floating battery," about the year 1855. We have seen H.M.S. *Black Prince* built and launched by the same firm, and as the turret system came into use, and as the heavily armoured broadside battery ships became more and more powerful, we naturally tried to discover a cause for such innovations, and found it in the continued efforts of the gun manufacturing people—chiefly Sir Joseph Whitworth and Sir William Armstrong—to obtain the supremacy. Hence, when such powerful talent was brought persistently to bear upon the destructive branch of engineering, it was not surprising that those connected with shipbuilding and armour plate working should devote their whole energies towards countervailing the damage thus produced by their learned brethren.

In all this there was a large amount of friendly rivalry. Science was wonderfully advanced. The cost of ships ran up, up, up, until it rose to about £750,000. Shipbuilders, the ordnance people, and armour plate manufacturers, became more highly appreciated at home and abroad, and the only individuals who really suffered by the perpetual changes were the nations who had to pay for them. There was, however, just one little point in the whole business that critical observers must have noted and pondered over.

Suppose that two great empires—say, Assyria and Babylonia—had each an army of 500,000, and that the latter, for private reasons, doubles his forces, while his next door neighbour soon afterwards does exactly the same thing. In what respect, may we ask, are those two nations benefited by the movement? None whatever. Indeed, they are both worse off than before, as the national expenditure, in each case, has been doubled without obtaining any compensating advantage.

So, too, has it been with Royal ships of the present age. They have been worked up to a high standard of perfection, but made, relatively speaking, no more effective than they were thirty years ago. The guns, too, have been similarly advanced in size and power until they have reached a cost of about £20,000 each, and after all, they are hardly more able to pierce a ship's side than they were during the "sixties." Eventually the contest between guns and armour plates resolved itself into a struggle for supremacy between Sir Joseph Whitworth and Sir John Brown, in which both greatly distinguished themselves.

Here we find the simple origin of the aforesaid changes in naval vessels, and the gradually increased thickness of their armour from 4½″ of solid iron in H.M.S. *Warrior* in 1862, to 24″ in H.M.S. *Inflexible* in 1889. When ship's armour had reached the, at one time, unprecedented thickness of 15″, Sir Joseph astonished every one by penetrating it with shots from his own improved 9″ bore ordnance. Something, therefore, had to be done to neutralise its power as much as possible, and this gave rise to a most important invention in which Sir John Brown & Co., of Sheffield, became greatly interested.

The original establishment was projected in the year 1847, and illustrates very forcibly the manner in which the difficulties of Sir John's early life were overcome by diligently improving every opportunity for opening out a path to future success. In 1856, the works, which had previously been carried on in four different localities, became concentrated in one undertaking, that soon became well known as the "Atlas Works." During a continental tour in 1860, Mr. Brown happened to be in

Toulon just at the time the imperial ironclad *La Gloire* was lying in the harbour, and attracting much attention, partly on account of her appearance, and partly owing to the inability of the heaviest naval guns of the period to penetrate her sides. Previous to this she had been a timber three decker, but the French Government had cut her down, and, after covering with armour plates the parts of the hull above water, she was put in commission.

The English Government at once gave orders for the similar conversion of ten large ships of the old wooden type, and this caused Mr. Brown to fancy he saw a field for the exercise of his skill and enterprise. Upon being refused permission to go on board the *La Gloire*, he made a minute examination of her exterior, from the nearest point of view, and was thus enabled to ascertain that the armour plates were 5′ 0″ long by 2′ 0″ broad, and $4\frac{3}{4}$″ in thickness, and that they had been made by the hammering process.

"*Forged* plates!" thought the interested visitor, "I think I can do something better than that by *rolling*."

On his return to Sheffield he erected a mill, selected workmen, and personally directed this initial movement to a successful issue. As described by himself, the operation of making his first armour plate of five tons, was as follows:—

"Several bars of iron were rolled 12″ by 1″, and cut to lengths of 30″. Two sets of these of five each, were separately piled and rolled down to rough slabs, which were then welded together and rolled again to form a plate $1\frac{1}{2}$″ thick, and 4′ 0″ square. Four of these were next piled and rolled down to one plate 8′ 0″ by 4′ 0″, by $2\frac{1}{2}$″ thick, and lastly, the same number of the latter were similarly treated, until the armour plate was finished. The final welding process was the most difficult, as the intensity of the white heat thrown off by such a quantity of iron was almost unendurable, and the loss of a few moments whilst conveying the mass from the furnace to the rolls would have been fatal to success."

No sooner had this experiment been satisfactorily accomplished, than formidable competitors arose and keenly contested Mr. Brown's claims to superiority. So much indeed was this the case, that the first orders from the Government were divided amongst different manufacturers, the "Atlas Works," however, came in for a large share at prices ranging from £37 to £45 per ton. In 1862, the question of superiority was finally settled by means of a series of experiments upon plates made in Government establishments, and also in private works, with the result that Sir John Brown carried off all the honours, and obtained gold medals for excellence in armour plating from the French as well as from the English. Thus was commenced a special branch of engineering which rapidly increased the resources and extent of the above establishment.

Sir Joseph Whitworth noted all these movements, and declared at a public banquet that he would make his guns to send shots through every plate that could be manufactured. And so he did, until at last he actually pierced three 5″ armour plates built up together into a solid mass to represent a portion of the side of a vessel. The Atlas Works Company now made a most important movement which neutralised the effects of the improved rifled ordnance, and restored to the ships the supremacy they had lost. Mr. J. D. Ellis, the Managing Director, having discovered that while thick steel plates were cracked and shattered by the heaviest shots, and iron plates were easily perforated by them, conceived the idea of making armour of compound form upon a plan of his own, involving the homogeneous combination of steel and iron, and in this respect he was eminently successful.

Some notion may be formed of the extremely rapid growth of the above establishment during the early part of its history, when it is stated that in 1857 it only occupied a single acre; ten years afterwards, however, 21 acres were similarly covered, and the Works have been gradually increased until at the present time they cover about 32 acres of land. They were also filled by degrees with machinery used in the production of armour, and also iron and steel boiler plates, beams, angles, &c., marine, land engine, and other steel castings and forgings, including crank and propeller shafts, propeller blades, &c., and a great variety of railway springs, and other work, and latterly, the manufacture of the "Purves" ribbed boiler flues, and "Serve" ribbed boiler tubes.

The whole of the extensive buildings were designed by Sir John, much of the special machinery was similarly treated, and all of it was made under his own supervision. During a recent visit we saw most of the above, firstly with the kind assistance of Mr. F. Gross, the Commercial Manager; and secondly, under the guidance of one of the staff, both of whom most courteously gave me the opportunity of observing everything. I had also the honour of lunching with Mr. Ellis, Mr. Gross, and the chiefs of the Executive, and was thus enabled to see, in collective form, the practical scientists who had helped to give the Atlas Works a world-wide reputation.

In the original development of the Armour plate mills, no less a sum than £200,000 was expended, and these, as well as the heavy machine departments, proved a very interesting study. Indeed the gigantic planers, slotters, etc., that filled one immense building in particular, seemed to have been intended for the heaviest purposes. And here too, surrounded by the Titans, I was pleased to find the productions of my old friends Messrs. Shanks, Hulse, Buckton, &c., shining with increased lustre. The planers and slotters of the first named firm are amongst the largest and most powerful in the world, and were specially made from new designs which gave them a truly magnificent appearance.

In the heavy turnery, the powerful lathes of Messrs. Hulse & Shanks were well to the fore, and while one of the former was occupied in boring out the centre of a steel propeller shaft, about 30 feet long, two or three of the latter were employed in crank shaft turning, with their usual amount of success, as we could discover while carefully noting their action.

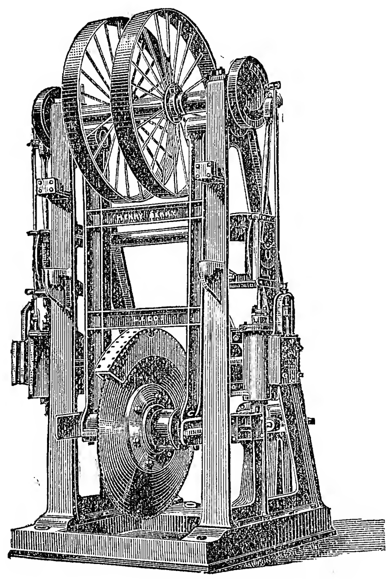
One of the most beautiful processes was the sawing of both sides, at the same time, of a steel armour plate $3\frac{1}{2}''$ thick, by means of two saws about five feet in diameter, each being rapidly driven by a 20″ cylinder engine, placed on either side of a large travelling table. After the cherry red plate had been fixed upon it in position, the engines were started, and as the table was automatically set in motion, the saws came gradually into play upon the tough metal. By night it would have been a splendid sight, but even in the dull light of the shadowed building, the scene was impressive, as showers of red hot steel cuttings fell close to us like the "golden rain" of the pyrotechnists. The saws swiftly cut their way along, making at the same time a deafening noise, until at last they cleared the plate, the firework display was over, and all was again still and murky as before.

Naturally one would have expected to find the saws stripped of their teeth after passing through such rough treatment, but, upon examination, we found them in excellent condition, and ready at any time to repeat the operation. This was owing to the splendid quality and temper of the steel out of which they were made, and also to the cooling effect of water beneath the table, and, it may be added, to the *shape* of the teeth, which were exactly suited to the work they had to perform. For plates up to ten inches thick the above initial machining process is admirably adapted; but when they exceed this thickness, the heavy planers and slotters are brought into operation with great effect.

A view of the machinery that performs such wonderful things as we have described would no doubt prove acceptable, but as this could not be obtained, we give on the next page an illustration of one of Messrs. Henry Berry's vertical frame *Hot Steel and Iron Saws*, 5′ 6″ diameter, driven by two engines, each having a cylinder 10″ diameter with 12″ stroke. For special purposes, this saw has a backward and forward travel of 24″ by means of steam or hydraulic gear, the table and its accessories, however, have apparently been left out, so that the principal gear may be more clearly seen. If the reader will now suppose the side frames placed a few feet further apart, and two laterally adjustable saws of about the same diameter placed between them, and driven direct by the powerful engines previously mentioned, while the travelling table fills up the foreground, it will give a fair idea of what is required for thus manipulating armour plates.

Whilst passing through the numerous and handsome buildings we inspected the department where the Purves *Ribbed Boiler Flues* and Serve *Ribbed Boiler Tubes* are manufactured very extensively for naval and mercantile ships at home and abroad. The plates out of which these are formed are made in the rolling mill. They are then shaped into cylinders by means of hydraulic bending presses, the joints being finished by welding in the usual way, as illustrated in a previous chapter.

For experimental purposes ten large marine boilers



HOT STEEL AND IRON SAWING MACHINE.

are employed on the premises, and to enable the working pressure to be obtained at a glance for flat plates variously stayed, boiler shells, riveted joints, in single or double shear, and ribbed furnaces, a very useful book has been published by the Company, which gives full particulars, tables, and formulæ for the above for all diameters, pitches, and thicknesses now in use. The Board of Trade rule for finding the greatest allowable Working Pressure of ribbed furnaces is as follows :—

$$14{,}000 \times T \div D = \text{W.P.}$$

On the other hand, Lloyd's rule is

$$1{,}160 \times (T - 2) \div D = \text{W.P.}$$

Where D = outside diameter in inches of body of furnace, and T = thickness in decimals of an inch for the former, and in sixteenths for the latter. It may only be added that these rules give very closely approximate results.

As we continued our ramble over the premises, we came upon the *Puddling Furnaces*, and saw the laborious operation of transforming crude iron into large balls ready for the shingling hammers, and subsequent rolling into merchant plates, bars, and angles, etc. Then we entered the heavy *Hydraulic Forge*, where crank and propeller shafts, and other ponderous gear, are manufactured. After that we saw the *Railway Spring*, and other parts of the works, and also the magnificent *Steel Foundry*, where ingots up to 100 tons in weight are cast. As a portion of their outer surface, however, may be unavoidably unsound, they are turned all over with the object of discovering lurking defects before being passed on to the presses or the hammers, and here we found a source of steady occupation for some of the most powerful lathes.

Some idea may be formed of the vast extent of the Atlas Works when it is known that they employ 160 steam boilers, and driving engines having in the aggregate at least 12,000 horse-power; all of which were fully employed with orders for various Governments and private firms at home and abroad at the time of our visit.

In continuation of our original theme, it may be said that when H.M.S. *Inflexible* was commenced in 1874, it was intended to make her iron armour 24″ thick, but before she was ready to receive it, important events occurred. At Spezzia, in 1876, a fatal blow appeared to have been given to iron as a defence for ships, owing to the Armstrong 100-ton gun completely perforating no less than 22″ of armour, and also its timber backing. Hence the French engineers directed their attention to the resisting power of *steel* plates, which the Italian Government highly approved of.

At the same period, Sir Joseph Whitworth obtained remarkable results with his own guns upon the same kind of armour. The Atlas people, however, at once began to run upon new lines, when Mr. J. Devonshire Ellis took out a patent for the manufacture of steel and iron plates on the "Compound" principle, which, after being subjected to the most severe trials, was found superior to all other systems. This was clearly shown by the fact that a projectile from the 100-ton gun only partially penetrated a 19″ steel-faced plate, and passed quite through an iron plate of the same thickness; but when steel alone was used, it became cracked all over and broken up. It is the same 19″ plates—some of which weighed fully 32 tons each when finished—that the Atlas Works supplied to the Italian warship, *Italia*, which carries about 1,800 tons of armour, and nearly 1,000 tons of deck plating, from 3″ to 4″ in thickness.

The most approved thickness of compound armour for the sides of ships such, for instance, as H.M.S. *Benbow*, *Anson*, *Howe*, *Rodney*, *Camperdown*, *Collingwood*, etc., is 18″, which appears ordinarily sufficient to withstand all the possible rough usage of modern times. This being the case, it may be interesting for readers to know how these plates were made. Let us therefore suppose that our party of investigators have obtained the kind permission of Sir John Brown & Co. to visit their works, and that we have just passed through the Saville Street main entrance on our way to the interior.

If the ladies and gentlemen of the party are sufficiently influential, the Managing Director, or the ever occupied Commercial Manager, will probably accompany them. Otherwise, however, one of the ablest lieutenants from the technical staff may be requested to act for them. In the works generally everything will be plain sailing, but in the *Armour Plate* department a unique order of things will soon become apparent. Should the adjacent steam hammers be somewhat noisily inclined, Mr. Dashe, the leader of the party, will have to give his explanatory remarks in disjointed sentences, such as: — "*Heating* furnace!"— "Armour plate!"—"*Take care!*"—"Cranes!" &c., and just as the Demon Crusher comes down with a bang that makes the earth tremble, shouts in your ear the ominous words "ROLLING MILL!" Thus it comes to pass that we find ourselves at last amongst the Titans in a region of fire and noise unparalleled.

According to Messrs. Brown's system, compound armour 18″ thick, when finished, consists of a 12″ iron plate faced with 6″ of steel in such a manner as to make the whole a solid, homogeneous mass. In the first place, however, ordinarily thick plates are piled, and welded, and rolled several times from a small beginning, somewhat as previously mentioned, until they become a solid slab of about 15″ in thickness. A light and narrow iron frame 5″ deep is next fastened round three of its sides by means of countersunk screwed pins at suitable intervals, and to the outside of this frame a steel plate is similarly secured, thus leaving a space of 5″. This plate is made of very hard metal, which has been pressed out of a large ingot, then rolled, and afterwards sawn while hot to the size and shape, as previously described. The whole mass of built-up plating is now heated sufficiently, and when taken out of the furnace, it is lifted vertically by a crane into a pit, where molten steel is poured into the aforesaid cavity.

When the fluid metal has solidified, the now fused together iron and steel is reheated, and hydraulic-pressed, previous to being taken finally through the rolls until it is reduced to the required thickness of 18″. After this, it is taken in a dull red state to the 6,000 ton press, and gradually bent to suit the varying curves of the side of the ship for which it is intended.

This is effected by means of full size models of various parts of her outside, which are supplied in consecutive sections by the builders, thus giving the precise curvature at every point, which is very carefully reproduced in the armour by means of templets.

After the plates are bent to shape, their required lengths and breadths are scribed upon the surface of the metal, in order to exclude the irregular edging unavoidably created during the process of manufacture, and also the iron framing, which has now become useless. They are next taken to the colossal planing and slotting machines, and, after being securely set on their tables, heavy ripping tools are used for cutting off the superfluous metal, whilst the other tools finish the plate to the exact size.

In the early ironclads the armour was fastened in position by means of conical headed bolts put in from the outside. Now, however, ordinary bolts are screwed into the plates from the *inside* of the ship, as shown in the section of H.M.S. *Victoria.* The same view also illustrates the tapering of the armour below the waterline for lightness and on account of the protection there afforded by the sea itself. Many of these holes can be bored and screwed by special machines in the planing department, but in some cases they require to be drilled in position by means of the portable hydraulic gear previously referred to. When the plates have been machined as above, they are tried in position on the model, and after any defects in fitting have been rectified, they are taken down and sent to their destination.

While we have been explaining the process of manufacturing ships' armour, and during the time that several iron plates have been heating in the furnace, previous to being rolled into an immense solid mass, our visitors have been taken by Mr. Dashe, from one point of advantage to another. The mills have been described to them with fluent simplicity. The mighty driving engines with their magnificent train of spur gearing, and massive fly wheels, etc., have been pleasantly noted, and now the ladies and the gentlemen are being introduced to one of the hydraulic presses, capable of curving armour plates up to 30″ in thickness.

While the adjacent "Demon Crusher," or 35 ton hammer, is pounding away at an awful rate, the engine before us is performing much heavier work without the least noise, and at this very moment is silently shaping a monster plate for the newest and costliest ironclad. The dull red mass, while lying on supporting blocks resting on the table of the machine, is curved by the skilful manipulation of other blocks, that more or less intensify the strain at any point when the bending power is put into operation.

Other machines of a minor character, including various steam hammers, etc., claim our attention as we pass on, until we arrive at last in the presence of the aforesaid Titan. What a monster he is to be sure! and lofty enough, too, to fill a church! All the required hands are in attendance, and as he thumps away most vigorously at a tremendous forging, red hot meteoric fragments are scattered all round with force enough to cut through the muslin dresses of the ladies, and somewhat damage the parade costumes of the gentlemen, if they do not keep well out of reach.

And now, nearly everything is ready for witnessing the final performance in the Rolling Mill department, which at this period is beset with dangers to strangers. As the visitors are standing in the vast building, they see amidst the surrounding gloom the main engines with their ponderous wheel work transmitting power to machinery in various directions. Steam, vapour, and flame, and hot iron permeate various parts of the edifice. Dark corners become suddenly illuminated, as furnace doors are occasionally lifted for the purpose of discharging vast masses of white hot metal, which are at once wheeled away. The men in attendance are dressed in thin steel armour. Their faces are covered by wire gauze masks, and in addition to this, they are protected by wet sack-cloth coverings to ward off the intense heat.

Those who gaze intently upon this scene, must take great care *not* to place their feet upon one of the still very hot forgings that are lying about, or stumble across a similarly non-incandescent armour plate. Should this be neglected, they may have cause ever after to remember the *Atlas Works* with somewhat mixed feelings. The leader of the party will, however, carefully watch his friends, and see that no accident can happen. On every side, the glare, and din, and steam caused by water coming into contact with hot iron, are alike deafening and blinding to visitors, and through the gloom may be seen a large number of men variously engaged, under the direction of the chief roller and chief furnace-man.

Whilst we have been roaming about the premises, several large and thick plates have been lying inside one of the furnaces for the purpose of being brought up to the welding state. These slabs are separated from each other at short distances by pieces of a certain material, which allow the gases to play between the plates, and thus greatly facilitate an operation that was once so difficult. When a white heat has been obtained, the fusion of these distance pieces allows the layers of iron to come into contact and become consolidated by cementation previous to withdrawal and future manipulation.

At a given signal, a large number of workmen arrange themselves on each side of the burning fiery furnace, and as the doors are opened wide, its interior, containing an immense quantity of dazzlingly glistering iron, is fully exposed to view. Some of the men now approach, encased in steel armour and wet sacking, as already described, and by means of a gigantic pair of forceps slung from a crane, lay hold of the mass of fizzing, sparkling metal, which is at once drawn by chains to the top of a long iron car. The forceps are removed with great difficulty owing to the intensity of the heat and light, which would be unbearable to any but those inured to them.

When everything is in readiness the truck is drawn at once to the top of an incline, where the force of gravity alone causes the plate to slide into the jaws of the rolling mill. All hands have now to get under shelter while it passes through the rolls, throwing out jets of liquid fire on all sides, and at the same time making a noise like that of muffled pistol shots. In spite, however, of every precaution that the best workmen can employ, they cannot always escape splashes of melted iron. The revolution of the rollers crushes the plate through to the other side, where it rests for a few moments on an iron truck. The mill is then reversed, after the rolls have been screwed closer to each other. These are again made to bite the plate and drag it back to its former position, thus gradually reducing it to the required thickness.

During every stage of the above process, quantities of fine sand are spread over the plate, which at once take fire and deposit a coat of silica, or glaze, like that of earthenware. After each discharge of sand, jets of water are played upon the metal, and when this operation is over, men rush forward with wet brooms, having very long handles, and sweep off all the oxidation.

Everytime the huge slab passes through the mill, this process is repeated, and its thickness guaged from end to end by the chief roller, who performs the operation under cover of wet cloths, until at last the plate is run on to a table and left to cool. During this period, however, any twist that it may have sustained is levelled off by means of two rollers of about 15 tons each, which are slowly moved backwards and forwards over the surface of the iron while hot, until it becomes perfectly flat. It is now subjected to the steel facing process, and re-rolled until the combined metals are reduced to 18″ in thickness, and weigh in the aggregate perhaps 25 to 30 tons. Thus prepared, the plate is ready for the machining and fitting processes previously described.

The important difference between a compound and an all steel plate, is that the face of the former is made of steel of a harder nature than can be obtained from any special treatment of material suitable for the body. This is due to the peculiarity of the system adopted for insuring the union of the two metals, so as to produce shot-resisting powers of the highest order. The protection thus afforded to ships cannot be over estimated, when it is considered that the bursting of a large shell, or the passage of a shot into the interior, may create the most frightful havoc amongst the machinery, or indeed throughout the whole vessel. And this is all the more important, as the triple expansion engines now employed are dependent for their safety upon the invulnerability of the outside armour, which alone was the cause of their introduction in place of the horizontal type at one time so much used in the old timber ships.

The story of the guns and armour plates, though very briefly given in this chapter, may still be sufficient to indicate the manner in which eminent practical scientists in two distinct branches of engineering, may incite each other to attain perfection. It will also form a very good example of individual successes won by the judicious exercise of natural or acquired talents; successes, too, that in the arts of peace, benefit not only whole nations, but the world at large, in endless ways, as we have previously tried to show.

Besides the large works at Sheffield, the Company has very important collieries near Rotherham, known as the "Aldwarke Main" and "Car House" Collieries, and a new one is now being sunk that will be known as the "Rotherham Main," from all of which more than a million tons of coal will be raised every year. In addition to these are numerous coke ovens, ironstone mines, and blast furnaces, to which only passing reference need be made.

The latest development of the armour question has taken a direction which has long been kept in reserve, namely, that of "hardening" the faces of the compound plates when they have been completely finished. A series of these plates, recently tested at Shoeburyness and Portsmouth, have broken up the best forged and tempered steel projectiles, just as a few years back the relatively soft faces of compound plates destroyed the chilled iron Palliser projectiles. As this chapter, however, is just going to press, we must allow the last remarks to foreshadow future results.

Mr. W. S. Jeans' very instructive book—*The Creators of the Age of Steel*—has supplied me with many tit-bits regarding the history and development of the Atlas Works. For the opportunities, however, of gathering the practical information upon which this chapter is founded, I am indebted, firstly, to the kind permission of the Company; and, secondly, to Mr. Gross, and the member of the staff, with both of whom I spent nearly a whole day in critically examining the establishment, whose description we hope will be found interesting to the reader.

CHAPTER XIII.

"THE EMINENT ENGINEER."

Popular Ideas of the above—First impressions of an Eminent Engineer—How he attained his Position—The "Eminent" as an Apprentice—Sir W. Fairbairn in early days—John Penn, of Greenwich—Comprehensive nature of Engineering Practice—How the E. E. acquired his knowledge—Effect of Engineering Study upon the Health—"The Eminent" as a Professional—As a Student of Natural Science—In Society—As a Lecturer on various subjects—His Simplicity of Character—Workshop Supervision—Valuable Hints to Apprentices—Nutshell Sketch of the achievements of Modern Eminents.

As celebrated engineering firms have been frequently referred to in the preceding chapters, it may be well, at this point, to describe somewhat in detail the well known individual mentioned above. To throw a few side lights upon the peculiarities of the professionals who scintillate and shine in the firmament of the engineering world. To explain their methods of attaining success, and to illustrate their idiosyncrasies of character, apart altogether from the halo of glory with which the public journals delight to encircle them.

To enable this to be done, let us imagine that our friend, Mr. Browne, has received an invitation to meet one of the greatest men of the day—Sir Ronald Osborne—at an evening reception. Now, it so happens that Mr. B.'s ideas of celebrities in general are rather mixed, and, although he knows that some of them have made their lives sublime, and left footprints on the sands of time, and so on, he is nevertheless doubtful about the "eminent" to whom he is going to be introduced. Probably he fancies the great man to be a tall, stately, dignified being, extremely courteous, frigidly polite, and so icily reserved in manner that few who know him once care to renew the acquaintance.

With these reflections on his mind, he is eventually ushered into the room where a large number of ladies and gentlemen are assembling for the occasion. After the "*Mr. Browne*, Sir Ronald Osborne, *Sir Ronald Osborne*, Mr. Browne," part of the ceremony has been satisfactorily accomplished, the latter thinks that a mistake must have been made somewhere, but *where* he cannot tell.

"Dear me! is it possible?" he mentally observes. "Can this be the man whose fame girdles the earth in every direction, and whose name is a household word in two hemispheres?"

This feeling of doubt, however, is soon removed when he sees the lion of the evening kindly allowing so many to shake his hand and say, "How do you do, Sir Ronald, I am glad to see you," or, "We are delighted to meet you, Sir Ronald," et cetera, et cetera. And as the E. E. receives all these delicate attentions, he bows and smiles, and says pleasant things in such an easy, natural, and amiable manner, as to disarm at once the uncharitable criticisms of those whose chief delight is to find fault even with their best friends.

In appearance, Sir R. O. is of medium height, and of handsomely intellectual expression, and, although heading for sixty, looks much younger. Superficial thinkers might easily enough conclude that he was *not* a talented man, but the careful observer would give quite a different verdict. He, or she, would tell you that the distinguished visitor is by physiognomical indications a clear-headed reasoner, and one who has the marks of that long-sustained and careful thought to which his works so abundantly testify. Besides this, under a placid and happy exterior, he bears traces of the high-toned energy and force of character which have so frequently carried him safely through all his difficulties, and which would have made the "wonderfully clever" Jones and Robinson tip top swells in their own professions if they had possessed, even in a very moderate degree, the same qualities. In addition to these peculiarities of mind and manner, he possessed rare tact, and knowledge of the idiosyncrasies of men and women of all ranks. He also knew how to say the right thing at the proper time, and if some were displeased because his frankly expressed opinions were not flattering, it well became them to remember that he, or she, who takes offence when no offence is meant, is with *himself* or *herself* offended.

Let us try to show how Sir Ronald attained his present position, and this will not be very difficult, because in doing so we are only describing the characteristics of well known eminents who have left *their* "footprints on the sands of time, footprints which perhaps another, some forlorn and shipwrecked brother, or sister, seeing may take heart again," as Mr. Longfellow used to say.

First and foremost, then, it may be stated, that Sir Ronald Osborne was a most steady and industrious apprentice while in the famous establishment of Messrs. Dashe & Blanque. Almost as steady, indeed, as the rich and generous shipowner who similarly began life at the

Crewe Works, and who, during a long apprenticeship, was not even once late.

In the various departments of the Works, from first to last, our future E. E. presented a striking contrast to a few of his associates, who seemed to think that as some of the fame of the establishment would certainly attach itself to them when they left it, they might take it easy and trust to chance. Young Ronald was not a genius, or he might have lost himself, nor a dunce, like Sir Walter Scott when at school, but he was richly endowed with common sense, fair abilities, and a desire to obtain advancement by his own efforts, and in this he ultimately succeeded, even beyond his expectations.

If he had been merely a specialist in one or two particular branches of engineering, his labours would have been greatly lightened, but having been thrown by the force of circumstances into a position where a more extended knowledge was indispensable, he was compelled to educate himself up to the required standard of efficiency. And although this entailed a heavy expenditure of the midnight oil, he found in the main, that the labour we delight in physics pain, and causes a fascinating occupation to arise out of what would otherwise have been dreary and monotonous.

The above remarks are amply confirmed in the history of Sir William Fairbairn, who was an all round engineer of the highest excellence. Bridges, locomotives, mill-gearing and machinery, waterwheels, shipbuilding and marine engines, constructional iron work of every description for mills and warehouses, etc., all seemed to come alike handy to him. He was, however, a most insatiable worker by night and by day, and not only the responsible chief in his own establishments, to whom everyone looked for guidance, but at the same time, a most able scientific writer, and a practical experimentalist whose discoveries have proved invaluable to the profession.

Another most indefatigable worker was John Penn, of Greenwich. He was one of those ever-active, ever-vigilant beings, who are never satisfied with anything that is not absolute perfection, and it may be said, that his magnificent reputation was based upon the practice of never allowing even the most trivial thing to pass his hands until every blemish had been carefully eliminated. Hence Mr. Penn became the one above all others amongst the "fifties," who not only made sweeping improvements in marine machinery, but, in accordance with the dictates of true practical science, developed the best proportions for his engines, thus considerably reducing their weight, and greatly increasing their elegance and suitability of arrangement.

When screw machinery was first employed in the old wooden ships of war, the engines of the period were found objectionable on account of their height exposing them so much to danger from shots above the water line. Mr. Penn therefore introduced his beautiful horizontal double trunks, which soon became highly appreciated at home and abroad. On the other hand, he superseded the old-fashioned and cumbrous paddle engines by his splendidly designed oscillators, which also greatly increased his fame. So much indeed was this the case, that with these two classes of propellers alone, he practically became the Engineering Dictator of the Admiralty, by whom he was entrusted with almost endless orders for machinery, which enabled him eventually to amass a princely fortune.

To the outer world, the Science of Engineering is about as little known as ancient Greek, and this is not to be wondered at, as the public have so few opportunities of comprehending, even in a popular manner, the methods employed for producing results of the most stupendous and far-reaching character. Perhaps, indeed, hardly any but the initiated can realise the fact that there is simply nothing that we can eat, drink, wear, or use in any possible form, that does not owe its excellence and cheapness to the facilities of manufacture and transport created by the engineer, although the means employed to attain these ends are necessarily obscured.

The millions who cross the Forth Bridge, for example, see for themselves the successful accomplishment of a colossal scheme which, after all, is simple in design when compared with the complex machinery of ten or twelve thousand ton ocean racers. And yet, these multitudes of people have in nearly every case not the slightest idea of the extensive and varied calculations involved in the planning of the structure, the machinery employed in its construction and erection, the difficulties that arose during these periods only to be successfully overcome, or of the constant vigilance entailed upon the responsible people from the beginning to the end of the undertaking.

The main branches of the profession, known as "Civil" Engineering, are very numerous, and include everything that has completely revolutionised the resources of the world during the present century, and enabled man to utilise the forces of nature in an infinite variety of ways. The popular belief is that there are two great branches—Civil and Mechanical—the former relating to all statical erections in brick, stone, concrete, earth, timber, and also in iron and steel. Whereas, the latter is supposed to cover the thousand and one more or less complicated dynamical systems of machinery that now exist.

The word "Civil," however, when thus applied, means, in reality, an entire disconnection from *military* engineering, just as the term "Civil Service" refers to one thing, and "the Army" to another. The five letters arranged as above are therefore authoritatively intended by the Institution of Civil Engineers in London to comprise everything that relates to the profession in its very broadest sense, apart altogether from the construction of fortifications, etc., which come under an entirely different set of laws.

Civil engineering, therefore, includes endless arrangements, great and small, for facilitating and improving internal communications throughout a country, and also for the transport of merchandise and passengers.

Works connected with the sea coast, and for facilitating communications between the sea and the land, such as harbours, docks, piers, breakwaters, sea walls, lighthouses, etc.

Works for facilitating communications across the seas, including every possible description of sailing or steam vessel, and also everything connected with the laying and maintenance of telegraph cables, etc.

Works in great variety for the reclamation, irrigation, or drainage of land.

Everything in cities and towns that comes under the supervision of the city engineer, the water engineer, and the gas engineer.

Girders, columns, beams, and all other constructional ironwork, employed in warehouses and buildings of every possible description.

Everything connected with the mechanical operations of mining and metallurgy.

The design and construction of engines driven by steam, water, wind, compressed air, gas, electricity, etc. And here we enter upon an inexhaustible field, which includes :—

The design, construction, and application of an infinite variety of machines and appliances used in the manufacture of all the above, and also in the manufactures of the world at large.

And last, but by no means least, the design and construction of great guns and little guns, and other munitions of war, including those mentioned in the previous chapter.

A somewhat approximate idea of the extent of ground covered by Civil Engineering, and also of the manner in which its ramifications extend along every degree of longitude, and between every parallel of latitude, from 80° north to 70° south, may now be formed.

Sir Ronald is well acquainted with many of the above branches, and is a perfect master of some of them, or, as they say in the works, quite a " dab hand." And this, through a series of fortuitous circumstances, so brought his talents into public notice that he has been insensibly led on, until at last the successful accomplishment of a colossal undertaking won for him the honour of knighthood, and carried his fame throughout the globe.

All this did not happen by chance. The E. E. had for many years past been collecting the cream of engineering practice, which he carefully condensed and noted. The aforesaid midnight oil had been frequently used beyond the smallest hour of the morning, whilst occupied with the preparation of simple rules and tables of proportions deduced from what he had seen and known most intimately about. Also with sketches of work actually accomplished, and having the dimensions of principal parts alphabetically tabulated in note books. Thus reducing the labour of working out calculations at a future time, either in general plans or on detail working drawings, and giving confidence to the designer in matters of strength and arrangement.

Brief memoranda, data, and tit-bits of information had been obtained from every conceivable source, and the results of experiments on a *large* scale in metals, timber, and all other materials were diligently collected, collated, and tabulated as above. The technical journals, and all the best books of the day, were either read or carefully examined, and the titles of hundreds of specially useful articles entered in a good reference volume, systematically compiled and indexed during the course of many years.

All this had been done, and much more besides, and thus the secrets of engineering were brought to some extent, at least, under immediate control for profitable employment when required. In short, Sir Ronald had raked the profession longitudinally and transversely, under, over, and through every one of its phases that might possibly be useful to him, and hence he was ready to take the tide at the flood and be carried by it into fame and fortune when the opportunity presented itself.

Perhaps some philanthropist, or member of the S.P.C.A., may here exclaim, "Well! Well!! Well!!! How *can* an engineer stand all this hard labour? Do not his mental faculties rapidly wear out? Does not the poor gentleman become careworn, and lined in features, and grey haired when he ought to be otherwise? In short, do not his arduous labours break up his constit*oo*tion and shorten his days?"

We think not. Slightly modifying Shakespeare's remark, the occupation that fascinates the intellect keeps us ever green in body and mind, and keeps us also in splendid health. I once asked a well known London engineer why some of the old and wealthy eminents in his city did not retire and leave the field to others. He replied, that "if they did so it would kill them, as they liked the mental excitement, and thus were induced to remain in practice as long as possible." After everyone but himself had gone to bed, Sir William Fairbairn used frequently to sit up till two in the morning busy with his writings and calculations, as a finish to his ordinary day's work, and yet he lived to the age of seventy-eight. Sir Joseph Whitworth died at about eighty-four. Sir Robert Napier, of Glasgow, nearly reached eighty; James Watt, eighty-three; and so on with others whom we need not mention.

To give my own experience on this point, it may be added that during my apprenticeship in Messrs. Denny's, I had the rare privilege of being allowed to make sketches from the shop drawings, and also from the actual work in progress, so that I could be enabled to produce complete finished scale drawings in Elevation and Plan, etc., at home. These dimensioned sketches were made during part of the dinner hour, and in light evenings after a six-to-six day's work. Sometimes, also, on Saturday afternoons, when compelled to hurry on with the desired particulars before the engines were taken down and sent to the ship.

This often entailed much more labour than I had expected, but as it proved an absorbing employment, I was frequently not in bed until about half-past one in the morning, and out of it again at 5.30. At that period, and indeed all through life down to the present time, I have enjoyed magnificent health, and this no doubt has been due to a primarily sound constitution, temperate living, and continuous occupation of a very varied character. Hence, we may conclude that it is not constant work of this nature that injures the health of people in general, but the *worries*, big and little, that sometimes beset those who have not power to rise above them.

In professional matters Sir Ronald was most exacting, but at the same time very lenient, so long as accidents occurred that were *not* preventable, and so long as mistakes were made through temporary mental blindness no one could explain. He himself took care that working drawings should be as perfect as possible, and specifications incapable of contrary reading, or even of hazy comprehension; but if, in spite of these precautions, anything went wrong, it had to be rectified at all hazards.

Besides the study of technical books and journals, Sir Ronald had been a very extensive reader of good general literature, which not only gave him a more comprehensive and thorough grasp of ordinary knowledge, but sometimes incidentally threw side lights upon knotty points of professional practice. He was also an admirer of the works of nature, which had so often exhibited to him the most wonderful skill in elaborate design, and indicated many things which engineers have certainly copied, or which at least, have given them fresh and good conceptions.

Where, for instance, did the idea of hollow columns and beams come from, but from birds and animals, whose whole structures combine in themselves the greatest possible strength and lightness of parts, with a faultless arrangement of details?

From what source did the safety valve for boilers emanate? No doubt from volcanoes, as our own sphere is only a gigantic boiler shell filled with fluid lava, which in *itself* can do no mischief. Let, however, the internal working of the earth cause cataclysms of water to rush upon the above, and then high pressure steam will be evolved in quantities sufficient to disrupt perhaps a whole continent, and create a calamity unheard of since the Deluge. All over the Pacific region this could easily be accomplished, and the only thing that prevents the coast line of the surrounding countries, and some of the island groups, from being shattered or swallowed up are the very numerous neighbouring volcanoes which act as outlets for the overwhelming forces beneath.

Where did the idea of perpetual motion come from but from the movements of the planets? Here again, men have tried to imitate nature, in this instance, however, ineffectually, and, although the schemes of some of these individuals have been theoretically perfect, Force of Gravity, Frictional Retardation, and Atmospheric Resistance, have baffled their efforts tooth and nail, and at last most hopelessly beaten them.

Whilst we have been chatting about Sir Ronald's professional accomplishments, he himself has been brilliantly entertaining those around him by humorously relating a few of his own curious experiences, and entering into conversation generally on all subjects. At this very moment he is thus engaged with those charming young ladies, Fenella Seymour, Mary Macpherson, and Emily O'Brien. Just note their expressions of delight as he appears to unfold something they did not know before. The truth is, however, that he is cunningly eliciting their opinions in the "What do *you* think?" sort of style, and unconsciously causing them to feel that they are much more attractive and clever than they imagined they were. When, too, Sir Ronald found out that our imaginary Mr. Browne was in the employ of the Acme Engineering and Shipbuilding Company, nothing could have exceeded the kind manner in which he interested himself in his welfare, and gave him a few valuable hints from his own experience which Mr. B. most highly appreciated.

As a lecturer or speaker upon various subjects, our good friend had a marvellous power of winning attention, not by a display of high-toned oratory, or profound learning dry-as-dustily delivered, but by his own admirable peculiarities of mind and manner that enabled him with little trouble to throw out *germs* as well as gems of thought, to the delight of his audiences, who were thus enabled to retain in memory much that would otherwise have been forgotten.

In matters of faith Sir Ronald was quite as simple and as practical as Frances Ridley Havergal, or General Gordon, on whose lines he tried to run as closely as possible. And this, as he had often proved, was a splendid protection from the evil effects of those anxious cares and worries, that sometimes eat the vitals out of people, and greatly prevent them from obtaining happiness amidst the vacillations and uncertainties of life.

The evening reception previously mentioned came to an end, as usual, and as each lady or gentleman departed, the last words addressed to Sir Ronald were—"*delighted* to have met you"—"*charmed* to have seen you," and so on. Mr. Browne also said "good-night" to his kind friend, and felt as he did so that *this* Eminent Engineer was in no degree less advanced in those qualities of mind and heart which alone can ennoble "great men," than he was in his professional attainments.

Perhaps one of the most important lessons to be drawn from the history of advanced scientists is that success in life can only be obtained through well-directed and sustained efforts, or, in other words, through close application and critical observation, as the ambitious well know. There is, however, another class of people, who, as apprentices, expect similar results with the very least amount of trouble, and these, as we can feelingly testify, are too often the plague of works and offices, where their pernicious example is demoralising to others. So much, indeed, is this the case, that in some instances the powerful influence, or handsome premium that ought to benefit them, becomes an all round and unmitigated evil, as we shall somewhat sketchily indicate.

One of the secrets of Sir R. Osborne's promotion in early days was that his excellent qualities were well known to his employers, who kept him in view for better things as time rolled on. For the same reason, the foremen supplied him with good work because they knew that he would execute it satisfactorily, and thus much was learnt that would otherwise have been missed.

It may not perhaps be generally understood that a manager, or managing partner knows exactly what goes on in the works from day to day. Suppose, for example, that a firm has received an order to build with all speed two 23-knot gigantic twin screw ocean liners, to be named *Seringapatam* and *Masulipatam*. Mr. Dashe, the engineering partner, at once gives the chief draughtsman his instructions, and as quickly as possible working details are issued to all departments, as we shall describe later on. The castings and forgings soon begin to roll in, to the ever-increasing interest of Mr. D., who is vigilantly watching every movement.

"Anything new transpiring?" was a question he put one day to the foreman of the pattern makers.

"No, sir," said Mr. Wood, "we are pushing on as fast as possible with everything," and finally adds, "I have just heard that one of the *Masulipatam's* hundred and twenty-inch cylinders has been so badly cracked that they will have to cast another."—

A similar visit to the officer in charge of the erecting shop reveals the important fact that "everything is coming in first-rate, and the new hands are doing well." "But," said that gentleman, "there seems to be a serious flaw in the *Seringapatam's* starboard crank shaft you might look at before going away, as we are finishing it off in the lathe." An immediate inspection of this dreaded evil, and slight notching with the edge of a half round file showed, clearly enough, to the delight of both, that the crack was only superficial, and that the final cut would take it completely out.

The light machine shop is now visited in the course of the morning's ramble, and as Mr. Turner, the foreman, is questioned in the usual style, he replies:—

"We are getting on as quickly as we can, sir, with the *Seringapatam's* gear," etc., etc., and ending with, "By the by, Mr. Dashe, what *am* I to do with that little divvle Smith? He's *most* unreglar, and when he *is* here, he does nothing but lark about and keep the hands off their work?"

Mr. Dashe already knows too much about this youth, including the unwelcome fact that it is his father for whom they are building the aforesaid ships, and, therefore, decides in his own mind that it will be better to bear the ills that are apparent, than run the risk of unconsciously giving offence to his highly-valued friend. He also thinks that in this case he should pay no regard to evils that are beyond remedy, and therefore quietly observes to his excellent and amiable foreman, as he departs for other scenes, "I have already written to Mr. Smith about his son, and am afraid we cannot do anything at present."

The mind of the now exasperated Mr. Turner becomes big, big D—ily occupied with such phrases as "little beggar," "little brute," and so on, and at once gives Mr. Albert Edward Victor Smith a "*step of promotion*" by taking him from his ill-treated planing machine to one of the usually coveted vices, on account of the excellent hand tool work they provide.

If the engine and boiler room ladders, gratings, and handrails for a Royal Yacht want burnishing all over, Mr. Smith gets the job to do. If a few hundred studs require to have their points toshed off, the same young gentleman has to perform the operation—with a worn out file. If the greasy and grimy main bearing brasses of a tug undergoing repairs want titivating, they are lifted up tenderly and taken with care to A. E. V. Smith, Esquire. In short, if there is any work, no matter how dirty and disagreeable, that can be reserved for this youth, it is sure to be kept in store for him. Until at last, bullied and contemptuously treated by the foreman, he leaves the "dirty old place" in disgust, to the delight of everyone.

Nothing in life became him so much as his renunciation of Engineering, as he was a senseless, heartless, vapid sort of fellow, with more money than wit, and one whose sole aim was to amuse himself, as much as possible, to the annoyance of others, under cover of his own youthfulness, and no doubt his worthy father's influence.

Examples of the Osborne and Smith types of apprentice are sometimes to be met with, but, generally speaking, our "cub engineers," as the Americans term them, lie between these two extremes. In any case, however, their success in life depends very much upon themselves, and on the manner in which they utilise the advantages of early training in works and offices.

With the object of indicating what some of the "Eminents" have done, let us compress their history into the smallest of nut shells, as follows:—

Archimedes originated a few good things that might have become universally beneficial if Plato had not interfered with him, and thus stopped all progress until *James Watt*, the uncrowned king of practical scientists arose, and with a few master strokes of genius, laid the foundation of the gigantic structure erected by his successors.

In 1788, *Patrick Miller*, a retired Edinburgh banker, made a few experiments on his own lake of Dalswinton, in Dumfriesshire, and succeeded in introducing Steam Navigation on a miniature scale, thus paving the way for its employment on the Forth and Clyde Canal in 1801.

In the year 1812, the first passenger steamer "Comet," engined by *Henry Bell*, began to run from Glasgow to Greenock, amidst the difficulties inseparable from a very shallow and mud-banky river.

In 1814, *Denny*, of Dumbarton, commenced the building of ships and steamers, and was followed by *Laird*, of the Mersey, in 1829. While *Napier*, *Caird*, *Penn*, *Maudslay*, etc, rapidly developed the powers of marine engines. And as these could not well be made without good constructive machinery, *Whitworth* effectually solved the difficulty as we have already shown.

Encouraged by the results of his Stockton and Darlington Railway, in 1825, *Stephenson* recommended another to be made between Liverpool and Manchester. This was opened in 1830, and at once began to revolutionise the travelling resources on land, just as they were being similarly treated on the water.

Fairbairn rapidly organised the best arrangements of mills and mill gearing, waterwheels, land engines and boilers, and also iron bridges, including those famous structures across the Conway river and Menai Straits.

Bramah introduced his hydrostatic press with its silently overwhelming power, which to this day has proved invaluable. Whilst *Armstrong* invented his own system of hydraulic machinery for cranes, and various other purposes, and this, too, has proved indispensable even to the present time.

Nasmyth, by means of his steam hammer, made the grandest "*hit*" ever known, because he enabled the aforesaid eminents to perform what they would not otherwise have been able to accomplish. And amongst a galaxy of miscellaneous talent, may be mentioned *Richard Roberts*, of Manchester, who made improvements in textile machinery, which coined wealth for nations, if not for himself.

These great engineers, and many others in different lines of practice, thus brought, as it were, their blocks of granite, some of ten tons, twenty tons, thirty tons, and so on. Thus gradually building up and consolidating that magnificent and enduring edifice known as the mechanical branch of Civil Engineering, which has left its mark for all time on every portion of the earth's surface. In the foregoing remarks, we have tried to indicate what has already been done, and how it has been accomplished by talented people, whose career has been to some extent exemplified by the "Eminent" described in this chapter under the assumed name of "Sir Ronald Osborne." What may further be accomplished is impossible to predict, as there are many highly gifted engineers still amongst us, and more of them springing up. We fancy, however, that full scope will be found for their labours in new lines of thought, as present practice has been so exhaustively developed.

Who can tell in what manner a few of their grand ideas of the *flash* description may yet cause the unapplied, or perhaps misapplied, forces of nature to be beneficially utilised. One thing, at any rate, is certain, and that is, that if during the next century engineering science is advanced as it has been during the present one, marvels piled upon marvels, now but dimly foreshadowed, or perhaps undreamt of, will be in store for the Coming Race, which will no doubt revolutionise everything in hitherto untrodden paths.

CHAPTER XIV.

NOTES FROM A MODERN CARGO LINER.

Description of Ship—A Model Engine Room—The Machinery and its Peculiarities—Progressive Movements in Marine Engineering—Methods of Reducing Weight — Lightened Framing — Marine Machinery from three points of view—Engine Room Staff at Sea — Single Guide Piston Rods — Improved Arrangement of Cylinders—Valves and their Working Gear—Link Motion of to-day—Present style of Bed Plate—Standard Design for Principal Details—Auxiliary Gear—Economical Steaming—Table of Proportions of various Engines — Experimental Sea-going Performances—Modern style of Rig.

As an excellent example of a very popular North-East Coast type of ship, chiefly used for cargo carrying purposes, we may here refer to a specimen of a class very extensively built by Sir William Gray & Co., of West Hartlepool, and engined at the Central Marine Works of the same Company. These steamers are highly appreciated on account of their variously interesting and important features, particulars of which have been kindly supplied by the firm.

The ship to which I paid a special visit was the S.S. *Macduff*, of 2,905 tons gross register, 4,300 tons dead weight capacity, and 1,500 horse-power, a description of which will perhaps be more generally useful to readers than if she had belonged to the limited class of gigantic ocean mail steamers.

Externally, the vessel had a very symmetrical appearance as she lay in the water nearly ready for a voyage to China, and this was partly due to a well shaped hull, smart rig, and a funnel quite the proper size to suit its surroundings. Her name was mounted in handsome brass block letters, which save unnecessary trouble every time a new coat of paint is put on the vessel, thus contrasting very favourably with the system of lettering directly on a plane surface.

The deck was of teak, with steel plating underneath, and the builders had taken care to arrange most conveniently the steam winches, and all other upper crust gear.

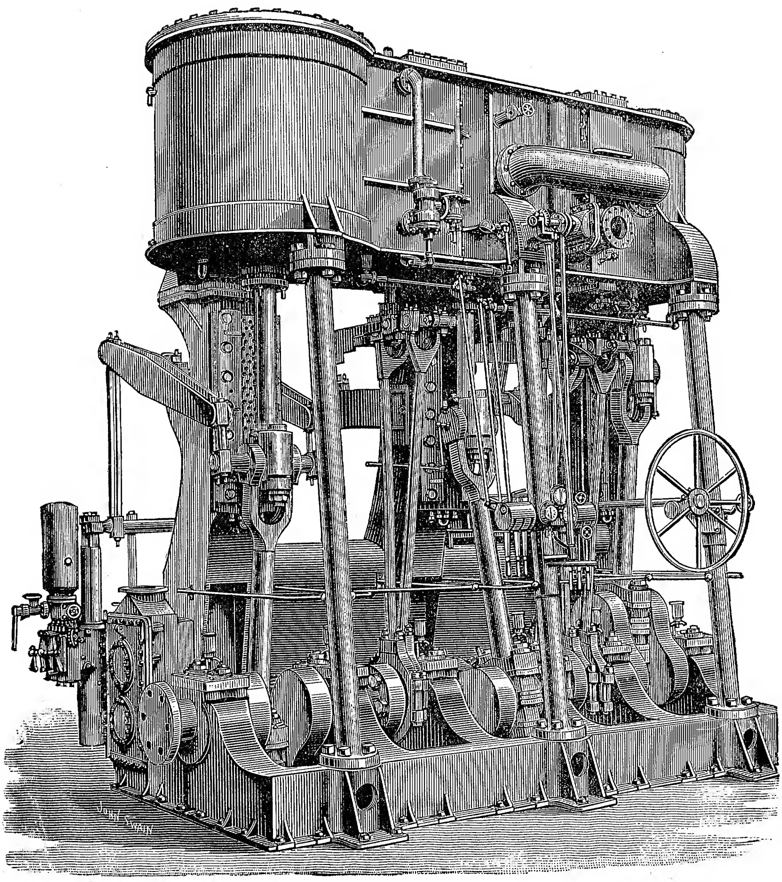
The engineers' and navigating officers' quarters were placed in the waist of the ship, with the usual alleyway between them and the engine and boiler departments. This, we may remark, is a very popular arrangement for Eastern ships, but not suitable for North Atlantic liners on account of the cold and stormy weather to which they are so much exposed. Hence, in the latter vessels the gentlemen referred to are snugly housed below out of the way of the gigantic seas that frequently create immense havoc, sometimes when least expected. The cabins just noted vary in appearance from the elegant and artistic saloons of a P. and O. steamer, to the dens of some of the ocean tramps that have often caused one to think that at least a little more comfort might have been given to those who spend most of their time in them.

Upon entering the engine room, we stepped at once on a very neat and suitable arrangement of platform, with the usual handrails, and main entrance ladders to the lower regions. Everything seemed to have been carefully considered, and all the gear on and around the tops of the cylinders had a very trim appearance. There can be no doubt that it is most desirable to have at least a well finished upper level to engines, as it is the only part visible from the deck, and can easily be made to look attractive. In this respect, however, we have seen much of a peculiar nature. On the one hand, unmitigated dirt and squalor, and on the other, a magnificent arrangement that was truly delightful to gaze at.

Under the courteous guidance of Mr. Dick—the chief engineer—we went below, and here I found the same liberal system adopted throughout, which made the engines and boilers, feed heating, feed pumping, and all other gear easily accessible from every point of view. The design of the engines, too, greatly helped to increase their general get-at-ability, and also the free access of light from above.

A very good and comprehensive view of these is given in the adjoining Plate, which clearly shows some of the leading features of this type of machinery. Two of the most noteworthy being the wrought iron column method of supporting the cylinders, and the shoe block, or slipper guide connections for the piston-rod crossheads, both of which deserve a few special remarks.

In the early days of the once famous side lever paddle engines, their framings were of cast-iron, in the Roman Doric, and Gothic styles of architecture. They were also very massive, and utterly at variance with the principles of good design. Mr. Robert Napier, of Glasgow, noted these defects, and accordingly introduced his own extremely elegant, light, strong, and infinitely more suitable wrought iron columns for supporting the main shaft entablature, and also for diagonally staying the latter to the cylinders. By changing, therefore, the style



TRIPLE EXPANSION ENGINES OF S.S. *MACDUFF.*

Cylinders—25″, 40″, *and* 65″ *diameter.*

Stroke—3′ 6″.

Standard Size—according to Maker's List of I.H.P.—1300.

Normal I.H.P.—as per North-East Coast Institution Rules—1500.

of framing from cast to wrought iron, Mr. Napier brought about one of the most sweeping practical innovations ever introduced. So popular did it become that all the other engines of the day—steeple, vertical trunk, grass-hopper, oscillator, etc.—adopted it, except the inverted direct action screws, whose framing was much the same in outline as it is now in some of the largest ships. Towards the beginning of the "sixties," however, the new arrangement came into favour even with the last named, but was, nevertheless, very sparingly used.

During late years an increasing change has set in in this direction, as extreme *lightness* of details is aimed at through the employment of improved designs, and hence the system of framing adopted by Mr. Mudd, and many others, is in the ascendant, even for engines of great power.

The fitting of these columns is of the simplest kind, as their bodies are finished all over in the lathe at one setting. The required spreading out at the feet, for extra stiffening of the structure, being attained to any extent by planing the seats for the column flanges on bedplate and cylinders to the proper angle. The bolt holes are rhymered out in the usual way, and when the bolts are tightly driven into them, and the nuts screwed hard up, the whole fabric is as solid as if it had been cast in one piece.

This system of framing has now become extremely popular with many firms on account of its various merits. With engines, however, of the largest class, running at high speeds, it is generally considered advisable in the merchant service to adopt the box columns, with spread out lower ends; but, even here, we have many examples in recent practice which clearly indicate that those of the *Macduff* type can be safely employed even in the most powerful machinery. One of the best illustrations of this, drawn from past practice, was to be found in the Inman S.S. *City of Richmond*, whose compound cylinders of 76″ and 120″ diameter, by 5′ stroke, were supported by four 11″ diameter columns to suit the double guide arrangement. And, what is still more remarkable, many large naval engines of recent date have a similar style of framing, *back and front*, without the aid of any other supports.

There are various ways of looking at marine engines and boilers, and all their surroundings. One being from the *draughtsman's* point of view, which includes the provision of a very compact and suitable arrangement of machinery, and the proper proportioning of every part. The *manager* sees for himself that these are well carried out, but also takes into consideration the simplest methods of executing the work in the shops. And, finally, the *sea-going engineers* mentally take every detail to pieces, and look only upon their efficient and economical maintenance, and freedom from breakdowns, and also upon their easy accessibility in every direction. Hence it will be seen that, when the above combination of talent is brought into play, the very highest results are sure to follow.

So far as the last named are concerned, it is only right to add that *their* peculiar experiences are gained by night and by day, in sunshine and in storm, when everything is going right, as well as when a trivial failure occurs, or a general smash up takes place in their midst. They, therefore, learn in the most practical manner, not only how to keep the machinery of a ship in continuously good order, but also how to rectify a disaster with the greatest speed when it actually happens, and at the same time, to prevent even the possibility of an accident.

The wrought iron column system is particularly adapted to the *Slipper Guide* arrangement, which is remarkable for simplicity and compactness, and, indeed, was used by Maudslay & Field for very many years in all their horizontal engines, even of the largest size. Amongst other firms at the present time, Palmer, of Jarrow, has the same style of detail for Government engines of similar type. And Hawthorn, Leslie & Co., also of the Tyne, employ a modified slipper for their horizontal machinery up to at least 4,000 horse-power. In this case, however, an elegant and compact arrangement results from using a rectangular stay bar to tie the cylinders to the crank shaft frames, thus producing lightness, as well as strength and suitability, as the guide block that works over it is on the sliding socket principle, and capable of easy adjustment for wear, etc.

With the ordinary slipper for vertical engines, the surface must necessarily be less on one side than on the other, as will be clearly seen by inspecting the Plate. This weak point is easily enough got over by driving them ahead in the direction which throws the whole of the strain from the piston crosshead continuously upon the large bearing surface of the guide, and also upon the solid resisting frame at the back of it. The lesser bearing surface is only brought into operation when the engines are going astern, and as this is generally at low speed, the excellence of the arrangement becomes at once apparent.

The above systems of construction intimately affect the design of marine engines, and also the comfort and convenience of those who attend to them at sea. They are both well tried, and worthy of confidence alike from shipowners and engineers. They are each capable of producing decreased weight of parts, and the wrought iron framing is all the more desirable on account of its beautiful simplicity, the full admission of natural light which it allows, and also the free access to, and unobstructed view of, every working part around the crank shaft. Especially is this the case in twin screw ships, where the central bulkhead cramps the engine room space and seriously interferes with the lighting of this department.

Another important feature in this class of machinery is the arrangement of the H. P. cylinder *between* the other two, instead of having it at the forward end. This modification tends to promote economy, since the high pressure cylinder is naturally the hottest, and its loss of heat is much reduced by giving it a central position. The receivers are placed on each side, so that the radiation of the steam jacket is utilised for drying the steam contained in them.

The cylinders are placed centro-lineally equidistant from each other, with the object of insuring interchangeability of each length of the crank shaft. They are also supported at the back by three cast iron columns springing from the condenser, and carrying the aforesaid slipper guides, whilst their fronts are securely fixed to the top flanges of the turned columns previously described.

In some engines the cylinders are brought closer together, with the valves at the back. These, however, are operated by means of Mr. Mudd's patent arrangement of "dynamic gear," which only requires one eccentric for driving ahead and astern. It also possesses very few working joints, and is easy of disconnection and adjustment at any time. In spite, however, of these important advantages, the link motion is frequently preferred in cargo ships, and is now universally adopted by the builders.

This beautiful gear is still very popular in these vessels, hence we find it in the machinery of the *Macduff*, although it involves greater length of engines, double the number of eccentrics, and six crank shaft bearings instead of four, which the other arrangement easily admits of. It is made adjustable at every joint, whilst the steam reversing engine of the "all round" description, is neatly placed upon the condenser, with the usual starting wheel in front of the machinery, as shown in the Plate. This gear has also an indicator attached to it, the pointer of which travels round a dial, thus showing exactly the position of the links at any time, which is very useful when going in or out of port. It will also be seen that the handles for working the engines are placed on the centre column, within a space of two feet, so that every movement can be kept under the most perfect control.

In very many engines of the past, the *Bed-plate* was carried by two longitudinal keelsons alone, thus allowing the part underneath the shaft to be unsupported. Now, however, it is considered advisable to make the box girders of the bed-plate flat on the under side, so that they may bear solidly throughout upon transverse keelsons in addition to the usual longitudinal supports. A further reason for this is the facility with which the bottom of the casting can be planed to enable it to lie perfectly true upon iron erecting tables.

When the bed-plate is placed upon the above tables, a steel boring bar, having automatic rising and falling and traversing feed motions, is put through the whole of the seats of the bearings in the casting, and after it has been set perfectly true, the circular shaping of their bottoms, and facing of their sides, are carried on simultaneonsly. All the main bearings are of white metal, which is run into strong cast iron blocks, that can be taken out for examination, or refitting, at any time, without removing the crank shaft. After these blocks are accurately fitted to the recesses made for them in the bed-plate, and their wrought iron caps screwed down, the steel bar is finally employed as before in boring them to suit the shaft. It will thus be seen that this process ensures absolute truth in every respect, and the complete freedom, even on long voyages, from the least tendency to heat when working.

From a constructive point of view, this system is highly advantageous, as all the building operations connected with a set of engines may be performed with a degree of accuracy and simplicity otherwise unattainable. To many, this plan may appear unnecessarily expensive at the outset, compared with the timber foundations that have long been very popular in some of the largest establishments. It has proved, however, so highly satisfactory for the reasons given, that the Central Marine Company have greatly extended its application in their own Works.

The *Crank Shaft*, as will be seen, is of the usual built description, and is made throughout of Siemens-Martin ingot steel, each of the three pieces being exactly similar. The crank-pin bearings of the *Connecting Rod*, like those in the bed-plate, as above described, are lined with white metal, and are thus enabled to run continuously without requiring the cooling application of water.

The upper ends of the *Connecting Rods* are of the good old Medo-Persian style, which the fluctuating changes of engineering practice for the last forty years have never been able to abolish, or even to amend; except, indeed, in the case of larger engines, where a different kind of piston crosshead is used, thus causing the forked ends to be made similar to those attached to the crank pin.

The *Air Pump Levers and Links* will probably remain as they are for the next hundred years or so, unless, during the interval, the marine *steam* engine of the present has been superseded by some other arrangement. The former have always been much the same as those shown in the Plate, but the designers of the latter have been vacillating in their ideas, as the solid butt and strap rod, the tee head rod, etc., have had their day, and been almost discarded in favour of the double rod link, which is the most economical on account of its easy forging and machining. And here, it may be added, that one of the marked innovations of modern times has been the introduction of details that involve the greatest amount of *lathe* work, which, as remarked in a previous chapter, is the least expensive to perform.

The *Tail-rods* are conspicuously absent, even in the largest cylinder of the *Macduff*, as it is found that by making the rim of the piston junk ring a little deeper than usual, they can easily be dispensed with. The remaining parts of the engine gear hardly require to be commented upon, as they are very similar to those in other ships, and will probably remain unaltered for some time to come. It may be noted, however, that although the cylinders are closely bolted into one compact mass, those of larger size are frequently detached, as their expansion, when heated by steam, has sometimes produced cracks that might otherwise have been avoided. When thus arranged, the tops of the columns, or the cylinders themselves, are stayed to each other so as to avoid this evil, and the valves are placed at the sides, and worked by Hackworth's, Morton's, Joy's, or other modern gear.

During our visit to the lowest floor in the engine and boiler rooms of the above ship, it was easily discoverable that the best modern appliances, suitable for such a vessel, had been adopted. These included Weir's feed-heater and evaporator, special Worthington pumps for feeding the boilers, and a few others that need not be specified.

The platforms, ladders, and handrails, were all that could be desired to promote the comfort and convenience of the engine room staff. Long ago, the first named were of a handsome open diamond pattern in cast iron, which looked well, and was easy to walk over. Now, however, wrought iron round bar gratings are most generally used instead, and, although they seem only fit for the boiler room locality, they are nevertheless desirable on account of the free access of light and good ventilation which they certainly permit. Hence in this, as in many other cases, practical considerations are allowed to overrule those of a merely æsthetic nature.

The S.S. *Macduff* has proved eminently successful as an economical cargo carrier, and the excellence of similar engines of different sizes by the same firm may be gathered from the fact that the S.S. *Inchbarra*, having engines with 27″, 43″, and 72″ cylinders, 3′ 9″ stroke, and 160 lb. steam, has carried 6,272 tons of cargo at a continuous speed of 10 knots an hour, on a coal consumption of 20·3 tons per day. And the almost sister ships, *Rangativa* and *Tekoa*, have made round voyages from London to Australia and New Zealand with practically the same results. That is, they have run from Teneriffe to Auckland, a distance of 12,059 knots, at the above speed, without once easing or stopping the engines, whilst the consumption of coal for all purposes, including main engines, and electric and pumping machinery, was only $21\frac{1}{4}$ tons per day, which contrasts in the most marked degree with the black diamond allowances of ocean racers of the same freight capacity.

The annexed table of proportions of various engines and ships built by Sir William Gray & Co., and by the Central Marine Engine Company, of West Hartlepool, will no doubt prove useful, as it indicates some of the most approved dimensions of details for different powers, and will help to confirm the remarks in later chapters upon engine design.

Upon the arrival of the *Iona* from a recent long voyage, the engines were overhauled as usual, the ship cleaned, painted, and loaded for a new trip, until her mean draught became $20' \ 7\frac{1}{2}''$, corresponding to a displacement of 4,430 tons, and in this condition she was taken out for the purpose of undergoing a complete series of experiments by Professor A. B. W. Kennedy and a powerful staff, under the auspices of the Research Committee on marine engine trials at sea.

The primary object of these was to ascertain from every point of view the capabilities of the engines, boilers, and propeller, so as to form a trustworthy basis for future operations. And, although the tests were efficiently carried out by the practical scientists, they were at the same time checked by the chief engineer, Mr. J. F. Brown, who, with his own staff, rendered valuable

TABLE OF PROPORTIONS OF TRIPLE ENGINES.

Name of Ship	*Reggio.*	*Iona.*	*Macduff.*	*Tekoa.*
Diameter of Cylinders	16½", 26", 44"	21⅞", 34", 57"	25", 40", 65"	27", 43", 72"
Stroke of Cylinders	33"	39"	42"	45"
Standard size of Engines, as per maker's list of I.H.P.	500	900	1300	1600
Normal I H.P. as per North-East Coast Inst. rules ..	590	1110	1500	2180
Revolutions per minute	74	67	65	63
Diameter of Crank Shaft ..	8½"	10¾"	12½"	13"
" Tunnel Shaft ..	8⅛"	10¼"	11¾"	12½"
" Air Pump	14½"	17"	20"	24"
" Circulating Pump	6½"	10"	12"	12"
" Feed and Bilge Pump	2½" and 3"	3" and 3½"	3¼" and 4"	3¾" and 4½"
Stroke of all the Pumps ..	20"	26"	26"	28"
Condenser cooling surface, in square feet	809	1360	2189	2570
Number of Boilers	1	2	2	3
Diameter of Boilers	13' 9"	13' 3"	15' 6"	13' 0"
Length of Boilers	10' 0"	10' 0"	11' 0"	16' 0"
Natural or forced draught ..	Natural.	Forced.	Natural.	Natural.
Total heating surface, in sq. ft.	1600	3160	4530	7140
Total fire grate surface "	50	42	137	220
Steam pressure, in pounds ..	160	160	160	160
Diameter of Propeller	12' 3"	14' 6"	16' 3"	17' 3"
Pitch of Propeller*	—	—	—	—
Surface of blades, in sq. ft. ..	45	63	80	97
Length of Ship	231' 6"	275' 0"	320' 0"	365' 0"
Breadth of Ship	32' 0"	37' 4"	40' 6"	47' 0"
Depth of Hold	14' 0"	19' 0"	24' 5"	26' 5"
Immersed L. D. midship section, in feet	463	692	859	1034
Register tonnage	1218	2094	2905	4050
Dead weight carried, in tons ..	1620	3100	4300	6220
Displacement at L. D., in tons	2520	4430	6216	8808
Speed, in knots, at L. D. ..	9	9	10	10
Consumption, in tons, per day	6½	11½	17	21

* Differentiated, according to special practice adopted at the Central Engine Works.

assistance. Mr. Brown subsequently conducted an independent trial of about eleven hours duration, the results of which agreed very closely with those previously obtained. It may be added, that the boilers were fitted with the forced draught system of Mr. J. R. Fothergill, the superintending engineer to the owners, under whose supervision the machinery was constructed.

The detailed objects of the trial were chiefly to ascertain the total *quantity of coal* burnt per minute, per hour, per square foot of grate, per square foot of heating surface, and per indicated horse-power. The *quantity of feed water*. The *carbon value* of one pound of coal—the *calorific value* of the same—the *efficiency* of the boilers and engines separately and combined, and a variety of other particulars too numerous to mention. The result of the trials proved that with the feed water at 106°, after passing through the measuring tank, the consumption of coal was 1·46 lbs. per indicated horse-power per hour, but at 159° of temperature this was reduced to 1·38 lbs., which closely corresponded with the long voyage performances of the same steamer, whose fuel expenditure ranged from 1·39 to 1·41 lbs. per hour.

The Report upon these tests and its discussion by those interested are far too exhaustive for anything but passing comment. They were, however, practically conclusive, and were considered so important in their bearings upon Marine Engineering Science as to be not only minutely recorded in the *Proceedings of the Institution of Mechanical Engineers* for April, 1891, but to a large extent also in the technical journals of the period, to which reference may be profitably made.

It sometimes happens that fashions run to extremes, as they are now doing so far as the reduction of sail power in steamers is concerned. Especially is this the case in twin screw ships, where it can be most appropriately accomplished, owing to the practical impossibility of their becoming helpless at sea. Single screw vessels, on the other hand, are liable to complete disablement in the most unexpected manner, but, even at the worst, jury spars and canvas can be fitted up that may prove very serviceable until assistance is obtained.

When the White Star S.S. *Celtic* broke down, many years ago, the voyage from New York to Queenstown occupied fully three weeks, but even then she could make five knots an hour under sail. Since that time, however, pole masts without a single yard have been adopted, even in some of the largest single screw steamers.

Our frontispiece, the twin S.S. *Empress of India*, gives a good idea of what masting has now become, when not so many years ago she would have been a full rigged barque or ship. The most advanced type has, however, been adopted in the new Cunarders, *Campania* and *Lucania*, whose two simple pole masts will act most efficiently for signalling and steadying purposes, if for nothing else.

CHAPTER XV.

COMMENCING A NEW ENGINEERING AND SHIP-BUILDING ESTABLISHMENT.

How Mr. Baxendelle and Mr. Farquharson became Managers at the Works of the "Great West Sou' Western Engineering and Ship-building Co. Limited" — Resignation of Mr. B. and Mr. F. — Commotion amongst the Employés—Their loyalty to the departing Chiefs — Difference between Public Companies and Private Firms—Projected "Sirius Works" of Messrs. Baxendelle and Farquharson — Operations begun on the Tyne — How a New Establishment is organised—Large Contract with the "Rising Sun S.S. Co.," of London—Science of Design—Drawing Office—Preparation of Working Plans—Changes in Practice—Failures and Successes—Difficulties of high-class Designing.

In previous chapters we have touched upon the subject of Constructive Machinery, because it so closely affects the commercial success of engineering and shipbuilding firms in general. This will be fully apparent when it is considered that while accomplished designing may lead to fame and fortune, the want of skill in the manufacturing processes may end in serious loss. Hence the greatest attention ought to be exercised in the selection of machines that facilitate every operation to the utmost. The recent developments of strike movements, too, have rendered this all the more necessary, on account of the delay and annoyance they have so often caused.

Having already described the leading features of the

Works, we shall endeavour to show what takes place when a new establishment is set in motion for the production of the highest class of steamships, and introduce by degrees the various people who individually and collectively bring about such important results.

There are two distinct species of engineers to be met with from time to time, one of which includes those who remain faithful to a single firm for an almost unlimited period. In other words, they begin as apprentices, then become draughtsmen, assistant managers, then full managers, and perhaps partners, or even sole proprietors. They thus come to know every rope, and block, and pulley, and also the system of navigation, throughout the whole ship, so to speak, but nevertheless, want expansion in more diversified lines of thought and practice. The other marked species of professional is an individual who loves variety, and who, after his apprenticeship expires, roams about with the object of bettering himself in some way or other, by continuous changes, but never remaining long enough in one place to gain much solid advantage. These, however, are extreme cases sometimes to be found in the oldest and most famous establishments. A *medium* course is to be preferred, as it gives one quite sufficient variety, and allows enough time for acquiring general information of an important character.

Let us now suppose that Julius Frederic Baxendelle, and Hector Maclean Farquharson, are two professionals of the intermediate type, who, under these assumed names will occupy a conspicuous position in the following pages. The former is an engineer of the John Elder class, who, during many years' practice, accumulated an immense amount of valuable experience in various Works, until, at last, he became the highly esteemed Manager for the

Great West Sou' Western Engineering and Shipbuilding Company Limited.

Mr. Farquharson had also been for a long period similarly occupied in the sister branch of shipbuilding, until eventually he was promoted to the rank of Commander-in-Chief in the yard of the above immensely celebrated Company. In course of time, however, these gentlemen naturally enough concluded that they could not do better than combine their talents in working an establishment of their own, which they decided to plant on one of the banks of the river Tyne, somewhere between Newcastle and the sea. Mr. Baxendelle's and Mr. Farquharson's resignations were accordingly sent in to the Chairman of the Directors, and preparations were shortly begun for making a new departure, which they expected would be successful, as it was well understood in influential circles that the celebrity of the G. W. S. W. people was entirely due to the skill and energy of the uncrowned eminents who were now leaving them.

No sooner was this proposed movement made known throughout the Works, than it set all the hands regretfully thinking about their good friends who were so soon to depart; about their successors who might treat them otherwise; and also about the numerous shareholders who did not care a single pin for any one of them. Like the little girl who said that as "father had died, and mother had married again, and mother had died and father had married again, she did not know whom she belonged to," so was it with those in the Works. None of them knew whom they would have to serve, beyond the new managers who might not take any kindly interest in them, and therefore a feeling of uncertainty spread over everyone.

There is often a silver lining to the dark clouds of adversity, and in this case it showed itself in a promptly formed desire to go to Newcastle with Messrs. Baxendelle and Farquharson, who, upon being applied to, at once accepted the services of all the draughtsmen and foremen, who thus found their minds unexpectedly relieved. The former were delighted at the prospect of splendid practice in the preparation of *completely new* sets of drawings of engines, etc., upon Mr. Baxendelle's patented and highly valued system. And the latter were equally glad to have the opportunity of helping to build up the fame of their own esteemed employers, by organising the executive part of the business on the very latest and most improved lines. When the men learned that the foremen were going to leave, their requests to be "taken on" at the new establishment were simply overwhelming. These, however, were acceded to as far as possible, during the early stages of the undertaking. That is to say, the patternmakers, turners, fitters, erectors, etc., were to be employed by degrees as soon as work was ready for them.

The apprentices also conceived the happy idea of going to the Tyne, but this, for obvious reasons, the G. W. S. W. Company would on no account permit, so they had just to stand by the old ship and await coming events. Thus it came to pass that the principals in the new firm had, unconsciously attracted towards them a powerful staff of most efficient workers, who were anxious to do their best under all circumstances. And the cause of this was that they all recognised the advantage of being with employers who could at least show that they took a kindly interest in their welfare.

The excellence of this system, so highly developed by many private firms of the past, is too well known to need much comment. It is the only one to which we were accustomed during many years' practice in the works, and it is highly satisfactory to be able to say that in no instance did a strike ever take place amongst the engineers. In some of the shipyards, however, there were several most unjustifiable disturbances amongst the "fifties," but the men who created them were chiefly of the labourer class, who were just as easily led by agitators as they are still throughout the country.

One of the most appropriate examples of the private firm system is to be found in the history of the Cunard Company under the reign of Mr. Charles MacIver. This gentleman ruled like an absolute monarch. He kept none but the best hands about him. He paid them well, and treated them kindly, and caused them to feel that *his* interests were *their* interests, and that when once in his ships they might consider themselves settled for life. This no doubt supplies one reason for the unparalleled freedom from loss which attended his Atlantic liners from the year 1840 to 1880.

It must not be imagined that the above remarks upon Limited Liability Companies are intended to apply to all of them. What has been said, however, is merely to indicate the difference that must necessarily exist between such undertakings and private firms, similar to those whose systems of working we had so long the honour of knowing intimately in a variety of ways, but which have now become more or less vitiated by the peculiar developments of modern labour, and by the changes that have thus been induced.

The first movement Messrs. Baxendelle and Farquharson made when they found themselves at liberty, was to bend their whole energies towards the organisation of the projected "Sirius Works." Small scale plans had primarily been made of the ground showing the general arrangement of the various workshops upon the lines that have already been mentioned. These again were shown on larger scales in elevations, sections, and detailed views in various drawings. Specifications and quantities were prepared, copies of which were sent to several local firms for the purpose of obtaining complete estimates of the cost of building, and after these had been received and examined, the contract was handed over to a Newcastle firm, who at once began operations.

During this period, orders for the required constructive and other machinery, including driving engines, boilers, cranes, lathes, planing, slotting, drilling, etc., machines were placed in the hands of Messrs. Whitworth, Hulse, Smith & Coventry, Shanks, Craig & Donald, Galloway, Ransome, Robinson, etc., which we need hardly say gave these firms very great pleasure. Firstly, because they all knew the two principals of the "Sirius Works," and were anxious to give them a preliminary lift into prosperity; and, secondly, because they greatly admired large contracts for *new* establishments, where they could have unlimited scope for the introduction of all their very latest improvements, many of which have already been described.

As we have now set the builders and engineers generally in motion, let us enter upon another scene of activity in which Messrs. Baxendelle and Farquharson and their draughtsmen are fully occupied in temporary offices. It may here be well to mention that in old establishments, where very many thousands of drawings and tracings have accumulated, there is a large amount of copying work done, or at least something akin to it. For example, an order has been received for a set of engines of about the same power as a previous set, but differently arranged to suit the wishes of the owners.

Under these circumstances, original plans, sections, and elevations of the engines complete, also of the general arrangements of engines, boilers, screw shafting in the tunnel, and a great variety of other gear throughout the ship will have to be made, as in other cases. Many fresh detail sheets will also have to be prepared, but a large number of the latter will consist of old tracings altered a little in red lines and dimensions, and with, say the following written clearly upon them :—" Connecting Rods for No. 1001. – 3 thus to red lines," and so on to the end of the series. Thus clearly illustrating the great saving in time and trouble that arises out of a good system of drawing office management, and the employment of large scale, accurate, and elaborate drawings to begin with.

When a *new* establishment commences operations, everything has to be designed from beginning to end, thus involving an immense amount of labour which is gradually decreased as the years roll by. Besides the drawings for engines, boilers, etc., in course of construction, numerous reference sheets of valves, and many other details in almost constant use, are most carefully got up, and the proportions tabulated for the various sizes in consecutive order, thus avoiding much trouble and delay afterwards.

All this has to be done in a great variety of ways in places like the proposed "Sirius Works," and hence it will be seen that the two partners and their staffs have very much to occupy them, by night and by day, for some time to come, as the "Rising Sun" Company of 333 Leadenhall Street, London, has entrusted them with the construction of three splendid ships, as an addition to their present fleet. It may be added, that some of these most successful vessels were built and engined by the above gentlemen, whilst managing the affairs of the aforesaid Great West Sou' Western, and that other orders are pending. With this in view, the reader will clearly understand the nature of the great activity that prevails in the temporary offices of the firm.

As we have now entered upon one of the most vital points in engineering practice, a few observations upon the *Science of Design* may here be introduced. Most people who examine the very complicated machinery of a great steam ship, and take into consideration the extreme care, and skill, and vigilance that are unceasingly employed in its design, construction, and management at sea, will probably wonder how any of it could ever give way. And on the other hand, when they contemplate its multiplicity of parts, and the extremely severe usage they often receive in bad weather, it may appear surprising that breakdowns do not more frequently occur. As the object of engineers, however, is to prevent even the possibility of accident in any sense, we hope to show how their good intentions are carried out, and also how they are occasionally frustrated.

It will not be too much to say that some of the engineering failures of recent times have been due to improper design. Formerly many of these were caused by secret flaws in the metals employed. Such, however, is the present excellence of the materials supplied by the Iron and Steel works, that no danger need be apprehended on *their* side, at least. Because not only is the very highest skill employed by the metallurgists, but the greatest security is insured by means of the elaborate system of testing now so general. Therefore, it is to the responsible people in the drawing office who produce faulty plans and working details, and to the managing engineer who approves of them, that we may attribute a few of the imperfections of modern date. When this is not the case, however, we must ascribe the breakdowns of shafts, propellers, pistons, furnace crowns, and general disablements of engines and boilers, either to occult causes no one can discover, to flaws that only develop themselves in working, or to bad management at sea, which in itself is quite sufficient to damage seriously even the best machinary that can be made.

The *Drawing Office* is in reality the technical seat of government of any establishment, as it locks or unlocks the whole of its resources, no matter how extensive, and either makes a great undertaking successful, or otherwise, according to circumstances.

This will be apparent when it is stated that—theoretically speaking—a complete set of working drawings and tracings for machinery of any kind, ought to be so clearly expressed in the required number of views, to a sufficiently large scale, and so accurate in lines and figures, that, to the workmen, they are self-explanatory and capable of exact reproduction in the shops. So completely should the drawings allow this operation to be carried out, that if all the machined parts of a 10,000 horse power set of engines for an ocean racer were laid out in order on a vast floor, they could at once be erected in position without any more labour being expended upon them.

In practice, however, there is always a considerable amount of adjustment to be performed by filing and scraping, and by finishing to the exact length of shafts, rods, pipes, etc., which in some cases are purposely made too long to allow for rectification before every detail can be brought to its proper bearing. And this, in connection with the skilful arrangements of parts to suit the end in view, is the true cause of the marked success of so many of the largest and finest ships, the continued maintenance of which, in actual work, is largely due to the proper proportioning of every part to enable it to resist the greatest strains that may arise, and to the able management of the sea going engineers who have carefully to guard every part in motion from possible injury. It may be added that there is nothing too small to escape the lynx eyed vigilance of the manager and drawing office staff, of the foremen who supervise the work in the shops, and of the chief engineer and his assistants, either while overhauling the machinery in port, or when driving full speed across the ocean.

In mercantile ships, as well as in those of the navy, many changes have occurred during recent years, not so much, however, on vital points of design as in the utilisation of the latest improvements that could help to reduce the total weights in engine and boiler rooms, and by the extensive introduction of steel. So much, indeed, has this been the case with many ships, that in some instances, according to authentic reports, the safe limit of strength was somewhat underrated.

In the above lightening process, engineers were for a time very successful, but changes affecting the strengths of engines and boilers were thus introduced which might wisely have been avoided, as the advantages to be gained were more apparent than real. The fact was, that the total weights of machinery had been so much reduced as to occasionally endanger its safety when full power was put on. Hence, in some cases, a diminished speed was considered advisable for ordinary steaming. Many proofs could be given of this, but perhaps the most noteworthy are to be found in connection with the naval manœuvres of 1888, when H.M.S. *Rattlesnake*, built by Messrs. Laird Brothers, was the only ship of her class that was never in trouble. This, moreover, appears to have been due to the extra strength that had been judiciously given to her machinery throughout.

One of the curious features of modern engineering is the resuscitation of old ideas that have become obsolete, either because they were in advance of the times, or were superseded by some newer arrangement. For instance, the compound engine was known long before Mr. Elder made it a practical success, and although triple expansion machinery was invented and constructed in 1872 by Mr. Ferguson, of Messrs. Fleming & Ferguson, it was not until Messrs. R. Napier & Sons fitted it to the S.S. *Aberdeen*, in 1882, that its merits became generally appreciated.

On the other hand, the steeple engine for screw and paddle steamers of all sizes, was extremely popular amongst the "fifties" and "sixties," and indeed formed one of the leading productions of Messrs. Tod & Macgregor, who supplied it to nearly all the ships of the Peninsular and Oriental, Inman, and other Companies at that period. These engines were remarkable for beauty and lightness of design, easy get-at-ability of all the parts, and full admission of light from the deck downwards. At last, however, they became obsolete owing to the introduction of modern improvements, but in the year 1890, Messrs. Laird made a new departure of special interest, which involved the application of the above style of engine under entirely altered circumstances.

In 1879, this firm built the express paddle steamer *Violet* for the London and North-Western Railway Company's Dublin and Holyhead service. Her original oscillators had cylinders 78″ diameter, by 7′ 0″ stroke, indicating 3,200 horse-power, while the speed of the ship on trial was 17¾ knots. After running most successfully for upwards of ten years, the Company decided to increase the speed to 19 knots by putting in new engines that would not only occupy the old fore and aft space, but have considerably greater power. This, Messrs. Laird accomplished, by making the machinery of the triple expansion steeple description, having cylinders 44″, 70″, and 108″ diameter, by 6′ 6″ stroke, whilst the steam pressure was increased from 30 to 140 pounds per square inch. By placing the low pressure cylinder in the middle of the ship, and the other two on each side of it, the balance of the machinery was conveniently sustained. And as the cylinders were bolted to the keelsons direct, and other modifications were adopted, the new engines were fully enabled to give out the required power and speed, whilst their total weight was reduced 25 per cent.

As previously stated, the true causes of some of the greatest failures and successes in engineering generally, have been due either to bad or to good design. On the one hand, perhaps through inattention to small but important details, and on the other hand, in some cases, to the experience of a life time judiciously employed. A really excellent design for anything new is by no means easy of accomplishment, indeed, the perfection of our present machines and engines of every description is owing to the skill and vigilance bestowed upon them during very many past years; to the gradual weeding out of every faulty part that showed itself in working; and also to the introduction of many valuable improvements.

The mental efforts that bring about such happy results are usually of the direct inductive species, but, strange to say, many of the very best arrangements have been caused by flash-thoughts somewhat approaching inspiration, after the scheme had been temporarily given up. A considerable number of the most profitable inventions of the age have been thus originated or developed, hence the simple, though illogical method of obtaining the desired end, is occasionally to become oblivious to it, as the following example out of many from my own experience will help to show.

Some years ago, a gentleman who had made himself obnoxious to the Brazilian Government by meddling with State affairs, came to England to try his fortune in a new line of thought, and accordingly invented an "Improved" type of Hydraulic Steering Engine, which he hoped would be immensely successful. He came one day with an ill-conditioned, sprawly, and most imperfect miniature model of his gear, and asked me to prepare all the working drawings, so that the apparatus could be made at once and put into ships.

As there was so much room for improvement, I at once tried to squeeze the machinery into the smallest possible space consistent with good working, and heie lay the difficulty. After making a few rough sketch designs for development in the usual way upon a large sheet, I pertinaciously held on to the plan in case I should lose the thread of my reasoning, and have some difficulty in finding it next day. On a vital point of arrangement I spent all my energies in vain, and at last put the drawing aside in the "we'll see about it in the morning" sort of style, and went home to a greatly delayed dinner.

Whilst, however, on my way up the fashionable street of our city, gazing at various objects of interest, all at once the very thing I had wished to know flashed upon me, and brought me up with a jerk. The idea was immediately sketched, worked out during the evening, and next morning the plan was fully matured. Many good designs have been similarly originated, indeed, the history of some of them bristles with most interesting facts, as the following will show.

From 1755 to 1850, numerous attempts were made to perfect the sewing machine, all of which failed until, in the latter year, an ingenious mechanic invented a new arrangement that appeared to solve the difficulty. As he had no money to help him, one of his friends advanced forty dollars to pay the working expenses, whilst another granted the use of his fitting shop, tools and workmen. The machine was completed and set in operation, but, like its predecessors, was unable to do what was required. Worn out with labour by night and by day, and with nothing but penury in front of them, the mechanician and financier eventually trudged homewards, and at length pensively sat down to rest upon a pile of logs in the city of Boston, little knowing that upon this midnight scene gigantic issues were hanging, to which the past hundred years had only been leading. Whilst discussing their sad fate, the capitalist was struck with an idea which he communicated to his friend, who at once saw a ray of hope. They immediately returned to the workshop to make the suggested slight alteration in the machine, and at last the genius and perseverance of Isaac Merritt

Singer were rewarded. Since then the manufacture of this machine has been extended to different parts of the world, one magnificent establishment alone on the Clyde, covering no less than 46 acres, with buildings from one to three stories in height, and employing 6,000 hands, whilst the proprietors of the invention have acquired fortunes amounting to many millions of pounds.

The difficulties experienced by the creators of many splendid inventions have been of the most marked description. For example, a good idea has been flashed upon some individual who has accordingly thought over it by night and by day, tried most earnestly and persistently to develop its practical features, and used up all his capital only to find in the end that the scheme was a *mechanical* failure.

In course of time some one else appropriated the discarded idea, discovered where improvements could be made, and enthusiastically developed its powers upon his own lines, and to his own entire satisfaction, little knowing that *commercial* failure awaited him, because people could not be induced to employ his patent engine, etc. Number Three now appeared on the scene, and after carefully noting the causes of failure in each case, made alterations that so much reduced the cost of manufacture as to insure his own prosperity, and that of all who employed his "patented invention," which, as we have shown, was founded upon the unrewarded efforts of those who perhaps died in poverty, or sunk into oblivion.

As an example of the difficulty of sometimes discovering the real originator of a valuable design, it may be mentioned that a few years ago I visited the works of an engineer who is known throughout the world for the excellence of his productions. As I knew he had for an extensive period occupied a highly responsible position with a firm whose name is a household word almost from pole to pole, I thought I should pay my kind friend an indirect compliment by referring to this fact, and by adding at the same time:—"What magnificent machinery Mr. Dashe used to make—how beautiful in outline!—how exquisite in finish!"

"Oh!" said my pleasant companion—with the charming ease and simplicity which so much adorns the characters of great men—"Mr. Dashe never designed any machinery in his life, *I* did it all for him."

This was quite an unexpected revelation, and as I gazed around at the splendid work in progress, I could not but feel that the productions of the present justified the somewhat boastful remark. At the same time my admiration of the works of Mr. D. was in no way diminished, as I knew he had been the head and front of his own establishment from the beginning. Here, however, we have a good example of the manner in which the talent of one individual may become universally known, whilst that of another may not be revealed until some fortuitous circumstance brings it to light.

Few people have any idea of the immense labour frequently involved in a high-class new design for machinery, whose object is the greatest simplicity of parts, and compact and general suitability of arrangement. When everything is done that can be done in this respect, clients may sometimes wonder, when looking at a beautifully simple and skilfully planned set of drawings, how such apparently high fees are asked by those who prepared them. Here, however, it may be said, that these plans being the result of great experience, save a a large amount of expenditure in material and workmanship, and produce in the machinery that is made from them the best and most economical results in working and in maintenance. The splendid examples of every description at present in use were thus designed, and hence they are enabled not only to perform their various operations much more rapidly than formerly, but in many cases to do things that were once impossible.

In the mechanism of birds, fish, and also in that of the whole animal creation, we find absolute perfection. But in the works of engineers who have to deal with the propelling machinery of steamships, the highest range of human intellect, and the best and most perseveringly directed efforts have not been able to attain the same standard of excellence, on account of the insurmountable difficulties that so frequently arise in practice. Nevertheless, our learned brethern deserve the highest praise for what they have so rapidly accomplished in the realms of Naval architecture and Steam navigation, whose successful application depends so much upon the *Science of Design* to which we have in this chapter briefly referred.

CHAPTER XVI.

OPENING OF THE "SIRIUS WORKS."

Finishing touches to the Buildings—Machinery in position—Magnificent Display—Titles of Firms—Opening Day Preparations—Arrival of Visitors—How Mr. Baxendelle "Bossed the Show"—The Lunch—Continued Survey of the Premises—Remarks of the Local Journals—Chiefs of the Executive Departments—"Bill Ogden"—System of Government in the Works—Chief Draughtsmen — Ordinary Draughtsmen — Source from which modern "Eminents" are drawn—Apprentices—Lady Tracers—Photographers—Foremen—Leading Hands—Workmen.

As described in our last, Messrs. Baxendelle & Farquharson and their staffs have been extremely busy in making the necessary preparations for giving employment to as many hands as possible in every department of the Works immediately upon their completion. The builders have also been very actively engaged, and everything has progressed to the entire satisfaction of those concerned.

The foundations have been carefully attended to, as well as the walls, etc., erected upon them. The massive cast iron stanchions for supporting the roofs and also the girders for sustaining the travelling cranes and their heavy loads, have been well bedded on concrete. The iron roofs have been set up and finished so as to give plenty of light. The lofty chimneys are completed, indeed, everything has been done from an architect's point of view that could in any way add to the future success of a really handsome and skilfully designed establishment.

For weeks past the floors of some of the shops, especially those for turning, etc., have been littered with light and heavy castings, and boxes containing the productions of our good friends, whose names have so often appeared in former pages. We may here remark that the details of polished machinery are carefully protected from rust, and unless too large for such treatment, are packed in strong boxes similar to those now before us. The engines and general machinery, which they partially contained, have now been erected on the solidly based, perfectly perpendicular, and dead level system previously mentioned, which is so indispensable for producing good and accurate workmanship.

The rubbish of a timbery kind has been removed, and on gazing around we see with admiration a magnificent array of turning, planing, slotting, drilling, and other machines and engines of various sizes ready for use, the beautiful works, indeed, of those whose names are cast on the framings in the massive Egyptian style which has been retained to this day. *Roman* lettering is not only difficult to make, but unsuitable in every way for such purposes, hence the land of the Pharaohs has all along been kept conspicuously to the fore, in this respect, by engineers of all classes. The extensive ranges of belting have been rigged up, and under the direction of the representatives of the firms who supplied the fixed and movable plant, things have been touched up all round, with the object of making a highly attractive show for a large company of ladies and gentlemen, who, to-morrow, are to grace with their presence our opening-day entertainment at the "Sirius Works." Hence the anxiety of Messrs. Whitworth, Shanks, and all the rest of them to put their best feet foremost, and have everything in exquisite order.

We are vain enough to imagine that the title of the new establishment has been wisely selected, as it cannot in any way be assimilated with the very celebrated "Neptune Works," of Messrs. Wigham Richardson & Co., in the same locality, who have made the name of our sentinel planet their own distinguishing mark. Messrs. B. and F. have adopted that of the monarch of the *stars*, as it is simple and expressive, easy to write, and contrasts sufficiently with its neighbours. And here it may be observed, that the titles of some firms are unpractically long, which is all the more surprising when Mr. Charles MacIver, ever so many years ago, set a good example by changing the ponderous designation of his "British and North American Royal Mail Steam Packet Company," to the simple "Cunard Line." And no doubt the trouble that people must have had who were so often obliged to write "The Great West Sou' Western Engineering and Shipbuilding Company Limited," in their letters, etc., may have induced Mr. Baxendelle to avoid such a *sirius* mistake.

The day was done, the night came on, but all hands were kept working late putting in the finishing strokes in every department, and giving the whole of the machinery a final trial under steam. The floors were now swept clean, the last touches of paint laid on the building, all the gear of the establishment made to look as beautiful as possible, and at midnight everyone departed in the expectation that the opening proceedings would prove eminently successful.

The long wished for morn was one of sunshine and splendour, and left nothing to be desired. By 5 a.m. the foremen were on the premises making preparations for giving employment to the hands they had previously engaged. Up to 6 o'clock the men poured through the gates in large numbers, but so systematic had been the arrangements that everyone had his appointed place to occupy, and every machine, as far as possible, its special work to do. The castings and forgings, too, that had been accumulating in the yard for some time past were now conveniently placed in the shops, so that the turners, planers, etc., could at once begin upon them in accordance with the detail tracings and heliographs affixed to boards in their immediate vicinity.

Before the breakfast hour had arrived, a very fair start had been made, and without noise or fuss of any kind, everything and everybody had fallen into their grooves, as far at least as could be done in such a very limited space of time. This, however, was largely due to the fact, that all the hands were well known to the foremen, who had mentally assigned to them the machines to which they were most accustomed. Hence a great deal of trouble and delay were saved that could not otherwise have been avoided.

In the shipyard things had progressed quite as favourably under the able direction of Mr. Farquharson, and as immense quantities of plates, and angle irons, also keel-bars, and stem and stern posts, etc., were lying about, the heating, bending, and machining operations generally could at once be commenced.

The forging and boiler departments, as well as all the others, were rapidly set a-going step by step, and thus the idle establishment of yesterday was now a scene of active industry, in which many minds and many hands were taking part. As everything on the premises, and in the sky above, was wearing its brightest aspect, and as the workmen looked quite smart in their clean white ducks and navy blue serges, our opening ceremony promised to be in every sense of the word a most notable event in the history of the new firm.

By 11 o'clock the expected visitors from the adjacent neighbourhood, and from a distance, were assembled inside the works, and after a most courteous reception from Mr. Baxendelle and his partner, were at once started on a tour of observation. The ladies and gentlemen comprising the party little knew what was in store for them, or that they were chiefly under the guidance of one who was not only a master of the Science of Engineering, but the happy possessor of the art of placing its too often dry-as-dust features before people in a fascinating style. Canon Kingsley, of Chester, could give charming lectures upon the most commonplace subjects, such, for instance as "The coal of the mine"—"The stones of the field"—"The slates of the roof," and so on. And similarly, Mr. B. can make a "scrap heap" so brilliantly scintillate and shine through his profound knowledge of its contents, combined with natural eloquence, refined wit, and numerous striking illustrations, that those who listen to his address will never forget it.

On the present occasion he has every encouragement to put forth all his powers, and give his friends ample food for future reflection. In this, however, he will be ably assisted by the representatives of the various firms who supplied the machinery, and who will only be too happy to bear a hand. The result of these combined efforts will be that when the visitors depart, they will take with them such delightful reminiscences of what they have seen and heard, that in years to come the present tour through the "Sirius Works" will prove a source of pleasant retrospection.

As Mr. B. was quite as thorough in everything he did as General Butler at the siege of Richmond—though in a different way—and as he wished to enable his friends, at the outset, to have as clear a view of engineering matters as possible, he took them at once into the principal machine shop. After a few general explanations upon things around them, he brought them all up to one or Mr. Hulse's truly magnificent lathes, and here he gave them an exhaustive lecturette upon its various uses and properties. With the help of the man who worked it he had the belt thrown, in sleight of hand fashion, from step to step of the driving cones, with the back motions successively in gear, thus illustrating the effects of such gradations upon the speed and power of the machine. The same belt-shifting process was repeated, but with these motions *out* of gear, which showed in a very marked degree how easily the number of revolutions could be increased, and also the beautiful effect of slip in the belt whilst gradually bringing into rapid velocity such a heavy and inert mass as the 15′ 0″ diameter faceplate, which in future will have to perform most important work.

The application of the shifting head was explained. The various slide rest movements, either for turning or surfacing, were fully illustrated. In short, every salient point was commented upon, until at last the visitors obtained a unique insight into the characteristics of the monarch of machines that greatly delighted them. The shafting and smaller lathes, etc., were also described, and special care was taken to show how screw cutting of all sizes, out of the solid metal, could be performed with ease and accuracy by means of the Change Wheel system.

From one point of vantage to another the visitors were taken, until they also became quite on easy terms with the peculiarities of the planers, slotters, drillers, etc., with which the place abounded, and also with the forgings and castings that were lying about on all sides. They were next piloted into the erecting shop, but here there was an unavoidable air of vacuity that would, however, be shortly dispelled, although, perhaps, under the circumstances, it was a welcome relief to some at least. But even here Mr. Baxendelle had many things of a very interesting and important nature to communicate, which greatly pleased his audience.

The whole strength of the company now adjourned for lunch in the general office of the establishment, which formed part of a separate building containing the admirably lighted, heated, and ventilated offices required for the commercial and scientific staffs, and the members of the firm.

The excellent entertainment provided for our friends afforded an opportunity for exchanging ideas upon things in general, and what they had seen in particular, and in this respect everyone seemed to be marvellously successful. Nothing could have exceeded the genial and happy way in which Mr. and Mrs. Baxendelle, and Mr. and Mrs. Farquharson and their amiable daughters treated their guests. We will not say that these ladies were "handsome," because undue stress is too often laid upon mere externals, they certainly were, however, in every respect, most attractive women, and eminently possessed that simplicity of character which must ever make the fair sex all powerful wherever they may be.

After a few complimentary speeches had been made, through some of which the anticipated "success of the 'Sirius Works'" seemed to run like threads of gold, the investigators resumed their explorations, and at once entered the machine shop of the Building Yard. Here the two chiefs of the firm clearly explained the various mechanical processes required in the construction of a ship, and gave several highly instructive practical examples. The most astonishing of which, in the eyes of the non-professionals, was the ease with which one of Messrs. Bennie's punching and shearing machines clipped and perforated a $1\frac{1}{2}''$ steel plate just as if it had been a piece of cardboard. The driving engines and boilers were next inspected and commented upon. The Forge, and Smithy, and Boiler shops, were similarly treated. The Wood-working departments were taken in detail, in short, there was hardly anything of general interest that was left unnoticed, and thus the "Opening day" performances came to an end.

On the following morning the local journals found space for at least a whole column containing an account of the proceedings, in which everyone received the greatest praise for their share in the construction of the various buildings, their internal arrangements, and also the machinery with which they were so abundantly provided. The article finished off somewhat in this style:— . . . . . . "We have much pleasure in adding that Messrs. Baxendelle and Farquharson have just laid the keels of three steamers for the "Rising Sun" Company, of which Mr. C. W. Robinson, 333 Leadenhall Street, London, is the Managing Director. These vessels are to be of 6,000 tons and 4,000 horse power each, and their machinery will be of the new triple expansion type, introduced most successfully by Mr. Baxendelle during his long connection with the works of the Great West Sou' Western Shipbuilding and Engineering Company, Limited. All the latest improvements will be utilised in every department of these ships, in accordance with the requirements of the Board of Trade, and of the Indian Trade for which they are to be specially built. We are also informed that two important contracts have just been concluded with Liverpool firms, and that other orders are pending which will give full employment to the establishment for the next two years."

Now that we have started the "Sirius Works" into full operation, let us briefly refer to the chiefs of departments under whose guidance their future success will so much depend. It may be observed that this success will be more easily attained, owing to the fact that all these gentlemen were previously well known to the principals, whose system was so thoroughly understood by the former. And here we at once disclose the reason why "old hands" are so much appreciated, or, in other words, why so much value should be attached to the services of those who for 20, 30, 40, or even 50 years, have thus become intimately acquainted with every movement that has helped to win prosperity for their employers. So fully is this recognised by engineers, that when reductions take place during dull periods, these faithful assistants are retained to the last.

We may therefore conclude that Messrs. B. and F. have entered upon their new career under most favourable conditions, as they have now in their works all the foremen, and most of the workmen, with whom they were so long associated elsewhere. The chief and also the other able draughtsmen, now so delightfully occupied, were only too glad to join the "Sirius Company" for the sake of being with a firm who knew how to appreciate their efforts, and give them every opportunity for acquiring experience on new lines.

As the Chiefs of the Executive will be referred to from time to time, we may here give some of their names—names indeed of similar officers, well and happily known to the writer during past years. All of them first-rate hands in their respective departments, and having peculiarities of mind and manner never to be forgotten.

Beginning at the seat of government we find *Mr. Winstanley* the chief draughtsman, who is quite a "dab hand" at strains, and strengths, and arrangements, and practical construction of the simplest forms, and everything else in fact, as Mr. Baxendelle well knows. As foreman of the pattern makers, *Mr. Young* is a real good sort of fellow, and much liked by all. In the turning shops we find *Mr. Jones*, a highly respected lieutenant, and one who possesses a most profound knowledge of machinery and its capabilities. *Mr. Barton*, another of the same breed, is somewhat peculiar in disposition, but makes a very admirable monarch of all he surveys in the erecting shop.

In the Boiler Works, *Mr. Ashton* is Commander-in-Chief, and has an excellent assistant, *Mr. Meredith*, who carefully watches the various manipulations under the general and most able supervision of his principal. The first named gentleman is somewhat reserved in manner, but is quite able to appreciate a good story, and laugh merrily at the witticisms of others, although his own education in such matters has been somewhat neglected. His satellite makes a very admirable sub-director, and is at the same time good hearted and amiable, and true to himself and everyone else.

As foreman of the forge department *Mr. Macqueen* is a really first-rate hand of the good old, solid, heavy, ponderous type. Almost unimpressible upon any point of general information, but nevertheless a master of the arts of steam hammer, and sledge hammer, and hydraulic forging, welding, drawing out, and setting up, in their very numerous phases. Hence a bad, or even an imperfect, weld will be with him as great an impossibility, as it was with the original character in Denny's amongst the "fifties."

Mr. William Ogden, or "Bill Ogden," as he was usually called, is to be one of the outside leading hands when the first of the ships is ready for him; at present, however, he is on the *inside* list. This personage is one of those sensitive people who are very much hurt if not considered perfect gentlemen, and although the opinions of those who knew him best may have differed materially upon the subject, this is only what one might reasonably have expected. Like many other individuals, Bill had his own idiosyncrasies, and his accomplishments were of a distinct order, as his contemporaries at the G. W. S. W. had discovered for themselves on various occasions.

He was, for instance, much more forcible than elegant in his remarks when things annoyed him. Besides this, he had a great love of "chewing baccy," and ejecting its residual essence upon the floor, or ground, or unconsciously through top engine room gratings, upon the heads and bodies of those who might be on the lower platforms. Although a kind hearted fellow in the main, he was very rough on the swell apprentices under his jurisdiction, who thought they could do as they pleased, and unconsciously retard the work of the establishment whilst they were "enjyin' theirselves," or being "ill" when there was no necessity for it.

Taken in the aggregate, Bill Ogden was a "good sort of a chap," and much esteemed by Mr. Baxendelle for his excellent all round working qualities. Here, however, we must describe the peculiar duties of the Principals, and of each member of the Executive, as they are to be found in first class establishments, where method and order reign supreme.

It may be taken as a general rule that the system of government in an engineering and shipbuilding yard is as perfect as in the army or navy, and the gradations of rank are perhaps quite as distinct. For instance, the leading partners act as *Commanders-in-Chief* of the whole of their respective forces, and take all the engineering and other correspondence, and supervision of every department entirely into their own hands. If this is too much for each of them to undertake, they will have assistants, but in any case, there will be an *Outside Manager* to look after all the machinery work connected with the ships "now building," or getting their engines in after being launched.

In those gigantic places, however, where the manufacture of iron and steel is carried on in addition to the above branches, it becomes necessary to have an independent *Manager* for each department, under the control of the *General Manager*, whose knowledge of the commercial and technical sciences combined requires to be of a very high order. As an illustration of this, we could not give a better example than the Works of Sir C. Palmer & Co. on the Tyne, which form in themselves the largest establishment of the kind in Great Britain. It is the naval and engineering commanders who negotiate with their clients regarding proposed ships, etc., but it is the latter who agree, or decline, to accept the offer of the former to build these vessels complete in every respect for so many thousands or hundreds of thousands of pounds, according to their size or number, or both combined. The estimate being based upon the cost of materials, workmen's wages, workmanship, management and staff expenses, etc., and other considerations which have been rendered necessary on account of recent strike movements.

The *Chief Draughtsman* is a member of the staff who is under the daily supervision of the principal, and forms indeed a highly valued colleague. It is these two personages who practically lay the foundations of the greatest successes, or, perhaps of serious failures, according to their professional light, and the manner in which they treat the apparently unimportant details that less experienced people so often overlook.

A Chief Draughtsman has one of the most anxious positions in the whole establishment on account of the intricacy of his responsible occupation—the innumerable calculations and figures he has to make, examine, or verify—and also the misunderstandings and occasional mistakes that are made in the shops, which the greatest care and foresight cannot always prevent. His occupation is, therefore exacting, especially while working out elaborate details upon the almost breakdown scale of strength, as well as the most complicated general drawings where pencil lines representing rods and shafts, levers and valves, framings, brackets, pipes, and all other work, are crossing each other in every direction in such apparently inextricable confusion as to be quite unintelligible to any but those thoroughly accustomed to them. For these reasons the lot of this gentleman is not always a happy, though usually a coveted one, as it is a decided step of promotion, and stands on the borders of an easier and more extended sphere of usefulness as Manager of Works, or perhaps as practitioner on his own account.

Since there are many splendid "hands" who will never have the chance of being foremen, so also are there numerous first rate general draughtsmen who will never be anything higher so long as they remain in that capacity. Fortunately, however, their path to fair prosperity may be from this point assured, if they have previously and substantially laid the foundation of success when opportunities presented themselves, in anticipation of others that might be expected. A better example of this cannot be found than in the history of Sir E. J. Harland, who was an apprentice of Stephenson's, in Newcastle; a draughtsman at J. & G. Thomson's, on the Clyde; and manager at Mr. Toward's, on the Tyne. Afterwards he held the same position in a Belfast shipbuilding yard, until he eventually became its sole proprietor. Thus originating the present gigantic and very celebrated establishment over which he and Mr. Wolff have reigned for so many years.

The *Ordinary Draughtsmen* are variously gifted, and have their own share of responsibility and independent action while in charge of sets of machinery that may be entrusted to them, under, however, the supervision of the "Chief." It is from this field that most of the eminents have been drawn, which is only natural when we consider that at this part of their career they have acquired experience quite sufficient, in some cases, to help to maintain them in the more advanced sphere of usefulness which has been kept steadily in view from the beginning. And here, in the course of our remarks upon the drawing office staff, we come to the apprentices, whose characteristics are but little known to the public. In the new edition of our treatise on *Engineering** we devoted the whole of a chapter to this important question, which no doubt has enlightened many.

The *Apprentices* in the works and offices of the highest standing are of every conceivable grade—socially, mentally, and morally. They may be aristocrats or commoners, or neither the one nor the other. They may be high-bred or low-bred, or something between the two. They may be moral or *im*moral – courteous or blunt—amiable or otherwise. In short, they may fairly represent the brightest and best characters—Penns, Maudslays, Harlands, Elders, etc., in embryo—or they may be idle and worthless in every sense of the word; those, indeed, whose shortest path to success is to retire as soon as possible from the noble profession of Engineering, and try something else.

We have long known some of the above characters, a few of which have been in my own office as pupils, and therefore, can speak feelingly on this point. Generally speaking, boys belonging to the refined but impoverished classes of society, are naturally ambitious, and often become enthusiastic and successful students. If, however, they have great, or even good expectations, engineering practice in the works may become a bore, and its science teachings a myth, because the incentive to active industry does not exist. Hence it would be well for them at the outset to consider the subject in all its bearings, and thus perhaps avoid entering upon a career where time and fortune may be wasted, which could have been more profitably expended.

* *Civil and Mechanical Engineering, Popularly and Socially Considered.*— E. & F. N. Spon, London.

The *Young Lady Tracers* and the *Photographers* are valuable modern institutions. The former are looked after by the chief draughtsman, who supplies them with the necessary drawings and instructions, which are very carefully attended to in every respect. The result being neatly lined, figured, and coloured copies of the originals. If these, however, are to be heliographed in white lines on a blue ground, the colour is left out, and various kinds of sectioning in Indian ink to indicate the different metals are used instead. The present order of things is as follows:—The draughtsmen make the drawings in pencil only; the apprentices or young ladies copy them, and at this point they are either sent into the works as tracings, or passed on to the art department, and from that to the shops as working heliographs.

The *Foremen* are drawn from the ranks of workmen, and are not only first rate hands themselves, but possess sufficient tact and knowledge of character to enable them to rule large numbers happily and successfully in their various departments. They are non-commissioned officers who know exactly how everything should be done, and how to guard against the introduction of inferior work by careless or inexperienced hands. They are also intimately conversant with the labour-saving powers of good machinery and appliances, and the systematic distribution of work, so that everything may go on smoothly and expeditiously. A foreman may be a tyrant who causes dissension or dislike where none should exist, or may be highly respectedby those under him, and, indeed, whose wishes will be anticipated by men who are faithful to their posts until perhaps paid off for want of employment, or removed by death, and of this we have had many excellent examples.

Next in order come the *Assistant Foremen*, but these are only to be found in very extensive establishments. Then the *Leading Hands*, who take charge of the construction of each set of engines from first to last in the works, and on board ship. After that we have the *Workmen* in their thousands, and amongst them are to be found the *Shop Apprentices*, who receive from them a large amount of their practical education, and the unskilled hands or *Labourers*, who do all the lifting and transfer of heavy loads from one point of a building to another. Thus we find that everything and everybody in the engine departments is arranged with great regularity throughout, so that operations may be facilitated to the utmost.

In the shipyard, a similar, but not so elaborate a system prevails; here, however, the labour is of a rougher and simpler character. The *Riveters*, *Platers*, *Wood-workers*, and *Machine Hands* generally have all their respective duties to attend to, the former being assisted by *Rivet-boy* satellites with their portable furnaces, whose aid, humble as it is, cannot be dispensed with.

In former chapters the machinery of the works was described in detail. In this one, the "Sirius" establishment has been started on a career of usefulness, and the occupations of its staff and workmen briefly referred to. It may therefore be interesting to show, step by step, in our next, how continuous and profitable employment may be provided for all of them.

CHAPTER XVII.

"SHIPS NOW BUILDING"—SPEED CALCULATIONS.

Success of the Rising Sun Co.—Their previous Steamers—Particulars of S.S. *Vencedora*, *Voltinia*, and *Vipsania*, now Building—Trip in the Sydney P. S. *Sophia Jane*, 1843—Increased Size and Speed of Ships — High Speed in Passenger Vessels — Masterstrokes of Engineers and Metallurgists — Complexities of Modern Steam Navigation — Speed, and required Engine Power—Failures of Early Experimentalists—Difficulty in obtaining Correct Results—Simple Rules—Examples from Practice—Applications of Popular Formulæ—Peculiarities of Ships—Water Tank System—United Efforts of Owners, Builders, and Engineers.

We have said that on the opening day, at the "Sirius Works," a large number of castings and forgings were lying about in the yard, and also in the inside of the machine shops. Hence the question that may have arisen in the minds of some of the visitors on that occasion was, "How did these things get there?" "By what means did these massive cylinders, condensers, bedplates, pistons, cylinder covers, piston rods, connecting rods, and a quantity of smaller gear become created?"

We shall endeavour to explain this. It is the old story of Dr. Paley's "Watch on the Moor" modernised. *None* of these things were originated by chance, because they all bore very distinct evidences of skilled design. No doubt crude and disjointed enough at present, but nevertheless indicating that highly intelligent minds must have been engaged in their production. This was so indisputable, even to the most casual observer, that we may profitably examine the secret causes of their presence, and try to show how the occult powers referred to carried out their part of the work, and how they are to be aided by the foremen and workmen, and by the machinery of the establishment previously described. Here, however, we must retrace our steps.

The Rising Sun Steam Ship Company had been very prosperous—so prosperous, indeed, under the admirable guidance of Mr. C. W. Robinson that, after due consideration, they decided to sell a few of their older ships, and build three others of larger size, thus following, to some extent at least, upon the lines of the famous Hebrew agriculturist. As several of the former ships had been built by the Great West Sou' Western Company during the reign of Mr. Baxendelle and Mr. Farquharson, the R. S. directors thought they could not do better than ask these gentlemen to construct the proposed new steamers. This decision was confirmed by the fact that the S.S. *Himalayan* and *Belshazzar*, built under their superintendence, belonging to rival firms, had proved very profitable, notwithstanding the severe competition to which they were continually exposed.

It may here be noted that Mr. Robinson's firm was not only rich, but liberal to those in their employ. In Calcutta, Bombay, Yokohama, and indeed all over the East, their ships were most cordially welcomed, and even their very house-flag was an object of interest. Perhaps the most distinctive of national flags at long distances is the Japanese, which consists of a large red ball in the centre of a field of pure white. This the Rising Sun people had partially appropriated for their own use, out of compliment to the above nation, with whom they had long traded. In other words, they had cut the Japanese ensign horizontally through the middle, and made a new lower half of blue to indicate the ocean bed, out of which the red-hot luminary is just rising. Here the firm had shewn its wisdom by adopting a long-distance distinguishing flag, which told its story quite as effectually as the similar adornments of the White Star and Anchor liners.

Another distinguishing mark was to be found in the names of these vessels, which were chiefly of ancient origin, having in every case the initial "V" and final "a." Hence, in accordance with this system, those now building are to be called the *Vencedora*, *Voltinia*, and *Vipsania*. And since the funnels of most steamers are generally of red, white, blue, and black, variously arranged, the chimneys of the above will be of cream colour all over, as an additionally notable feature.

The result of the deliberations of the Rising Sun Company was that some time before the opening of the "Sirius Works," they had requested Messrs. Baxendelle and Farquharson to prepare the plans for the new ships, in accordance with full specifications provided for them by their own superintending engineer, Mr. Delamere. Hence the temporary offices, previously referred to, soon became a scene of interest in which the two principals, with their respective staffs, were actively engaged. The leading particulars of the above steamers are as follows:—

Length over all, 440′ 0″; breadth, 48′ 0″; depth of hold, 32′ 6″; and gross register, about 5,600 tons. Each vessel to be capable of carrying a dead-weight cargo of 6,500 tons on a draught of 26′ 3″, or 7,000 tons on 27′ 6″, the engines being sufficient to enable a speed of 12 knots an hour to be obtained when fully loaded. These results will be obtained by giving them somewhat fine lines fore and aft, thus avoiding the tub-like finish of so many purely cargo carriers.

Steam steering apparatus to be provided, and all the windlass, lifting, and capstan gear to be similarly worked, thus involving additional engine power of a special nature.

The ventilation must be perfect, and the water-tight compartments and bulk-heads, water ballast tanks, and safety appliances of every description arranged in the very best manner possible. In short, all that high science can accomplish is to be utilised, with the object of making these ships complete in every sense of the term, without undue expenditure.

Their propelling and general machinery will be described later on, but here we shall make a digression, and show how the speed of ocean-liners has been worked up to its present position, and also throw light upon the methods employed for ascertaining the power required to drive a steamer at a certain velocity.

With the exception of about a six years' residence in inland Australia, I have spent all my days either in sight of the sea, or on the banks of the Clyde and Mersey. Before the age of reason, I was taken by ship, from my native city of Hobart, to Sydney, but the very earliest voyage that I can remember was from the latter to Wollongong, one fine night in the year 1843. Young as I was, I was able enough to remember this, and also other events of great importance, which happened at that period in the land of the kangaroo, and which a long-distance memory has often enabled me to recall, even to the present, for the benefit of one who was with me in those southern climes. Events, too, that will ever stand out in strong relief amidst the everyday occurences we are now so often compelled to forget, or neglect.

We left the wharf at 10 P.M., in the paddle steamer *Sophia Jane*, and somewhere about seven in the morning, saw for the first time the beautiful blue Pacific rolling in sunshine and splendour upon the rocky coast of our future home. Nearly nine hours for a run of sixty miles gives about $6\frac{3}{4}$ knots an hour, but perhaps it was $7\frac{1}{2}$, or even 8, part of the way. Of course, after the lapse of so many years, it would be impossible to state the exact speed of that once famous steamer on this occasion, nor indeed, is it necessary to do so, as the figures given are accurate enough for the purpose.

Eighteen months afterwards we returned to Sydney by the P. S. *William the Fourth*, which made about 5 knots an hour against a strong wind, and at last landed us in safety. On November 18, 1844, we sailed from that exquisitely beautiful harbour for London, in a "fast-sailing" and dangerously overloaded ship of the period, whose speed hardly ever exceeded 9 knots an hour, and even at this rate, we made the passage round Cape Horn in the unusually short period of four and a half months. From London we went to Leith by one of the grand old timber-built paddle liners, *Royal William*, whose Scott and Sinclair cast iron framed side-lever engines propelled her at the high velocity of 10 knots. During my school days in Edinburgh, and apprenticeship at Dumbarton, some important improvements must have been made, because we find that the speed of steamers had been gradually developed until, in 1856, the Cunard P.S. *Persia* could make 13 knots, and the *Scotia* still more than this in 1862.

The demand of the public for greater velocities, not only for the transit of the mails, but also for themselves, caused the White Star Company to increase the power of their vessels, until, in 1874, the S.S. *Britannic* and *Germanic* had reached 15 knots. As it was noted, however, by the other great Atlantic firms, that the ladies and gentlemen of the fashionable world flocked in large numbers to the new ocean racers of high degree, they also found it necessary to make a new departure. Hence the Guion Company introduced the *Arizona*, with a 17 knot speed. Her engines and boilers were unusually large, heavy, and costly. The space required for the extra fuel was relatively very much greater than it had previously been. The weight to be carried was correspondingly increased, and it soon became evident that the improved ship was less able to bring in freight revenue to her proprietors, or even to pay her own working expenses, than she would have been at 15 knots. It therefore became quite clear that a vessel of this kind must depend almost entirely upon passengers, and light but valuable goods at high rates, to enable her to run profitably.

Notwithstanding the disadvantages referred to, the demand for such steamers on the part of the owners, not only continued, but amazingly expanded. The *Arizona* was soon followed by the larger and faster liners, *Oregon* and *Alaska*, of the same Company. Then came in succession the ships of other Companies, including the *Servia*, *City of Rome*, *Aurania*, *Umbria*, *City of New York*, *Teutonic*, *Campania*, etc., running up the scale of tonnage and powers, until the former became 12,500, and the latter about 30,000, with a regular ocean speed of at least 22 knots, which proved commercially beneficial in spite of the enormous cost of ships and machinery, and the greatly increased working expenses thus entailed. The last named velocity has, however, been exceeded in some of Messrs. Thorneycroft's torpedo boats, where a mean speed of $27\frac{1}{2}$ knots, in smooth water, has been attained.

It may be added that the secret of the commercial success referred to lay in the great popularity of the ships with the travelling public, their position as mail liners, and also in the fact that it was much less costly to feed, say, 1,000 passengers, and from 200 to 350 or even 400 of a crew for six days, than for double the time on one voyage. And although the consumption of coal and stores used in the working of a ship on the passage was enormously increased, it was also reduced in the above proportion through the shortening of the trip.

Besides this, the general introduction of the compound engine, and of triple and quadruple expansion machinery at a subsequent period, rendered many things possible that would otherwise have been impossible. Never, perhaps, did the metallurgists appear to greater advantage than during their persistent efforts to aid the shipbuilders and engineers at this period, by the "all pull together" sort of style in which the former tried to discover the causes of mysterious failures in steel plates, etc., thus ultimately providing their learned brethren with faultless materials that enabled them to bring about simpler and better arrangements, and also a reduction in the weights of ships and engines, with a corresponding increase either in their speed or in their carrying powers.

Much may be gathered at a glance of the progress of steam navigation from its commencement, and also of what we may expect in the future, from the fact that while the speed of screw ships was increased from 9 knots in 1850, to $13\frac{1}{2}$ knots in 1871, and 22 in 1893, the velocities of their engine pistons were respectively at each of these dates, 200, 530, and 1000 feet per minute. This being the case, may we not expect, at even an approximate rate of progress, results absolutely undreamt of at present, but nevertheless foreshadowed by the events of the past? This, however, will depend upon the manner in which engineering science is developed during the next twenty years, and also upon possible changes in other directions of a purely commercial character.

As it is not everyone who knows why a ship's speed cannot be doubled simply by giving her twice the power, we may here explain the reason of this apparent anomaly.

In accordance with a well-known law regarding the passage of a solid body through water, the fluid resistance that a ship has to overcome increases in the ratio of the squares of the velocities. In other words, if for a 10 knot speed she requires 1,000 horse-power engines, it would take about 4,000 horse-power—or as 10^2 to 20^2—to enable her to overcome the increased resistance of the water at 20 knots. This, however, would be much too little, as the whole weight of the vessel has to pass over *double the distance* in the same time, hence the theoretical power required becomes 8,000, or as 10^3 to 20^3, = 1,000 to 8,000. This, however, is quite independent of the effect produced by "skin," or submerged frictional resistance, which becomes very serious when the bottom plates are heavily covered with barnacles, or other objectionable parasites.

There are, perhaps, few subjects connected with naval architecture that have received more attention from eminent scientists, or have been more extensively discussed by engineers and shipbuilders alike, during later years, than the theory of the propulsion of ships; and although the early theories of fluid resistance have been set aside in favour of newer and better ones, it appears that no really definite settlement has been arrived at regarding this most important question.

The old rules recognised the cubes of the velocities, displacement, and also area of immersed midship section, but took no notice of the skin resistance, and thus they became misleading. In course of time, however, more trustworthy formulæ were employed, as the science became better understood, partly through the efforts of shipbuilders themselves, and partly through those of the late Dr. Froude, of Torquay, who experimented with the models of ships in a large and specially constructed water tank, and was thus enabled to discover many things hitherto unrevealed.

Previous to the introduction of this system of calculation, experimentalists frequently came to incorrect conclusions, and these led, naturally enough, to unsatisfactory results in practice, and in some cases to litigation, because a ship failed to attain the contract speed. The subject, indeed, is so complicated throughout as to have given rise to an immense number of high-class lectures, papers, discussions, etc., that have appeared from time to time in various books and technical journals, to all of which we are more or less indebted.

The difficulties that have hedged about the whole question have arisen out of the extreme variation in the size of ships; in the shape of their hulls below water; in the peculiarities of their propellers and machinery; in the nature of the trade in which they are to be engaged; in the most profitable speed of the vessel either as a purely cargo carrier, or as a mail liner; and in other particulars to which we need not refer, all of which require very careful consideration so as to ensure the highest efficiency throughout.

It may here be observed that the "velocity cube" rule is specially applicable to ships whose dimensions and lines are adapted to their speeds. This becomes clear enough when we consider that if a tub-shaped cargo carrier is to be driven into the ranks of ocean racers by the sheer force of new machinery, the power will be found to increase at a *higher rate* than the above rule will allow, owing to the obstructive wave of water a bluff bow is sure to raise, which would be avoided by means of finer lines. Hence it has been found that, generally speaking, the most profitable and popular velocity for ordinary cargo vessels is between nine and ten knots an hour.

In shipbuilding as well as in engineering matters, it is often found that great exactness may easily enough be vitiated by unforeseen, or, perhaps, by trifling circumstances. Hence simple rules are extensively used when based upon sound data, and capable of being modified by means of the "allowances" which experienced professionals know so well how to employ. Indeed, these rules are sometimes so exact as not to require any correction. So far, however, as speed calculations of this nature are concerned, we may here give examples that have been verified in practice.

Take for instance, in the first case, the application of the *velocity cube rule;* and here we could not do better than quote the following trial trip experiments upon four well-known ships, which explain themselves with sufficient clearness, and show at a glance the effect of changed velocities:—

Table A.

P.S. *PARIS*.

Speed in Knots.	Cubes of Velocities.	Number of Revolutions.	I. H. P.
7·93	498	17·88	175
11·06	1353	27·00	497
12·20	1816	31·50	716
13·41	2411	35·00	1030

S.S. *MERKARA*.

Speed in Knots.	Cubes of Velocities.	Number of Revolutions.	I. H. P.
6 20	238	31·15	299
9·20	778	44·75	718
11·09	1364	54·35	1225
12·91	2151	63·23	1948

P.S. *PRINS HENDRIK*.

Speed in Knots.	Cubes of Velocities.	Number of Revolutions.	I. H. P.
12·18	1807	21·87	1259
14·19	2857	25·50	2082
16·72	4674	31·30	3678

H.M.S. *WARRIOR*.

Speed in Knots.	Cubes of Velocities.	Number of Revolutions.	I. H. P.
11·04	1346	38·00	1988
12·17	1802	44·50	2867
14·36	2961	54·25	5469

By comparing the results of very many clean-painted ships of the cargo-carrying type, Mr. William Allan, of Sunderland, constructed the following formulæ based upon the frictional or skin resistance of his own and other vessels, for the determination of speed on a given indicated horse power, or *vice versa* :—

$$\text{Speed in knots} = \sqrt[3]{\frac{\text{I. H. P.} \times 20{,}000}{L \times (B + 2D) \times \cdot 91}}, \text{ or}$$

$$\text{I. H. P.} = \frac{S^3 \times L \times (B + 2D) \times \cdot 91}{20{,}000}, \text{ where}$$

S = Speed in knots per hour.
L = Length on load line in feet.
B = Breadth of beam in feet.
D = Load draught.

As good examples of the practical value of the above, let us take the results of three steamers, for which we are indebted to the above well-known engineer :—

Steamer C. L = 265′, B = 38′, D = 19′, calculated horse power = 950. Then

$$\sqrt[3]{\frac{950 \times 20{,}000}{265 \times (38 + 38) \times \cdot 91}} = \sqrt[3]{\frac{19{,}000{,}000}{18{,}327}} =$$

$$\sqrt[3]{1036} = 10\tfrac{1}{8} \text{ knots.}$$

When at sea this vessel steadily maintained a speed of $10\frac{1}{4}$ knots.

Now let us suppose that a shipowner decides to have a vessel of the above dimensions, and wishes her to go 10 knots, the engine power will thus be found :—

$$\text{I. H. P.} = \frac{10^3 \times 265 \times (38 + 38) \times \cdot 91}{20{,}000} = 916 \text{ H.P.}$$

If we try a similar steamer, D, whose L = 258′, B = 32′, D = 19′, and calculated horse power 500, we shall find her velocity comes out at 8·47 knots, whilst her ordinary running on the ocean was at 8 knots.

And if we add, for the sake of comparison, another cargo carrier, E, whose L = 300′, B = 36′, D = 22′, and proposed I. H. P. = 1000, we find her estimated speed = 9·7 knots. In reality, however, it was $9\frac{1}{4}$ knots.

With fine-lined steamers Mr. Allan also used the above multiplier or divisor of 20,000, but adopted the coefficient ·71, instead of ·91, because the former better suited the shape of the vessels. One example of its application may perhaps be enough for the purpose, in connection with steamer F, whose L = 475′, B = 44′, D = 26′. The calculated horse power and speed in knots of this ship were 4500 and 14 respectively, the true ordinary speed, however, proved to be from 14 to $14\frac{1}{2}$ knots.

Two other simple rules for ascertaining the I. H. P. necessary to drive a vessel at a certain speed are the following, which are given with all their surroundings in Mr. Seaton's treatise on *Marine Engineering*. They were for many years the only ones employed more or less usefully by shipbuilders, according to the information they possessed, and to their discretion in choosing values for the constants C. and K.

When the *displacement* of a ship is taken into account, the first formula stands thus:—

$$\text{I. H. P.} = \frac{D^{\frac{2}{3}} \times S^3}{C.}$$

D, being the displacement in tons; S, the speed in knots per hour; C, one of the constants, and as the fluid resistance varied as the $\sqrt[3]{(\text{Displacement})^2}$, it was generally noted $D^{\frac{2}{3}}$ for simplicity.

When the *Immersed midship section* is considered, the second formula is thus expressed:—

$$\text{I. H. P.} = \frac{\text{Area of Immersed Midship Section} \times S^3}{\text{K.}}$$

K. being the other constant, which, as well as C., varies, as shown in the annexed table. As both, however, are only approximate, care must be taken that the vessel for which a calculation is to be made is similar in form, size, and speed to the one whose constants are selected.

TABLE B.

General Description of Ship.	Speed in Knots.	Value of C.	Value of K.
Ships over 400 feet long, finely shaped	15 to 17	240	620
,, 300 ,, ,,	15 ,, 17	190	500
,, ,, ,, ,,	13 ,, 15	240	650
,, ,, ,, ,,	11 ,, 13	260	700
,, ,, ,, fairly shaped	11 ,, 13	240	650
,, ,, ,, ,,	9 ,, 11	260	700
,, 250 ,, finely shaped	13 ,, 15	200	580
,, ,, ,, ,,	11 ,, 13	240	660
,, ,, ,, ,,	9 ,, 11	260	700
,, ,, ,, fairly shaped	11 ,, 13	220	620
,, ,, ,, ,,	9 ,, 11	250	680
,, 200 ,, finely shaped	11 ,, 12	220	600
,, ,, ,, ,,	9 ,, 11	240	640
,, ,, ,, fairly shaped	9 ,, 11	220	620
Ships under ,, ,, finely shaped	11 ,, 12	200	550
,, ,, ,, ,,	10 ,, 11	210	580
,, ,, ,, ,,	9 ,, 10	230	620
,, ,, ,, fairly shaped	9 ,, 10	200	600

The above rules are still popular, as they form a very good check upon the newer methods, and can be used by themselves with fewer data than are required when calculations embodying the wetted skin resistance of a ship are employed. The actual values of C. and K. are given in enlarged tables in the above volume, deduced from the skilfully analysed performances of steamers on trial trips, all of which will be found very instructive.

Let us try, for example, the last rule with the White Star S.S. *Britannic*. This ship is 450′ 0″ long, 45′ 2″ broad, 23′ 7″ mean draught of water. Displacement, 8500 tons; immersed midship section, 926 square feet; indicated horse power, 4,900; and speed, 15 knots, as a mean of eleven sea voyages.

If we wished to find the *power* necessary to drive the vessel at this rate, we should have,

$$926 \times 15^3 = \frac{926 \times 3375}{K = 620} = 5040 \text{ I.H.P.}$$

And if the *velocity* is required with 5,040 I.H.P. then,

$$\frac{620 \times 5040}{926} = 3375,$$ the cube root of which is 15 knots.

It will be seen that by the above rule the H.P. comes out a little in excess for ocean running, which is all the better for the ship. Such, however, are the resources of engineers and shipbuilders in practical data of their own, that by means of the allowances dictated by extensive experience to suit ever-varying circumstances, fairly exact preliminary results may easily be predicated, subject, of course, to confirmation by more elaborate formulæ.

A prominent cause of retardation to a ship in her passage through the water is the *skin resistance*, which in itself, under even ordinary circumstances, requires a large amount of power to overcome. Hence it follows that speed calculations, chiefly referring to displacement, or area of midship section, are not quite trustworthy, but at the same time, those which specially recognise the wetted surface resistance vary so irregularly in vessels of different size, or shape, or velocity, as unavoidably to complicate the whole question. Dr. Kirk, however, so carefully investigated this subject by means of block models, that the results he thus obtained have been favourably received by shipbuilders. When these models were made to represent the hulls of proposed ships, the wetted surface measured from them was found in practice to be only from two to five per cent. in excess of that of the actual vessel. And so closely were these areas approximated that for total I.H.P. calculations it was found sufficient to trust to the model, and to allow so many horse-power according to circumstances for every hundred square feet of surface.

In all speed calculations there are at least five leading considerations that individually and collectively affect the ship alone, quite apart from engine, boiler, screw, or paddle efficiency. These refer to the displacement—co-efficient of fineness—co-efficient of water lines—immersed midship section—and skin resistance.

The *Displacement* is exactly equal to the weight of water corresponding to the cubic space occupied by the submerged portion of the hull, taken at 35 cubic feet per ton for salt, and 36 for fresh water. This displacement tonnage gives the precise weight of a ship of any kind or size, and in any possible condition regarding her loading or internal fitting, and is by far the easiest method of obtaining what is desired. This will be clearly seen if we consider her hull to be of box form, and say, for example, 300′ long, 30′ broad, and 20′ deep, the draught being 10′ only.

Now $300' \times 30' \times 10' = 90{,}000$ cubic feet, and this divided by $35 = 2{,}571$ tons, or the total weight or displacement of the structure. If we now imagine the immersed portion to be shaped like an inverted triangle its contents will be at once reduced to one-half, because a triangle has only one-half the area of a rectangle, if they both have the same base and altitude. Hence the *Co-efficient of Fineness* is thus found:—45,000 ÷ 90,000 = ·5.

This co-efficient varies according to the formation of a ship below the load draught line, and ranges from, say ·55 in "finely shaped" Royal Mail steamers, etc., to about ·78, in more or less "fairly shaped" cargo carriers. Hence from these figures the comparative submerged outlines of different ships may be at once ascertained with ordinary fairness. As shown above, the method of finding the required distinguishing number is to divide the displacement in cubic feet by the contents of a rectangular box whose dimensions are equal to the length, breadth, and mean draught from the *top* of keel or— $\frac{D \times 35}{L \times B \times W}$

The *Co-efficient of Water lines* is similarly found by the rule:—

$$\text{Co-efficient of water lines} = \frac{D \times 35}{\text{Area of Im. Mid. Section} \times L}$$

which gives a co-efficient of about ·63 in finely shaped vessels, to ·83 in the fullest cargo steamers.

The *Immersed Midship section* explains itself, and so also does the *Skin resistance* already noted, especially if it is increased by a few millions of barnacles adhering like a coat of shaggy fur to the bottom of a vessel, and thus taking a knot or two off her speed.

Simple calculations such as those we have described, have done good service to shipbuilders generally, and will no doubt continue to do so. Serious discrepancies, however, have occasionally arisen, but these have been caused by mistaken ideas concerning the laws of steamship propulsion, which sufficiently indicated that the calculations of the builders must have differed considerably from experimental facts. And it is in the elucidation of these, that the Froude system has proved so beneficial.

One of the most interesting features of Messrs. Denny's establishment is their water tank, 300′ long and 10′ deep, contained in a building where every provision is made for practically determining the speed resistance, and other properties of proposed ships before their plans are completed. This is accomplished under specially skilled supervision, by means of paraffin wax models, whose shape is cut to the exact form, and to any desired scale, by an automatic self-registering machine designed by the late Dr. Froude. Much valuable light has thus been thrown upon some of the most difficult problems in Naval Architecture, the solution of which has proved most acceptable to designers.

It may be added, that before a vessel of any rank or condition can become a commercial as well as a professional success, the concentrated talent and experience of three prominent individuals must be brought into requisition. In the first place, the owner knows exactly the kind of ships suitable for his trade, whether at lightning racing with the mail bags, or at moderate speed passenger and cargo traffic, or as mere ocean cargo carriers, according to circumstances. When the above gentleman, aided by his consulting engineer, has decided which of the above vessels he is to add to his fleet, the selected shipbuilding firm prepares a small scale model of the proposed vessel for his approval. Whilst at the same time, the engineering partner looks after the designing of the machinery, in accordance with what he knows will be most suitable for that particular ship.

When the proprietor of the vessel and the chiefs of the scientific staff have acted *their* parts wisely and well, and the executive staff in the works have carried out their portion of the programme in the same manner, all concerned may rest assured that the most perfect success will crown their efforts. This, however, is due to the judicious combination of profound theoretical and commercial knowledge, and the accumulated practical experience gathered from many sources such as those we have tried to describe.

The last words of Dr. A. C. Kirk, on this important subject, will have a melancholy interest to many, and will help to confirm our previous observations, as they bear directly upon the "Graphical form of Froude's law," which is the title of a paper he intended to have read before the Institution of Engineers and Shipbuilders in Scotland, on October 25th, 1892, had he not been removed by death.

"Perhaps I ought to apologise for occupying your time with a matter so elementary as this short paper, but the calculation of the speed of a proposed ship is one that occurs so often, and is of such importance, that my excuse must be that what I am about to lay before you, I have practised during the last sixteen years, and have found it useful and convenient because simple and elementary. I do not mean to lay before you any new principle, new theory, or new formula; only a simple, graphical method of registering the results of progressive trials, and of applying them.

"I think I may say, even without qualification, that all we really do know of the laws that govern the resistance of ships, and of the methods for ascertaining the power required to propel them, is due to the labours of the late Mr. Froude, and to the enlightened support and assistance he received from the Admiralty. By his wonderfully worked out system of substituting experiments with models on a small scale for full size experiments on actual ships, so difficult and costly to conduct, he has been able to do much that before was impracticable; and he has so firmly established the laws of comparison that the results of these model experiments may be accepted and applied to practice with every assurance of accuracy.

"Although the trial of a ship at various speeds has been done occasionally for many years past, the full value of the importance to be attached to such trials was never sufficiently appreciated till, following on Mr. Froude's suggestive papers, it was powerfully taken up and persistently advocated by the late Mr. William Denny and Mr. John Inglis. It was at once adopted by most of the Clyde shipbuilders, and now may be said to be almost universal. The need of analysing these trials, and registering the results, at once suggested the formation of *speed curves*, and the object of this paper is simply to put before you a graphical method of doing this, and of applying the results in practice."

After these remarks, by such a distinguished scientist and accomplished engineer and shipbuilder as the late Alexander Carnegie Kirk, LL.D., we cannot do better than recommend the study of his beautifully simple system to the consideration of those who desire such knowledge, and who will no doubt be greatly benefited thereby.

CHAPTER XVIII.

INITIAL MOVEMENTS IN DRAWING OFFICE.

Designs, &c., for the S.S. *Vencedora's* Engines—Notes upon Empirical Formulæ—System in Designing—Triple Engine Cylinder proportions—Increased speed of Marine Engines—Its Advantages—Modern improvements in Detail Proportions—Crank Shaft empirically treated—Amended Board of Trade Formulæ—Examples from Practice — Frequent failures of Crank Shafts — Hollow Shafts—Piston Rod smash in a Mail Steamer—Notes upon Piston Rods — Value of complete Bolt and Nut Tables — Practical Examples—Effects of Heat expansion—Tapers for Rod ends—Latest Practice—Guide Block calculations.

In continuation of the remarks contained in the early part of last chapter, let us now proceed to show how the proprietors of the Sirius Works were partially employed while the premises were in course of erection.

As a first movement in the preparation of the working plans for the new ships, Messrs. Baxendelle and Farquharson had to examine most critically the owner's specification from a practical science standpoint, and also in a similar manner their own preliminary sketch designs, with a view to improvements of some kind or other which required development, before commencing the general working plans. As the leading particulars of the vessels given in the above document had originally been taken as a basis upon which to calculate the power required to drive them at a speed of 12 knots an hour, no one need be surprised to hear that this power proved to be no less than 4000 horses.

With this as a foundation, the next thing to be done was to verify the dimensions of every thing of a primarily important character. These calculations, however, need not here be gone into, as Mr. Seaton has so fully and clearly given them in his book. And, it may be added, that as high science reasoning is frequently complex, and dry-as-dustily deterrent to many people, we intend to let the above gentleman tell his own story, in his own way, to those who need his aid.

This will allow space for a few observations upon the good old simple, though empirical formulæ, that have proved invaluable to engineers past and present. These rules have been based upon sound practice, and should never be employed unless this is the case. To those, however, who know how to *construct* as well as to apply them, the amount of time and trouble saved by their use is immense, not to mention the confidence they give the designer as he proceeds with his work. It is at this initial stage that the results of long-continued labours in earlier years begin to show themselves in a directly profitable manner. Even in preliminary sketch designs this is clearly apparent, as these views of proposed engines are intended to form a basis for all future working drawings.

Of course, every draughtsman has his own system of doing things in this respect, according to the peculiarities of the engines he is engaged upon, which may only be a slight modification of previously constructed machinery, or an entirely new design, or something between the two. Drawings of this nature have often to be hastily prepared, for the purpose of getting out an estimate of cost, and for enabling the owner to have at least some idea of what the builders intend to give him. In cases of this kind good empirical formulæ are simply indispensable, and so also are the innumerable notes and data with which an ambitious engineer is sure to be well supplied.

When Mr. Winstanley began his sketch design for the machinery of the proposed S.S. *Vencedora* and her sisters, of 4000 horse-power each, the first thing he did was to work out on a sheet of foolscap the required diameters and stroke of the three cylinders necessary to develop the above power with a working steam pressure of 150 pounds per square inch.

He soon discovered that the high pressure, intermediate, and low pressure cylinders when proportioned to each other in accordance with the generally accepted formula, must have their areas as 1, 2·71, and 7, or respectively 908, 2463, and 6361 square inches. Hence the diameters of the cylinders will be 34″, 56″, and 90″, and the stroke 60″, as it is usually about two-thirds of the L.P.C.

When, however, the H.P.C. alone was decided for sketch plan purposes, the diameters of the other two were approximately found thus:—34″ × 1·6 = 54·4″, and 54·4 × 1·6 = 87″, which is near enough under the circumstances. For the sake of comparison, we may add that the S.S. *Macduff's* cylinders have ratios of 1, 2·56, and 6·76—areas of 491, 1256, and 3318—diameters of 25″, 40″, and 65″, by 42″ stroke—and ratios of the latter by using the above 1·6 multiplier, = 25″ × 1·6 = 40″ and 40 × 1·6 = 64″. These proportions, however, vary a little according to the cut off point of the steam, which is generally about ·6 of the stroke.

It is curious to note how the speed of marine machinery has been gradually increased during later years.

Among the "sixties" and "seventies" the velocity of steam pistons, even of the largest size, seldom went beyond 500 feet per minute. Since that time, however, this has been very considerably exceeded, and while engines with a 4′ 6″ stroke used to run at about 55 revolutions or 495 feet in 60 seconds, we now have them in ocean racers of the largest size, and in the navy, actually making from about 900 to 1000 feet in the same period. The power of a set of engines, whether triple, quadruple, or any other kind, depends upon the area of their pistons, the mean steam pressure upon them, and also their speed; and although a good deal of variation is allowed regarding the latter, practice, and even prejudice have—for the present at least—fixed the extreme limits.

The benefits derived by high piston velocities may be thus explained:—If the speed of engines is doubled, the power will also be doubled, or increased proportionately to the number of revolutions, but as great engine velocity in cargo ships is not desirable, the economical, or coal saving efficiency of the machinery is made to depend upon the manner in which the diameter and pitch of the screw propeller are adjusted to suit only a moderate speed. And while in slow-going vessels this arrangement is considered the best, the newest clippers of the seas are fitted with engines of the highest velocity.

By increasing the speed of a piston its area can be correspondingly reduced, and for a certain power this will be inversely proportional to the number of revolutions. Or, if the cylinders remain unaltered in diameter, the stroke may be similarly reduced. That is, by doubling the revolutions, either half the piston area or half the stroke is necessary, and between these two extremes much of the present practice may be said to lie.

The three crank arrangement of triple engines now so generally employed, is specially adapted for high piston speeds, on account of the more equal distribution of power round a shaft, that is, at three points 120° apart, instead of two points 90° from each other. Thus it comes about that with the increased use of steel, the very best materials and workmanship, extreme pressures and velocities, marine machinery has now reached a high state of efficiency in lightness, space occupied, coal consumption, and economy in management and maintenance.

From the above remarks it will be seen that modern improvements have had much to do with the proportions of engine details, and especially the *Crank Shaft*. Its diameter can be found by different methods of calculation, that is, by the very highest science rules; by Board of Trade, and other formulæ; and also by the simplest mental calculation. So simple indeed, that while philosophers and sages are trying to work out the problem by algebraical and mathematical reasoning, the practical engineer can tell them at once that while 12½″ would be the proper size for the *Macduff*, 17″ will do equally well for the *Vencedora*, by simply dividing the H. P. Cylinders by 2. By the Board of Trade rule 16″ would be the least size allowable for the latter, but as we like to be well on the safe side of everything, we shall make the shaft 17″ diameter.

The above empirical rule has been tried over with many other engines for the sake of verification, and with somewhat similar results. It must be borne in mind, however, that so long as "extra strong," "moderate," and "extremely light," or verge of breakdown schools of thought exist, discrepancies more or less marked will show themselves, and apparently vitiate even the best standard formulæ. The Board of Trade only provides the *lowest* limit of strength for anything, but such is the leniency of the Court that it kindly allows engineers and shipbuilders to give any *extra* strength they please to their structures, if their clients desire it. Hence we find that crank and screw shafts are usually made a little larger than the Board of Trade rule would indicate.

We may here give examples from practice which will no doubt confirm the foregoing remarks :—

Take for instance the magnificent liners "A" and "B" whose engines have cylinders 40″, 66″, and 100″ diameter, by 6′ 0″ stroke, and boiler pressure 160 pounds. These vessels carry the mails from London to Australia, round the Cape of Good Hope, and hence if anything serious occurred to their machinery on such a long voyage out of the usual track of ships, it might prove disastrous.

The amended Board of Trade rule for triple, etc., engine, crank, and tunnel shafts, is as follows :—

$$S = \sqrt[3]{\frac{C \times P \times D^2}{f\left(2 + \frac{D^2}{d^2}\right)}}$$

Where S = diameter of shaft in inches.

d^2 = square of diameter of high-pressure cylinder in inches or sum of squares of diameters when there are two or more high-pressure cylinders.

D^2 = square of diameter of low-pressure cylinder in inches or sum of squares of diameters when there are two or more low-pressure cylinders, no notice whatever being taken of the intermediate ones.

P = absolute pressure in lbs. per square inch, that is, boiler pressure plus 15 lbs.

C = length of crank in inches.

f = 1047 for crank and tail end or propeller shafts, and 1221 for tunnel shafts when two 90° cranks are used, but with triple cranks 120° apart, these constants become respectively 1110 and 1295.

By the official formula just given, the crank shafts of "A" and "B" would have had a diameter of $19\frac{1}{8}''$ at the bearings, 20″ — or H. P. C. ÷ 2,—however, would have done well enough in ordinary cases. Nevertheless, either the owners, or the builders, or both together, piled on another inch, and made them of Vickers' steel, so that even the possibility of a costly breakdown in comparatively unfrequented seas might be averted. Hence the crank, tail end, and tunnel shafts were made 21″, 21″, and 20″ diameter.

If we similarly examine the R. M. steam vessels "C" and "D," which carry the letter bags and passengers over the more frequented path between Southampton and the West Indies, we shall find that their engines have cylinders 43″, 66″, and 92″ diameter, with 5′ 6″ stroke, and a boiler pressure of 150 pounds per square inch. By the Board of Trade rule their crank shafts came out at $18\frac{1}{2}''$ diameter, but they were nevertheless made of steel $19\frac{1}{2}''$, and the tunnel shafting $18\frac{3}{4}''$ diameter.

Lastly, let us take the short voyage ocean racers "E" and "F," whose steam cylinders are 45″, 74″, and 113″ diameter, by 5′ 0″ stroke, and boiler pressure also 150 pounds. The above authority allowed that their crank shafts were on no account to be less than 19″ diameter, to avoid, however, the possibility of an accident, the builders made them $20\frac{1}{4}''$, and the tunnel shafts $19\frac{1}{4}''$ diameter, although these vessels were continually in the track of ships that might easily have helped them if required.

The above examples will no doubt show clearly how engineers amend for themselves the official formulæ provided for their use, with the object of meeting every possible contingency that may arise. Either on smooth seas or stormy waters—on the crowded ocean highway, or on a long and lonely run, such, for instance, as that of 4300 knots from Vancouver to Yokohama, almost entirely appropriated by the Canadian Pacific S.S. *Empress of India* and her sisters, the former of which is illustrated in the frontispiece. Besides the increased strength given to the main shafts of steamers, there is another method of protecting the latter from prolonged detention at sea, if not from actual danger when disabled. And that is to give them twin screw engines, so that if one set should break down entirely, the other set will enable the ship to proceed on her voyage without help from anyone.

Hollow shafts have become very popular in naval ships because they possess the greatest strength with the least weight. As the strength of solid shafts varies as the cubes of the diameters, and the latter as their squares, the advantage gained will be clearly seen. The central hole is generally made about half the exterior diameter, and if we take, for example, a shaft $20''$ outside, and $10''$ inside, we shall have $20^3 - 10^3 = 8000 - 1000$, or a loss in *strength* of one eighth, or $12\frac{1}{2}$ per cent. Whereas the reduction in weight becomes $20^2 - 10^2 = 400 - 100$, that is one fourth, or 25 per cent. Shafts of this kind, therefore, have a considerable amount of lightness imparted to them, but at the same time they are much more expensive to manufacture. Their relative power-transmitting values may practically be found by treating the interior and exterior diameters as those of two separate solid shafts calculated in the usual way, and then deducted one from the other. If made, however, of Whitworth fluid compressed steel, the diameter of shaft may be thus approximately found:—

$$\sqrt[3]{\frac{\text{I. H. P.} \times 90}{\text{No. of revolutions per minute.}}}$$

The internal diameter being $= D \times \cdot 56$.

For example, the diameter of crank shafts of this material for the previously mentioned steamers "A" and "B," to transmit 6000 horse power at 64 revolutions per minute will be $\sqrt[3]{6000 \times 90 \div 64} = 20\frac{1}{2}''$, whilst the internal diameter will be $11\frac{1}{2}''$.

A few years ago a large and splendid mail paddle steamer had just begun her very popular season's running, and while at her highest speed, one of the piston rod crossheads gave way, and a smash immediately followed that caused the ship to be laid up for months just when her services were most wanted. Hence a few remarks on this detail will be appropriate.

The *Piston Rod* of any engine may be treated as a solid column fixed at both ends when substantially guided, but in the works such niceties of calculation are dispensed with, and simple formulæ based upon sound practice are used instead. It therefore comes to pass, that the good old standard rule—$D \div 10$—for the diameter of an iron rod, is still used in connection with the L. P. cylinder of marine engines. It may be noted, however, that the letter D, which may represent the bore of a cylinder or a pump of any kind, when divided by 10, or by any other number to suit the circumstances of the case, proved most trustworthy to early engineers. In proof of this we have only to remember the successes of Messrs. R. Napier & Sons, Tod & Macgregor, etc., and others of the present time who similarly treat the fourth letter of the alphabet.

In triple expansion machinery the low pressure cylinder is generally the most powerful of the set, but in many engines it has to work some of the pumps, and in others the whole of them, besides taking its own share in driving the propeller. For example, in the S.S. *Vauban*, the indicated horse-powers were as follows:—H.P. engine, 328; Intermediate, 357; and L.P., 363; and on the trial of a much larger ship these proportions became respectively 1615, 1606, and 1775. Hence, with the calculations for the piston-rods, connecting rods, and all their attachments for a set of engines, the last named cylinder fixes every dimension, not only for itself but for the other two, so that uniformity and interchangeability of parts may be maintained throughout.

If the *Macduff's* piston-rods had been of iron, $65'' \div 10$ would have given $6\frac{1}{2}''$ as the diameter, but as they were made of ingot steel, $5\frac{3}{4}''$ was found sufficient, or a little over $65'' \div 11{\cdot}5$, which may be taken as a good standard rule. In the navy, 12 has been employed as a divisor, but for the hard worked ships of the merchant service the above is preferable. The really crucial point, however, is the screw for securing the rod to the piston, and the size of this is determined in the most direct manner by finding the amount of tensile strain that will come upon it, and by allowing so many square inches of iron or steel at the *bottom* of the thread to meet this strain as fully as possible, and also that due to hard screwing up of the nut.

Let us, for example, apply this reasoning to the engines of the *Vencedora*, whose H.P. cylinder is 34″, and L.P.C. 90″ diameter, whilst the boiler pressure is 150 pounds, and the assumed greatest pressure in the latter cylinder, say 25 pounds, or 10 for steam, and 15 for vacuum.

Now 34″ diameter = 908 square inches area, and this × 150 = 136,200, and 90″ diameter = 6362 × 25 = 159,050 pounds. The latter divided by 5000 pounds, or the safe working strain for iron = 31·8 area at *bottom* of piston-rod screw, or say $6\frac{1}{4}$″ diameter, and if to this we add the depth of the thread, the outside size of screw will be 7″. If, on the other hand, we use a divisor of 6500 pounds, as the safe load for steel, or say one-tenth of the breaking strain, the external diameter of the screw will be $6\frac{1}{4}$″ when calculated as above, and the diameter of the rod 90″ ÷ 11.5, or say 8″ diameter. In these and other engine detail forgings the iron usually employed has a breaking tensile strength of about 22 tons, and mild steel, say 30 tons per square inch in the direction of the grain. And although a still greater strength may be obtained for the latter, it is not considered advisable to adopt it.

Calculations similar to the above are applicable to all the tension bolts of engines, including those for main bearings, connecting rods, pump rods, valve gear, etc., but they are not necessary when a good *Bolt and Nut Table* is at hand to give all that is wanted at a glance. This requires very careful construction; when once made, however, it becomes an invaluable reference for every day practice in the drawing office.

Many tables of this kind have been published, but not one of them is to be compared with those employed by the great marine firms, in which the bolt diameters usually advance from $\frac{1}{2}$″ to 9″, or so, by "eighths" of an inch up to 6″ diameter, and by "quarters" above this. Although the headings to each column are extremely brief, and also alphabetically noted, we shall give them in full for the benefit of the reader.

Suppose we take a 4″ bolt as an example. Then according to the tables, the *Diameter at bottom of thread* is $3\frac{5}{8}$″—*Number of threads per inch*, 3—Width of nut and bolt-head *across flat*, $6\frac{1}{16}$″—Width *across angles*, 7″—*Nut thickness*, $3\frac{1}{2}$″—*Head thickness*, $2\frac{1}{2}$″—*Head dia.*, $5\frac{5}{8}$″—*Point of bolt dia.* for cross pins, $3\frac{9}{16}$″ by 1″ long.

As the nuts for connecting rods, etc., are recessed into the covers or butts, so that a set screw can be applied to keep them from slackening at any time, this *recess* for a 4″ bolt is $5\frac{13}{16}$″ dia. by $1\frac{1}{4}$″ deep, whilst the set screw itself is $\frac{5}{8}$″ dia., and the hexagonal part of the nut outside is $2\frac{15}{16}$″ long, thus making the total depth of a nut of this kind $4\frac{3}{16}$″, instead of $3\frac{1}{2}$″, as given above. In addition to these, we have a column containing the working loads that can safely be put upon bolts at 5000 pounds per square inch, if of iron; and in another, similar loads at 6500 pounds, for steel. Hence, as the *bottom of thread* diameter of a 4″ screw is $3\frac{5}{8}$″, or 10·3 area, the W.L. becomes 51,500 pounds in the former metal, and 66,950 in the latter. It may further be noted that when nuts have to be frequently slackened their depth should equal the diameter, otherwise they may be $D \times \cdot875$, and when calculated mentally, the width across the sides should be taken at $D \times 1\cdot5$.

There should also be a table of screw threads in full size section, systematically arranged in lengths of, say $1\frac{1}{2}$″, so that the relative number of threads per inch, as well as their actual depth and pitch, can be at once transferred either to a half size or to a full size drawing.

After the diameters of the piston-rod and its screw have been satisfactorily decided, the method of attachment to a piston is the next consideration. Sea-going engineers admit that defects sometimes show themselves in this respect owing to the unequal expansion of the boss of the latter and the portion of the rod that fits into it by the heat of the high pressure steam, and especially is this the case when a driving taper and small shoulder are used, in accordance with the practice of past days. When these are employed, a rod may be gradually slackened and jerkily wedged into a piston until the boss is split. The direct cause of this evil is easily understood when we remember how the cranks used to be taken off broken paddle wheel shaft by making a fire underneath the boss, and thus heating it until, when sufficiently expanded, it could be taken off without much trouble.

It is this same irresistible expansion by heat for which we have to allow in engineering generally. Bridges, for instance, are left loose at one end, so that the range of temperature from the cold of winter to the heat of summer will not cause the rupture of a pier, or of an abutment. Rails are laid with a small space between their ends, instead of being closely fitted to each other, to prevent their distortion on a hot summer's day, and the numerous disasters which would consequently follow. And straight steam pipes are, for the same reason, either passed through a stuffing box or radially bent at one end, so that linear extension can do no harm owing to the elasticity thus introduced. Hence, by paying proper attention to the laws of nature in connection with advanced science in its multitudinous forms, grave dangers are averted. And, it may be added, that as steam at 30 pounds pressure per square inch has a temperature of

250°, and at 150 pounds 358°, it is to the introduction of the latter, and even higher pressures, that some of the latest alterations in details are due, even when *heat* alone is concerned.

Rods having a driving taper of about ¾″ per foot, with the accompanying shoulder, still do good service in Air and other pump crossheads, etc., but for the reasons given, they are not to be so much depended upon in marine high pressure pistons of the present day. In one famous establishment alone, previous to the triple expansion era, thousands of these rods were most successfully made up to 11″ diameter, with a taper of 1 in 8, and without a shoulder. When screwed hard up they were proof against the effects of piston expansion, and at the same time could be *easily disconnected*, which the other kinds will not permit. Now, however, this firm, and indeed others of similar nature, give a taper of 1 in 6, and a collar as well, say 10″ diameter for an 8″ rod; and for the sake of interchangeability of parts, all the rods for a set of engines are made exactly alike in every respect.

The mission of the engineer is to utilise the forces of nature in countless forms for the universal benefit of mankind and womenkind, and as we get along we hope to "show how the thing is done," as Doctor Lynn, the conjurer, used to tell his admiring audiences. If these forces resist our efforts we must conquer them by skill, whether they are in the form of electricity, chemistry, water, air, steam, or even "*heat*," as we have been trying to show already on a small scale, and one of the best books for giving a practical insight into this most useful branch of science, is Mr. Box's simple and admirable treatise bearing the above title.

Another point that vitally affects the working of machinery is the area of all surfaces exposed to wear, such, for instance, as those of the piston rod *Guide Blocks*, which may give great trouble by overheating, and perhaps sustain abrasion of their polished surfaces, if not carefully proportioned, and here the *Laws of Friction* become conspicuously visible. The necessary calculations are doubly useful, because they not only affect the smooth and prolonged working of the blocks themselves, but also the proper strength of the guide, especially when upon the the rectangular bar stay principle, now so popular in horizontal and diagonal engines.

The problems to be solved are :—What maximum strain is thrown on the above blocks when in their worst position, or at half stroke, and also how much rubbing surface should be allowed so as to insure the best results.

The strain part of the question may be worked out by means of a beautifully simple diagram on the graphic system; it is easier, however, to divide the total load on the piston by 4 when the connecting rod is four cranks in length. Otherwise, the length of rod is to length of crank, as the load on piston is to the strain on guide at half stroke. This is not absolutely correct, because with a piston load of 50,000 pounds, and a 4 to 1 C rod, trigonometry and geometry would give a pressure on guide of 11,619 pounds, whereas, the drawing office rule would allow 12,500 pounds. Here, however, we have the advantage of fulness on the safe side, which can always be modified more or less to suit circumstances.

The records of past engines of all sizes clearly indicate that the total working pressure upon their double guide block go-ahead surfaces has been from 60 to 73 pounds per square inch. One eminent engineering firm allowed even more than the latter, but as the above proportions refer to engines that have worked well for many years they may be considered trustworthy. With the single guide arrangement, however, as shown in the Plates of the *Macduff's* and also the *Vienna's* engines, 52½ to 57 pounds were used in the former, so that the greatly diminished go-astern surfaces might have a little more area.

As the aforesaid calculated load on the *Vencedora's* 90″ piston is 159,050 pounds, and as her connecting rod is 4½ cranks in length, we have a guide pressure of 35,344 pounds ÷ say 55 pounds = 643 square inches. Now the length of slipper guide blocks averages about 3½ times the piston rod diameter when it equals D ÷ 10, and their breadth is approximately L × ·6. And as an iron rod for the above ship would be 9″ diameter, her guide blocks work out as nearly as possible at 32″ × 20″, or 640 square inches for each.

When these, as well as the guides, are truly planed, the action to which they are exposed in working produces a very hard and burnished surface that is highly beneficial to both. To prevent the surfaces from being abraded by insufficient lubrication, oil grooves are cut upon them, but perhaps the best plan is to have a number of flatly drilled recesses about 1¼″ diameter, by ⅛″ deep, as shown in the *Macduff's* engines. These act as little reservoirs for the lubricant, which is thus enabled to spread itself evenly over the surface of the guides as the blocks move up and down upon them. The go-astern rubbing surfaces are naturally much less than those for the go-ahead, but as piston rods of this nature are now constructed, the pressure must always be well within the safe limit.

CHAPTER XIX.

DRAWING OFFICE PRACTICE—*Continued.*

Drawing Office practice as it is—How Theory holds the Light while Practice does the Work—Sketch Designs—Preparation of General Working Plans of "*Vencedora's*" Engines — Graphic method of avoiding Errors—Utilisation of Past Experiences—How extreme Compactness of Arrangement is obtained—Crank shaft and its Accessories — Connecting Rods — Jet Condenser and its Evils—Surface Condenser and its Early Troubles — Its effects upon Steam Navigation — Chemical Difficulties — Improvement of Details—Cooling Surface Proportions—Considerations affecting Weight and Strength of Machinery.

WHEN we carefully examine the interior of one of the ocean racers of the present day, it may appear somewhat strange that such complex machinery is able to withstand the extremely severe usage it frequently receives. And the true cause of the Royal Mail liners so seldom becoming disabled, even when driven to the utmost, is the profound theoretical and practical skill which has been brought to bear upon every part by those who design, construct, and manage them. It is also curious to note how marvellously our learned brethren combine two sciences that so often contradict each other, and which taken separately would produce the most disastrous results.

Theory certainly holds the *light*, but Practice does the work, and as they unitedly perform their own parts in brotherly and sisterly fashion, and as the latter frequently overrules the former by considerations of an extremely varied nature, we are sometimes enabled to discover at a glance the cause of the great successes, and even of the failures of modern times. Engineering never can be an exact science like mathematics; indeed, if all the details of engines and boilers were made for the next six months strictly in accordance with the dictates of theory, they would reach the shipowner's idea of lightness sure enough, but from India, China, Japan, and other places too numerous to mention, howls of anguish, yells of despair, ebullitions of wrath, and other unpleasantnesses would soon come pouring in upon the unhappy builders by the mail-ships of the old school, which could alone be trusted with the letter bags, and with their more or less extensive floating populations.

The experience that has heen accumulated during many years by various eminent firms, or by their technical commanders, is of a very far reaching character, and, judging by the antecedents of Messrs. Baxendelle & Farquharson, it is only reasonable to expect that these gentlemen will take good care that all the ships and engines they build will be quite up to the highest standard of strength for everyday working at full power.

The term *Sketch Plan* is intended to mean a drawing which embodies in a general way the leading conceptions of the designer that have been tentatively scribbled on paper until somewhat matured. They are then worked out in a sufficient number of small scale views, until at last a fair idea is obtained of the proposed arrangement, space occupied by the engines, boilers, etc., and the leads or directions of their main attachments in the ship. When these have been satisfactorily accomplished, a neatly lined and coloured tracing is sent to the owners for approval, and when this has been obtained, the *General Working Drawing* is proceeded with.

So accurately have the simple calculations for the *Vencedora*, *Voltinia*, and *Vipsania* been made out as the basis of the above plan, that its verification, so far at least, has given little trouble. We shall therefore have all the more pleasure in noting the movements of the engineering partner and his chief draughtsman as they proceed with the general drawing.

With his sketch plan and picture gallery of figured rough detail and other scribblings around him, and a noble damp stretched sheet of web paper in front of him, Mr. Winstanley at once begins to arrange the position of each view on the board, so that the space may be utilised to the best advantage throughout. These views include *Longitudinal Sectional Elevation* — *End Sectional Elevation*, *Sectional Plans*, and any others that may be necessary, to a scale of one inch to one foot. When the positions of the above have been fixed on the paper, the main centre lines are put in in red because they will thus be permanently visible, instead of being partially rubbed out with every trivial alteration that crosses them.

The *End Sectional view*, which invariably looks towards the stern, rules to a large extent the others at the very outset, and the first thing to be done is to draw one circle on it to represent the crank shaft, and another to indicate the path of the crank pin during the whole revolution. From the centre of shaft now mark off the connecting rod—in our case 11′ 3″—and show in the crosshead and guide block, and similarly the crank pin, all of which will be in half stroke position. Then fill in the details of crank, connecting rod, guides, etc., and after allowing sufficient clearances in every direction, proceed with the delineation of the cylinder belonging to the view, the columns, bedplate, condenser, air and circulating pumps, feed and bilge pumps, etc., and all their connections above and below, inside and outside, in section where necessary. It may here be observed that the enthusiastic engineer enters at this point upon labours that become increasingly absorbing day by day as his ideas become developed, and as one point of difficulty after another is surmounted by skill and experience.

After this elevation has been sufficiently matured, its lines are transferred as far as possible to the other views, each of which, however, requires a greater or lesser amount of work to be bestowed upon it, until the whole of them are brought into harmony with each other, and the details carefully enough worked out for enlargement on separate sheets.

To avoid costly and sometimes troublesome mistakes, however, at the outset, it is necessary to trace the main working parts in the end view on paper, and pass them through a complete revolution on the drawing. If this is carefully done it will be seen at a glance whether a connecting rod end is going to cut into a bed plate or a condenser, or a piston rod crosshead and its attachments will foul anything. The most glaring faults have happened unaccountably in the past, and although the erectors will quickly enough discover inaccuracies at any stage of the building process, the above simple method of detecting mistakes is in itself a sufficient safeguard.

The only bolts shown on a *General Working Plan* are those of large size, in the main bearings and the principal rods, etc., above mentioned. As these are all in tension they are governed by the same law that regulates the size of screws for similar purposes, modified, however, by considerations that practice alone can dictate. For instance, where two bolts are used as in the crank pin end of a connecting rod, their united area at the bottom of the screws should be at least equal to that of the piston rod screw at the same point. When, however, *four* bolts are employed, as they sometimes are in the upper forked end of the connecting rod, their collective area should be about one half more. And although theory says, rightly enough, that the same total area for each set is quite sufficient, practice directs us to give the above extra allowance, because the strain upon so many bolts at one place may not always be equally distributed.

It is at this point that Mr. Baxendelle and Mr. Winstanley have many earnest discussions upon some of the leading features of practical design. Not, indeed, that the former has any want of confidence in the latter, but knowing that two heads are better than one, he likes occasionally to pay his confidential assistant a visit for the purpose of comparing notes and suggesting improvements when possible, either in proportion or arrangement, or for verifying the dimensions of important parts. Mr. B. has thus entered the office to have an all round conversation with his colleague, and after gazing silently at the plan for a few minutes, he says "Are you sure there is plenty of strength in that crank shaft? Far too many of them break now-a-days, and we must not have *this* one giving way on any consideration."

"Lots of strength, sir," replies the chief draughtsman, "It has exactly the same proportions as the *Belshazzar's*, and, although she has been constantly running for the last five years, it has not gone yet."

"That will do. By-the-bye, in case I forget, you had better not cramp things so much as you have done of late; the chief of the *Melpomene* told me the other day he wished we had given him a *little more room for working*."

A few other features are similarly examined under the light of past experience, an experience, too, that each of our friends knows full well how to utilise to the very best advantage. Heights here, distances there, positions of this, that, and everything else, clearances at certain points, areas at others, and so on, are commented upon until the conference comes to a close, only to be repeated with variations at intervals.

After this discussion is ended, both gentlemen have a turn through the office to note, observe, and remark upon the work of Messrs. Smith, Brown, Jones, etc., and to see if they cannot cut down the weight of the details for the ships "now building," or amend them in some way or other. This is all the more necessary because the engines in hand are the first ever made at the Sirius Works, and hence everything has to be originated instead of being partially modified from at least a few of the past drawings, as in old establishments.

The initial movements in connection with the *Side Elevation and Plan* consist in arranging the cylinders with their valves at the *front*, as it affects very closely their convenient get-at-ability, and also the distance apart of the vertical centre lines of each engine. When these points are satisfactorily determined with the object of obtaining extreme compactness fore and aft, without unnecessary contraction of the engine room, the first named view may be proceeded with in full section.

This, it may be observed, takes in the whole length of the engines as indicated in the *Macduff* engraving, and although it obtains its initial dimensions from the Transverse Section, it originates and develops very many independent ones of its own, and these, in combination with each other enable the *Plan* to be proceeded with. These three views, therefore, endlessly varied, form in themselves the head and front of what may be a series of drawings that individually and collectively are intended to produce the machinery of a colossal ironclad—an ocean racer of the very highest order—a cargo ship of greatest capacity—or, in humble form, the engines of a canal boat or a mud hopper.

As already mentioned, the arrangement of the valves on the cylinders regulates to some extent the centro-lineal distance apart of the latter, but this must be simultaneously worked out in connection with the bedplate, whose length fore and aft depends upon the length of crank shaft bearings and pins, thicknesses of cranks, and space required for eccentrics and coupling flanges; all of which can be clearly seen in the plate of the *Macduff's* engines, which not only gives a good idea of an *external* Side Elevation, but of a similar End view. In this case, however, the latter is taken at the after end and in perspective, for pictorial effect, instead of geometrically at the forward end as in drawings, for convenience, as illustrated in the adjacent plate of the *City of Vienna* machinery.

The ordinary length of a *Main Bearing* is diameter of *Shaft* × 1·5, when four are used, as in tandem Quadruples or other two crank engines, but when, as in triples, with ordinary link motion valve gear, six are employed, the length of each is usually 1 D. to 1·125 D., or a total of from 6 to 7 diameters. But if, on the other hand, the valves are placed on the outside of the cylinders and worked by means of the newer kind of gear, thus allowing four bearings only, the same *total* length may be given by adding so much to each according to the arrangement.

The Crank Pins are usually made the same diameter as the shaft to which they belong, and their length from D. to D. × 1·25, thus providing ample strength and good wearing surface at the same time.

As *Crank Shafts* are now almost always of the built-up description, the cranks are made of solid slabs of steel whose depth is at least ·75 D. and thickness of metal round the eye about D. ÷ 3.

The crank shaft and crank pin brasses are generally cast with dovetailed recesses for the reception of various "White metals." Mr. Mudd, however, has discarded brass altogether, and by using cast-iron instead, well lined with one of the above alloys, he obtains very satisfactory results. The Magnolia Anti-Friction metal is much used for this, and also for many other similar purposes, light as well as heavy, and has been very satisfactorily tested by some of the greatest authorities.

The breadth of the *Eccentric Straps* equals twice the diameter of their bolts, which is found in the usual way by ascertaining the net steam load on the valves, and the tensile strain on their spindles after allowing for the frictional resistance of the working surfaces. Whilst the boss of the *Eccentrics* is slightly more in breadth than the straps, to allow a little clearance for them.

The diameter of the *Couplings* is taken at D. of shaft × 2, and their thickness at least D. × ·3.

The *Connecting Rod*, previously referred to, has its least diameter about $\frac{1}{12}$ less than the piston rod to which it belongs, and the taper towards the butt is generally $\frac{5}{16}''$ per foot. The covers at this point are about $2\frac{1}{4}$ times the bolt diameter in breadth, and their thickness the same as the diameter, the butts being somewhat thicker.

These considerations, above and below, regulate the fore and aft space occupied by the engines when the ordinary link motion is used. As it is intended, however, to use Morton's gear instead of Stephenson's, and thus do away with all eccentrics, this space will be four feet less than it otherwise would have been.

Few inventions connected with marine engineering have done more to advance the interests of Steam Navigation than that of Hall's *Surface Condenser.* The idea was excellent, but like many others of similar importance, its application was retarded for many years owing to defects in construction, and also to the prejudices of shipowners and engineers.

At Denny's, amongst the "fifties," all the Cunarders and the early ships of the Allan Line, indeed, every other we built, had the jet condensers. On one occasion the river steamer *Merlin* lay at our quay for repairs, and although she, curiously enough, had Mr. Hall's condenser, it was said to be a failure. Even in later years no one cared to adopt it, hence the beautiful P. and O., Inman, and many other fine steamers built by Tod and Macgregor, and other firms, were fitted with the old arrangement. In this way we jogged comfortably along the beaten track under 20 and 25 pounds steam, until a Mr. Davidson paid us a visit at the Clyde Foundry, which proved the beginning of a new era, as the amended condenser at last obtained a substantial introduction to the Engineering world.

With the object of showing how it proved so beneficial, let us go back to the year 1838, when the *Sirius* and

Great Western had successfully opened out Atlantic Steam navigation. The side lever engines of the former, by Wingate, of Glasgow, had the new condenser, but history is apparently silent on this point, whilst the $73\frac{1}{2}''$ by $7'$ $0''$ engines of the latter, by Maudslay, were supplied with jets. The steam pressure was only 5 pounds per square inch, and the consumption of coal per hour amounted to 8 pounds per indicated horse-power, which, at the very outset, was a most serious defect.

The old style of condenser consisted of an approximately rectangular box casting, placed close to the cylinders from which the exhaust steam was led as directly as possible. On one side of the condenser an *Injection Cock* or *Valve* was fixed, which admitted water directly from the sea, and allowed it to form into spray internally by passing through a pipe filled with small holes. As the steam came into contact with the showery jet thus formed, it was changed into water, which fell to the bottom of the condenser, and along with the air that came in from the sea was at once taken away by the *air pump*, and discharged into the hot well, and then overboard through the waste water valves. Whilst at the same time the feed pumps drew their share from the hot well for the purpose of supplying the boilers. In addition to the ordinary injection valve, a similar *Bilge Injection* apparatus was used for drawing from the bottom of the ship at any time in case of leakage.

The Jet condenser was extremely simple in all its details, but it nevertheless caused a most extravagant consumption of coal, and prevented the introduction of high-pressure steam on account of the injury that would have been entailed on the boilers that generated it, if continuously fed with sea-water. When this condenser was in fashion, a considerable quantity of supersalted water had to be "blown off" at intervals to prevent the deposition of scale and salt on the flues, and their consequent loss of steam raising power, which would have been much worse at a higher pressure.

The boilers were practically fed with saline water, owing to the large quantity which was taken from the sea for condensing purposes. When, however, the gauge pressure went beyond 35 pounds, or a temperature of 281° was exceeded, the salt and other substances that had previously and extensively been held in solution in the fluid were so rapidly precipitated on the flues that they became positively dangerous. Hence, to avoid explosions through overheated and greatly weakened furnace crowns, hot water had to be wastefully blown out to prevent a still *hotter* state of things unexpectedly arising, and perhaps causing the loss of the ship. With the object of removing these evils, Mr. Hall invented the *Surface Condenser*, to which we shall now refer.

The Jet condensing gear is still fitted to marine engines, only, however, to act as a substitute in the event of disablement of the circulating pump, and it is also still very popular with land engineers on account of their boilers only using fresh water. But it is to Mr. Hall's invention alone that the triple and quadruple engines of the present day owe their existence, thus causing through their use a reduction in the coal consumption to about one pound per I.H.P. per hour. And in addition to this, a great diminution in the weights of machinery and fuel, and a corresponding increase in the cargo carrying capacity of ships, and their ability to run with profit to the owners on long voyage stations. The surface condenser, as it now stands, may be of any shape to suit its surroundings, but, under all circumstances, the tubes ought to be so arranged as to allow of easy removal, or of end packing when required. Its interior should have free access for the purpose of inspection, and cleaning out, etc., and its exterior must be fitted with the necessary small gear.

It may here be interesting to note the Chemical difficulty that originally brought this invaluable appliance so often into disgrace, and so frequently baffled the very best efforts of engineers. At first, copper was employed for the tubes, as it proved, in some respects, the most suitable material, but it was soon found that the acids derived from the tallow used in the cylinders, mixing with the exhaust steam, dissolved some of the copper and produced soluble salts of that metal, which, when pumped into the boilers with the feed water, partially destroyed their interior plating. In the hope of obviating this evil, the tallow supply was stopped, and the tubes were tinned, and although this process greatly added to their costliness, the chemical destruction of the boilers was nevertheless continued from a subsidiary cause.

Brass tubes were now tried, but with only a limited amount of success owing to want of care in their manufacture. When, however, this difficulty was removed, the latter material was found in every way the best, and hence even to the present it is universally employed.

Another difficulty lay in the fixing of the tube ends, and, as thousands of these may exist in one ship, the gravity of the situation will be at once apparent. In the year 1861, however, Mr. Davidson called at Tod & Macgregor's with an improved method of jointing the above. He had a very genial and logically attractive way of explaining the advantages of this system, which consisted in placing a large perforated sheet of indiarubber over the whole of the tube ends in each division of the condenser, and then making their joints tight at one operation, by bolting an outside brass plate on the top of the india-rubber. Mr. William Tod saw the advantage of this arrangement at once, and we accordingly fitted with surface condensers the *Princess Royal*, No. 3, then building, and also the *City of New York*, No. 1. Other vessels followed.

Although Mr. Davidson's system was considered the most suitable at that period, it nevertheless proved very inconvenient, as so many joints had to be dislocated before even one of them could be rectified when leaky. This, naturally enough, caused a variety of independent fixings to come into use, the best of which is now employed by most of the leading firms. The plan is elegantly simple and efficient, and consists of small stuffing-boxes formed in the brass plate through which the tubes are passed, and then packed with tape or cotton by means of screwed ferules to keep them tight. Thus fitted, each joint is ready for being taken asunder at any time without interfering with its neighbours.

The system of arrangement of tubes universally adopted is to cramp them into one, two, or more large nests, through which the cooling water circulates in zigzag fashion, and amongst which the steam is expected to find its way as rapidly as possible. As the space between each tube is extremely limited, the difficulty of at once reaching those in the centre of the mass will be apparent, and this has been experimentally tested by Mr. Mudd, who recently obtained one inch better vacuum than formerly in the condenser of an old steamer, by simply withdrawing some of its tubes, thus causing a less obstructed flow of steam to the interior cooling surfaces. With this broad principle in view, and also the little improvements in details to which it has led, we may expect in future the best results in a more practical fashion than has hitherto prevailed.

As we proceed with the general drawing of the *Vencedora's* engines, it is necessary that the condenser with all its surroundings should be accurately shown upon it. In the first place, however, the suitable cooling surface has to be found, and this may be done in various ways. When, for instance, the terminal absolute pressures in the L.P.C. are 12½, 10, 8, and 6 pounds, the area of tube surface in square feet may be equal to I.H.P. × 2·0, 1·8, 1·6, and 1·5 respectively, when the temperature of the sea water is about 60°. For ships on tropical stations these allowances should be *one fifth* additional, but if only occasionally visiting hot regions, *one tenth* extra will be enough. For constant running in cold climates, however, one tenth *less* than the above multipliers indicate may be considered sufficient.

Professor Jamieson has given in his *Text Book on Steam Engines* a table of proportions of condensers relating to 22 sets of triple expansion engines from 151 to 1140 H.P., the mean of all of which is as follows:—

Terminal Pressure in L.P.C., 10 pounds; I.H.P. 517; *Revolutions* 83; *Content of L.P.C.*, 36·37 cubic feet; *Content of double-acting circulating pumps*, ·85 cubic feet; *Cooling Surface*, 1,024 square feet; *Cooling Surface ÷ I.H.P.*, 1·95; *Heating Surface in boilers*, 1,793; *Cooling Surface ÷ Content of L.P.C. × Terminal Pressure*, 3·24; *Cooling Surface ÷ Heating Surface*, ·553.

After finding the cooling surface required to suit the station on which the ship is to run, the most convenient length of tubes may be ascertained for the purpose of regulating their number, which will also depend upon their external diameter of, say, from $\frac{3}{4}''$ to 1″, according to the size of the engines. When these are decided upon, the most suitable transverse area of condensing space must be calculated, and its breadth and height carefully adjusted to each other so as to obtain the most compact arrangement of parts all round. The best method of accomplishing this, however, is to work out the dimensions, say to a 3 inch scale, by showing in accurately with a 60° set square the centres of a set of tubes for one division only of the condenser, and this will give a correct idea of what is needed for the other divisions. It may be noted that the thickness of the brass end plates should be about 1″ for $\frac{3}{4}''$ tubes, and that all the bolt and nut fixings must be of the same metal to avoid corrosion.

From the above considerations, the surface in the *Vencedora* will be 6,045 square feet. The tubes will be 1″ external diameter, and $1\frac{3}{8}''$ pitch, and with these proportions as a basis, the exact condenser space in every direction can easily be found from the sketchy detail drawing, and then transferred to the general plan.

From the inner top side of the condenser will now spring the box standards for supporting one side of the cylinders, on which the shoe-block guides will be cast; the other, or starting side, being carried by four turned wrought iron columns $8\frac{1}{2}''$ diameter to suit the Morton valve gear. The condenser, and also the bedplate, will each be cast in two pieces for convenience, with all the necessary flanges, openings for doors, valves, etc., and facings of every kind for the various attachments that will be bolted on in the course of time; some of which, at least, may be seen on reference to the *City of Vienna* Plate, which we shall imaginarily utilise for the *Vencedora* and sister ships.

It is here where the flash thoughts of Mr. Baxendelle and Mr. Winstanley have full play, as they carve out to the right and left the best arrangements. Circles are put in and taken out again. Minor shafts, rods, levers, valves and their connections, etc., are shown in the different views and altered for something better, by degrees. The ordinary junior draughtsmen and *really good* apprentices, are most appreciatively supplied with figured sketch tracings of details from the general plan, to elaborate either full size, half size, or to 3″ and smaller scales. All the drawings of castings and minor forgings, when ready, are given to the foremen of the pattern shop and smithy. The Steel and Iron Companies have forge tracings of major details sent to them, and thus the work proceeds to the entire satisfaction of everyone.

So far as we have gone, we have only indicated a few of the simplest methods adopted in engineers' offices to obtain the proportions of details, and although the still simpler graphic system is largely adopted in bridge, roof, and other similar work, it is not so generally suitable for marine designing. A calculation may be statically right but dynamically wrong, as there are many surrounding circumstances that, in the latter case, require the most careful consideration, as we have tried to indicate. A simple calculation, that shows clearly what is desired with the least amount of trouble and risk of error, is much more useful than those in which squares and cubes, square roots and cube roots, plusses and minuses, are pictorially arranged and profusely ornamented with algebraical notation, when a flash of thought or a skilfully constructed triangle might do at once all that is needed.

Whole pages of these elaborate formulæ will not, for example, so clearly convince us as a rapid mental exercise, that a 35 ton pull on a rod 3″ diameter gives 5 tons per square inch, or that by a triangle, or parabola, or combinations of both, we can get the strains at any point of a girder, either concentratedly or otherwise loaded, by direct scale measurement. Here, however, enough has been said, if it only indicates the manner in which two invaluable systems of calculation may be variously utilised to the best advantage.

It may be added that there is a consideration which overrules these and every other system of calculation, and that is the service for which a ship is intended. Naval vessels, for instance, that are to be used for intermittent service, and only occasionally at full power, can afford to have their machinery made lighter than if they were in constant employment of the most arduous nature, and this circumstance is well taken advantage of in their design. When, however, ocean racers, such as those of the present Atlantic type, are kept constantly up to their full power, even in the most tempestuous weather, which, at high rates of speed, seriously affects them, a different state of things must naturally exist. Hence we find that the engines of these vessels are made so much heavier than in war ships, with which they contrast unfavourably, so far as weight of machinery is concerned.

There is still another consideration of the utmost importance, and that is *commercial economy*. This involves undiminished *prestige*, extreme velocity, and at the same time absolute freedom from breakdowns. Nothing short of these will satisfy the proprietors of the mail liners; otherwise, instead of earning small dividends, they might incur serious losses. If weights must be reduced effectually, let it be in the boiler department, and here, with all the latest discoveries, inventions, and improvements at hand, much may yet be done to increase the commercial value of ships of every class, and of every nation. This is becoming more clearly apparent as time rolls on, and, as will be seen by reference to Chapter XXIII, the extended employment of distilled water on board ship for steam raising purposes, will no doubt pave the way for such a desirable end.

CHAPTER XX.

FURTHER DETAILS OF ENGINES.

Minor Details of Machinery—Air Pump, and its Modern Peculiarities—Improved Valves — Circulating Pump, and its Connections—Independent Pumps—Centrifugals, and their Advantages—Combined arrangement of Air, Circulating, Feed, and Bilge Pumps—Connections to Ship and Engines—Pulsometer Pump, and its Uses—Feed Pumps and their Performances—Bilge Pumps and their Application — Communication Boxes — Sanitary Pumps—Hand Pumps—Donkey Engines and their Uses—Duties of Engine Room Staff of a Ship—Number and Uses of all the Engines of an Ocean Racer—Rapid filling of a Ship explained.

AFTER the foregoing remarks upon Surface Condensers, we must now describe the peculiarities of their indispensable auxiliaries, the *Air*, *Circulating*, and *Feed* and *Bilge Pumps*. In the jet condenser days the first named had necessarily a great deal to perform, as so much water was admitted to the condenser which had afterwards to be drawn from it. Hence the diameter of each *Air Pump* was generally D. of cylinder × ·6 when the stroke was half that of the engines, or at least one eighth of the content of each cylinder for any length of stroke. Now, however, the feed pumps might perform all that is necessary were it not for the air which has to be abstracted.

For instance, it requires a certain amount of water to make the steam that is used at each stroke of the pistons, and when this is condensed it should, theoretically, enable the same quantity of fluid to be returned to the boilers through the feed pipes, and thus the cycle of operations might go on perpetually without any external aid. This, however, cannot be, since a small quantity of extra water must be admitted to the condenser to make up for slight leakage at the various joints, etc. And besides this, when the condenser is fitted with sea-injection gear, to be used only in case of accident, a pump must be provided for the purpose of freeing the former, not only of the cooling water, but of the air that enters with it, amounting to one twentieth of its volume. And since, under these circumstances, it would be unwise to hamper the engines with an air pump suitable for efficient jet condensation, and as, for the reasons given, one too small would not be desirable, it is usual to make the size of this detail only large enough for cases of possible and temporary emergency.

The capacity of the single acting pump is therefore made equal to the content of L.P. Cylinder ÷ 14 to 17. In the *Vencedora*, however, we shall make it 15, or say 29″ diameter by 3′ 3″ stroke, which will be a good allowance, the rod being of Muntz metal $4\frac{1}{4}$″ diameter.

The *Valves* were, at one time, invariably made of vulcanised indiarubber discs about $\frac{5}{8}$″ in thickness, but Kinghorn's, and also Thompson's metallic arrangements are now considered more suitable, as the material cannot be destroyed by the action of the mineral lubricants now used in the steam cylinders, the old discs, however, are still employed for circulating pumps. Messrs. Kinghorn's productions are made of thin, flexible sheets of phosphor bronze that cover the gratings in the buckets, etc., as before, and being durable and efficient are highly esteemed by those who use them. Mr. Thompson's valves are also very popular; and it may be added that Mr. Beldam's corrugated disc valves are amongst the latest successful improvements in this direction.

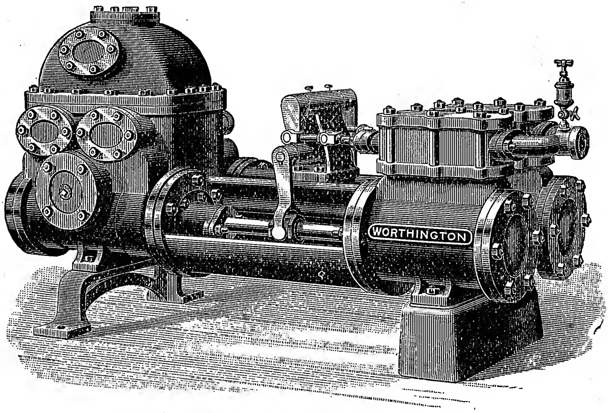
Thousands of *Rods* for pumps as above, without top guides, have had their diameters equal to D ÷ 7, or 4″ for a 28″ pump, and even to the present this seems to be a general rule.

Horizontal Double-acting Air Pumps, having ordinary pistons, have been much employed, and although they are simpler and less expensive than the single acting species, they neither work so well, nor are so easy to examine. In some naval engines these pumps are driven direct from the steam pistons, and as the rods are long, their diameter is about D ÷ 6, with a little extra, according to length.

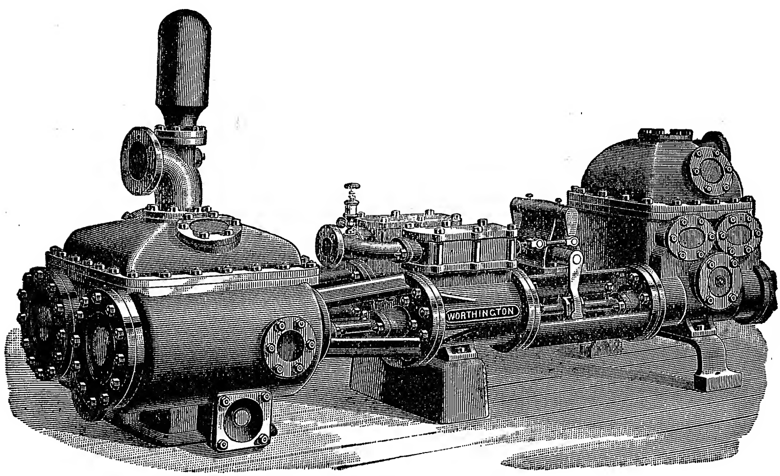
No sooner was the surface condenser introduced than the *Circulating Pump* sprang into existence, since all the cooling power of the former was due to the amount of water forced through its tubes. This pump is generally of the double acting plunger description, or a centrifugal, both of which have proved invaluable. For engines of moderate size the usual custom has been to work the air pump, circulating pump, and feed and bilge pumps, by means of levers that are linked to one crosshead to which all the rods of the former are attached. As, however, it is possible that all the pumps may be temporarily disabled by the fracture of an important part, it is now considered advisable in large engines to keep at least the circulating machinery separate from the others.

The annexed view represents a set of Messrs.

Worthington's well known pumps for *Circulating*, or *Bilge Discharging purposes*—the air and other pumps being driven



BILGE AND CIRCULATING PUMP.



AIR AND CIRCULATING PUMP.

in the usual way by the main engines. The steam cylinders of these range in size from $4\frac{1}{2}''$ diameter and $4''$

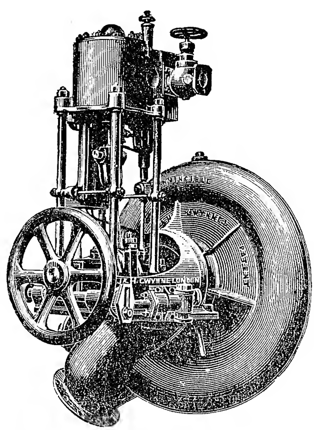
stroke, to 17″ by 15″, and the quantity of water delivered by both engines is from about 60 to 4,000 gallons per minute. In cases of emergency, however, the duty may be considerably increased, thus materially helping to free a dangerously leaky ship.

The adoption of quick running engines for passenger steamers ordinarily necessitates a speed of pumps that in some cases is neither economical nor safe, the result of which has been the introduction by the above firm of the independent *Combined Air and Circulating Pumps* shown adjacently, with the steam cylinders placed in the middle. These can be run at any desired speed, and may be single or compound, according to circumstances, the whole of the machinery may also be arranged to work vertically when space is limited.

For circulating purposes *Centrifugal Pumps* are very much used, and these must not only run continuously while the engines are going, but keep in motion during all temporary stoppages, so that the condenser may be kept cool and ready to receive the steam from the low pressure cylinder.

Although in most cases only one of them is required in a ship, it may be worked either by a single engine or by a pair, or two pumps by two pairs, as in some of the latest ocean racers, which needs only half of the driving power to be used at a time, whilst the other half is kept in reserve for any emergency. If, however, the vessel has to be freed quickly from a large quantity of water the whole of the power can be used for this purpose, and, perhaps, save her from sinking.

One of Messrs. John and Henry Gwynne's single engine "*Invincibles*" is shown in the annexed view, which illustrates a specially designed and very light arrangement to suit fast cruisers, torpedo boats, yachts, and launches. The cylinder is supported on steel columns, and the casings of the pumps are made of gun metal. When required, feed pumps are attached, one being fixed to the front of the bedplate, as shown, the other being placed at the back, whilst both are worked by means of a wormwheel and screw actuated by the crank shaft. The curved vanes that work inside the snail-like case are easy to examine at any time in a few seconds by removing the hand-hole door, and the whole can be at



CENTRIFUGAL PUMP, FOR FAST CRUISERS, ETC.

once disconnected by taking off the large circular cover, both of which are shown in the next view. A notable feature in the crank pin of some of these engines is a zig-zag oil hole which is bored through one end of the shaft, up one of the cranks, half way through the centre of the pin, and out at the side, thus insuring constant and regular lubrication of the bearing, which is *centrifugally* increased or decreased according to the speed of the engines.

Amongst the advantages to be derived from the use of the "Invincibles" may be mentioned :—

(1) Their great handiness, and the ease with which the circulating pump can be manipulated independently of the main engines.

(2) They enable these engines to start with a vacuum in the condenser.

(3) They admit of the quantity of water being varied when the temperature changes.

(4) They require no injection cocks and gear on the condenser.

(5) As they have no valves or air vessels, all sorts of refuse from the bilge can pass unobstructed to the outlet on ship's side when used merely for freeing a vessel from water.

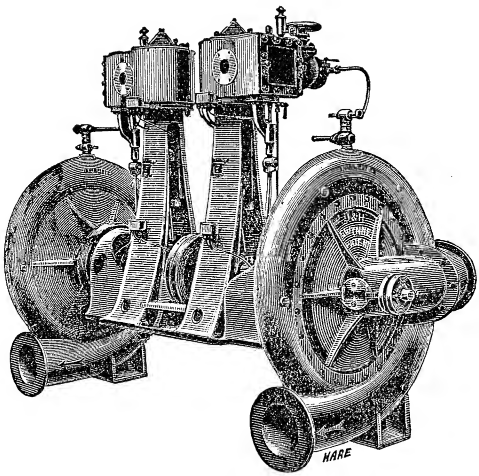
(6) The engines exhaust into the condenser, and as they work chiefly with a vacuum much steam is saved.

(7) The racing of the main engines does not affect them in any way.

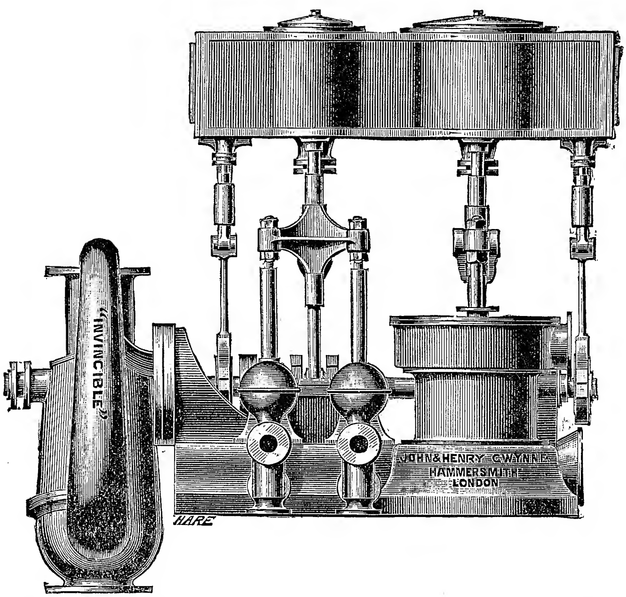
In addition to these advantages may be mentioned the lesser cost of the apparatus when compared with the usual lever pumps, and its general usefulness for numerous other purposes about a ship.

In steel-clads, and large mail and other liners, etc., two pump chambers are frequently employed, as shown in the accompanying view, and as each chamber is capable of discharging 7,500 gallons per minute for condensing purposes, it is evident that both together would soon improve the condition of a leaky ship. Messrs. Gwynne also provide the independent system of *Air*, *Circulating*, *Feed and Bilge* pumping machinery shown on next page, that can also be used when required.

A general view of their *Combined Air and Circulating*

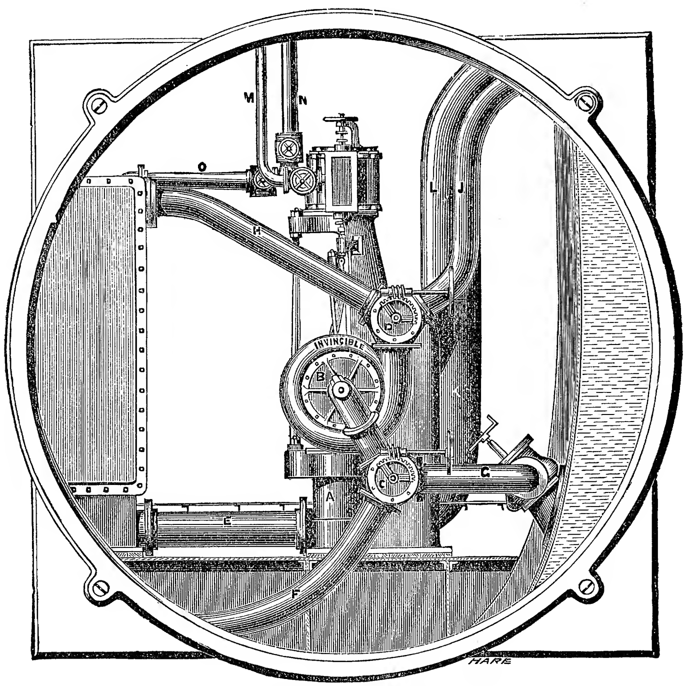


CENTRIFUGAL PUMP, FOR MAIL STEAMERS, ETC.



COMBINED CIRCULATING, AIR, FEED, AND BILGE PUMPING ENGINE.

Pumps, when attached to the main engines and ship is adjacently illustrated. In this case A represents two single-acting air pumps—B, two circulators—C, an "Invincible" non-return valve—D, a similar valve for discharging overboard or into the condenser—E, air pump suction pipe from the latter—F, bilge suction to circulating pumps—G,



AIR AND CIRCULATING PUMPS IN SHIP.

sea suction to the same through Kingston valve on outside plating of ship—H, circulating discharge to condenser—J, circulating discharge overboard direct without passing through condenser—K, circulating water discharge overboard from condenser—L, air pump discharge overboard—M, steam to engines from main steam pipe—N, exhaust of engines to air—O, exhaust of engines to condenser.

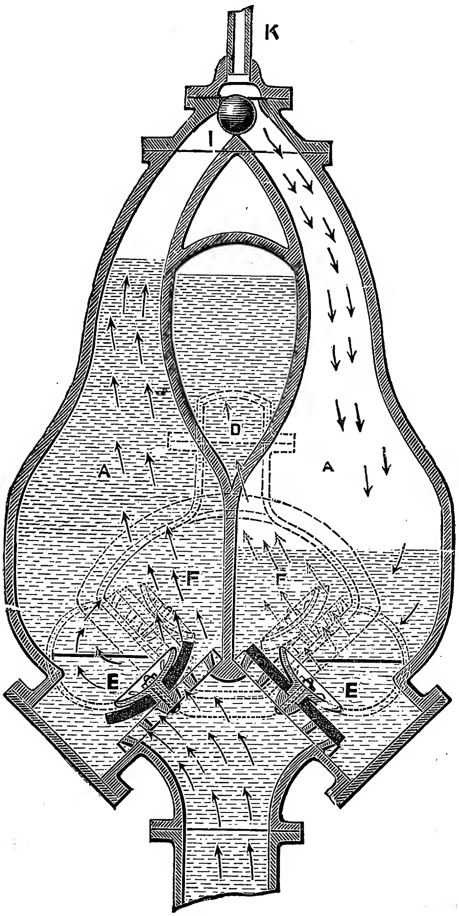
By means of the very simple arrangement of "Invincible" non-return valve and hand gear, shown in the engraving, not only may the direction of the flow of water be easily changed, but it becomes impossible, through carelessness, or otherwise, for any large quantity to pass unobserved into the bilge through the sea suction pipes. The necessity of this will be obvious from the fact that, owing to want of attention to this vital point, the safety of ships has been endangered by an influx of water which no one knew how to stop.

For reasons already given the centrifugals are extremely popular low lift pumps, not only for sea service, but for land purposes involving in some cases a delivery of at least 250 tons of water per minute from one pump alone. The absence of all valves is a most important feature in their construction, so also are the curved vanes which work inside the casing, to which easy access for examination or repair is fully provided. For lifts up to 30′ 0″ in height, the usual ship arrangements have discharges for each pump ranging from 28 to 1870 cubic feet per minute, through pipes 3″ to 24″ diameter, and for convenience in fixing, the position of the flanges can easily be altered a little by slackening the bolts in the couplings, and swivelling the pump case so that the pipes leading from it may be as straight as possible. In addition to this, the suction and discharge branches on the casings of right and left hand pumps, are made in no less than eighty combinations to suit varying conditions.

In the year 1698, Thomas Savery patented an engine for raising water by the direct pressure of steam *upon its* *surface*—the vacuum being formed by the condensation of the waste vapour. The stimulus thus given to mining operations was immense, and yet, strange to say, the inventor's important lead was not followed, as every successive improvement was directed to the raising of water by the action of steam upon a piston, owing to the uselessness of the new pump for the almost universal high lifts of mines, unless arranged in vertical tiers 60 to 90 feet apart. On account of this the engine was considered a failure, until its principle was utilised in a highly developed and amended form by the Pulsometer Engineering Company, of London, who have brought this extraordinary pump to its present excellence by means of innumerable experiments, one of which led to the introduction of a valuable improvement which has reduced the steam consumption to about one half of what it had previously been.

The annexed view shows the interior of a *Pulsometer*, whose action may be thus described: The pump consists of a single casting, having two peculiarly shaped bodies AA, with a separate neck piece I, forming a common steam chamber in which the ball valve oscillates. The lower ends of the main chambers contain the indiarubber disc suction valves EE, behind which may be seen, in dotted lines, the discharge valves FF with their chamber and outlet pipe D, whilst underneath all is the suction branch.

Upon filling the pump with water, it can at once be set in motion by admitting steam through the pipe K sufficient to expel the fluid without commotion through the outlet as indicated by the arrows. When the water, however, falls to the level of the horizontal opening leading to the discharge, the steam agitates it by violently blowing through, and is at once condensed. The vacuum now formed in the emptied chamber reverses the position of the ball valve, which allows the



SECTION OF PULSOMETER PUMP.

steam to act as before in the other chamber that has now become full. Hence, with rapid changes from right to left, and steady flow through the pipes, even *without* the usual air vessel, the cycle of operations goes on continuously, the ball valve oscillating and turning on its seat at every stroke, thus enabling its surface to keep in good order for a long time.

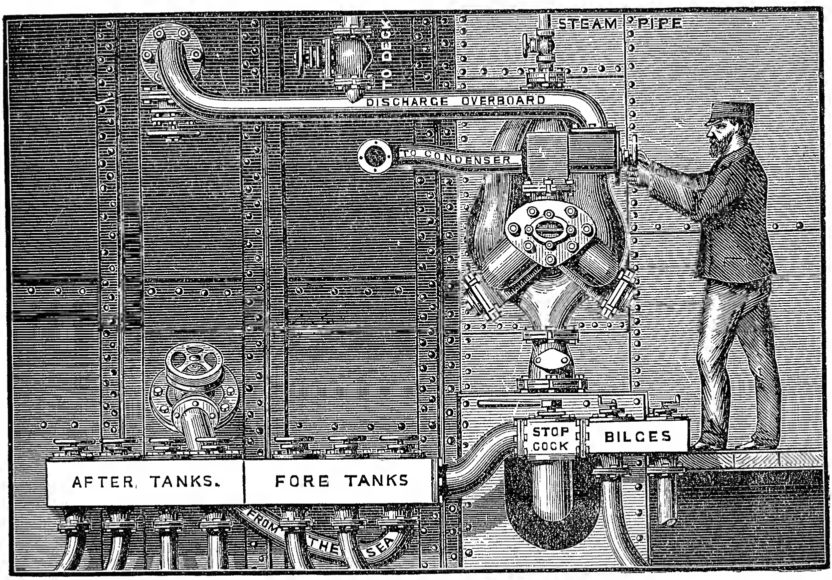
This pump is extensively used for a great variety of purposes on land, but in ships it is chiefly employed for emptying water ballast tanks and bilges, extinguishing fires, sanitary pumping, auxiliary surface condensing, etc., and in these respects it has proved a valuable acquisition, as the work is done silently and effectively with only a small quantity of steam. For marine purposes the apparatus is made in sizes capable of discharging from 9 to 232 tons, or 2,000 to 52,000 gallons of water per hour, and one of its peculiar properties is that although in a steamer it is necessary to secure it permanently in one position, in mining or other operations it can be temporarily slung by a chain when working at any required level.

Its application to a ship is shown on next page by an exterior view of a pump capable of discharging 130 tons of water per hour. Here we have the usual Kingston valve for sea suction, and three different sizes of *Communication Boxes* for after-tanks, fore-tanks, and bilges, with pipes leading to the various parts of the ship, all of which are indicated by means of engraved brass plates fastened to the top of each separate valve box, thus avoiding all the confusion in working that existed before this system was introduced. The other connections are self-descriptive and need no comment.

Without entering into the scientific phases of the question, it may be said that the capacity of the usual double acting *Circulating Pump* when worked by the main engines is about equal to the content of the L.P.

Cylinder ÷ 50. We shall, therefore, allow this ratio for the *Vencedova*, and as the stroke has been fixed already at 3′ 3″, the required diameter of the pump will be 16″, and its rod $2\frac{3}{4}''$ diameter, or D ÷ 6.

The most suitable position of the *Kingston Valve* for sea suction will be guided to some extent by the absence of butt or other joints, etc., in the plating of the ship at the



VIEW OF PULSOMETER PUMP ARRANGEMENT IN SHIP.

desired place, which has to be found by reference to the working model and transverse sections; this, indeed, is necessary for all other similar attachments. The aperture in the outer plating should be covered by a brass guard, filled with small square holes, whose total area should be at least 1·5 times that of the pipe, to allow for fouling. For such purposes the above valve is a great favourite, as it is easy to manage, and if by any chance the spindle should break the pressure of the water outside automatically closes the valve, on the well known safety or "non-return" principle. Its ordinary position is shown in the ship arrangement of Messrs. Gwynne's pumps, which illustrates the method of variously angling the flanges of all similar fittings on boilers, or ships, etc., throughout the whole domain of engineering. The Pulsometer Pump, etc., general view, also shows the *clear spaces* that have to be found for all ship-side fixings in any part of a vessel.

Amongst the indispensable adjuncts to engines of all kinds, none can be more important than those for restoring to the boilers the water that has been taken from them in the form of steam. To provide for this, two *Feed Pumps* are always fitted, each of which is large enough to supply the whole of the boilers in case of need. And while both of them are constantly going, and thus keeping up the proper level of the water, as seen by the gauge glasses, the surplus is discharged into the hot well through an escape valve attached to each pump. At the same time the quantity admitted to each boiler, under any circumstances, is exactly regulated by means of a check valve fixed on the front or side.

The above arrangement involves a waste of power that might be avoided, as Sir William Fairbairn discovered for himself at Millwall, and therefore gave the feed and bilge pumps of H.M.S. *Dragon*, and others, a very simple disconnecting gear, which enabled their rods to act as air pump guides, and simultaneously saved much useless wear and tear of working parts.

As the proportions of the boilers are regulated by the amount of steam used at each stroke of the high-pressure piston, so also does the content of each pump depend upon the quantity of water required to make that steam. Since, however, a comparatively fresh supply is obtained from the hot well, and there is therefore not much lost by blowing off, the feed pumps can be of lesser capacity than they used to be with jet condensation. Nevertheless, leaks, or accidents, may involve the application of the supplementary jet, and hence each pump will be sufficiently large if made capable of delivering *three* times the net quantity to the boilers.

Taking the usual steam pressure for triple expansion engines at 150 pounds per square inch, the content of each pump may be about equal to the H.P. Cylinder capacity ÷ 80 to 90, and the bore of the pipes should be large enough to allow the water to flow through them at a maximum speed of 400 to 450 feet per minute. That is, if a plunger 6″ diameter and 28″ area is running at the latter velocity, the pipes should be the same size, but if the speed is only 225 feet, their area may be 14, or the diameter at least $4\frac{1}{4}$″.

To suit the *Vencedora's* H.P. engine, her feed pumps will be $4\frac{3}{4}$″ diameter and 3′ 3″ stroke, or capacity of cylinder ÷ 80, and the area of pipes in accordance with the aforesaid rule.

The *Bilge Pumps*, as their name implies, draw from the bottom of each compartment in the ship, by means of *Communication Boxes* fitted with the required number of valves, as previously mentioned. The Board of Trade also requires that one of them should be made to draw from the sea as well, and thus act as a fire extinguisher in case of need. For the sake of uniformity they are often made the same diameter as the feed pumps, but some engineers prefer to give them about one third more capacity, or say content of high pressure cylinder ÷ 60.

The suction pipes are made of lead for chemical reasons, but the tail ends, leading directly from the bilge to the *Straining or Mud Boxes*, are usually of cast iron, or, as in the Navy, of galvanised wrought iron for lightness. These boxes prevent the valves of the pumps from being choked by small coal, bits of wood, pieces of dirty waste, etc., washing about at the bottom of the ship, and are divided into two partitions by a brass plate filled with holes not exceeding $\frac{3}{8}''$ diameter, and having a total area of at least twice that of the pipe. As the pump draws water only on one side of the perforations, the mud and dirt is deposited on the other side, and thus all danger is averted. These receptacles have covers that are made air tight by means of indiarubber joints, and are so hinged and swivel-bolted that the plates can be at once taken out, and the interior cleaned with great ease.

Besides the main engine pumps previously referred to, one for *Sanitary purposes*, of at least one third of the capacity of one of the bilge pumps, is actuated at intervals by the air pump levers, etc., and is used for discharging water on deck in various parts of the ship.

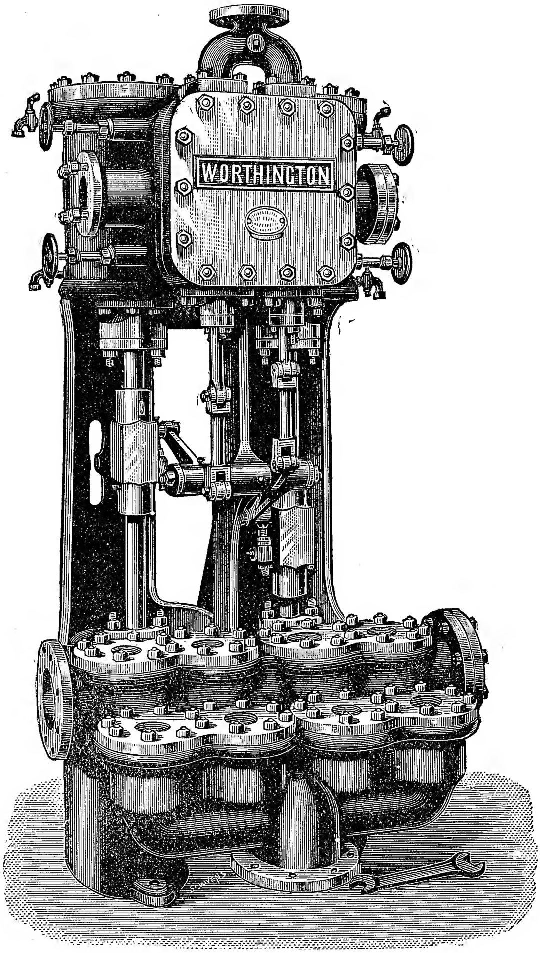
A *Hand Pump* is also employed to fill the boilers, empty the bilges, and wash the decks, etc., when steam power is not available. Independent of this, however, the pump is made workable at any time when required, by means of a stud screwed into the forward end of the crank shaft, or in other ways, which make it an excellent auxiliary in case of damage to the others.

The last named just about completes the list of pumps that have all along been driven by the *Main Engines*, or at least until racing speeds caused so many modern innovations to be made, which have now become a necessity for the reasons previously given.

There is no *Auxiliary Pump* in the machinery department that is so generally and conveniently useful as the well known "Donkey." In other parts of the vessel he is termed a "pumping engine," or a "fire engine," according to circumstances. He gets his steam from the donkey boiler and also the main boilers. He draws water from the sea for a variety of purposes too numerous to mention, including the filling of the condenser tubes before the engine begins to move. He draws from the bilges and keeps the ship dry when in port. He draws from the hot well to feed the boilers when necessary; in the Navy, however, he has, in an amended form, superseded the engine feed pumps for this purpose. He discharges on deck for cleansing or fire extinguishing operations, through flexible hose pipes. In short, there is nothing that he will not do if only prompted.

To meet the demand that has arisen for machinery of the latter description, for boiler feeding up to 250 pounds pressure, Messrs. Worthington designed the adjacently illustrated *Vertical Marine Pump* to suit the views of the Admiralty. This has been subjected to critical tests at Devonport Dockyard, and with such excellent results that it is now supplied in numerous sizes to very many naval and mercantile vessels throughout the world. The steam cylinders and their connections embody some of the latest patented features, as also do the pumps, all of which are arranged with the object of obtaining extreme compactness, easy access to internal parts, and the least amount of attention and repairs.

In all the greatly diversified and extensive pumping arrangements of a ship, the greatest possible care has to be exercised to prevent a careless or ignorant attendant from flooding a vessel perhaps to destruction—instances



NEW STYLE BOILER FEED PUMP.

of which are on record. The Board of Trade, knowing this, exercises severe and constant vigilance upon the safety of every ship "now building," so that the greatest simplicity and efficiency in these important details may be secured. To further this most desirable end, all suction and discharge openings in a vessel's side or bottom must have valves or cocks, or both together, fixed to them, so that if a pipe should be damaged or broken, the inrush of water can be at once stopped.

As inlet openings of every size must be covered by gratings whose required area of round or square holes may be troublesome to find, it is well to have at hand variously arranged large scale sheets of the above for immediate reference. On these drawings, circles and also rectangles should be shown in red or blue, enclosing a sufficient number of apertures to suit the standard sizes of valves, cocks, and bilge strainers, which will be found most useful whilst preparing working details.

The *Duties* that devolve upon the chief engineer of an ocean mail liner, as well as upon his colleagues, are most important and greatly diversified. For instance, in the S.S. *City of Paris*, there are 14 compartments in the double bottom of the hull, having in each case from two to four pumps, the former of which require to be sounded at least twice a day in port, whilst the temperature of the cold storage room has to be taken every four hours in port, and at sea every twelve hours.

The *Ventilation* of the ship, throughout its entire system, involves the application of pipe arrangements with hundreds of openings that, in addition to the following list of pumps and engines in various parts of the vessel, have to be carefully attended to.

The *Machinery*, as a whole, includes two sets of *Main Triple Expansion* engines, each of 10,000 horse power; two *Pumping* engines immediately connected with the above; twelve *Hydraulic* engines; two *Cold Storage* engines; four *Centrifugal* pumping engines; four *Auxiliary donkey* engines for boilers; eight *Dynamo-working* engines; twelve *Blowing* engines; five *Elevator* engines; six *Pumping* engines in stokehole; two *Pumping* engines in stokehole for *Sanitary* purposes; three *Fresh water* pumping engines, and eight engines directly connected with the *Refrigerating* plant, besides a few more of minor character. Thus giving a grand total of ninety-two single engines of every size, inclusive of all their attachments, and a mazy labyrinth of valves, cocks, pipes, etc., that have to be looked after by the engine room staff.

The *Chief Engineer* is supplied with an executive numbering one hundred and eighty-four, assigned as follows:— eighteen assistants for the machinery and boilers, three cylinder and two hydraulic experts, and two refrigerator engineers. The rest consist of petty officers, firemen, coal trimmers, etc.

From the above some idea may be gathered of the interior of modern high class liners, and of the skill required, not only in those who work them, but in the designing and constructive staff at the establishments where these vessels are built, and where *everything* is considered from first to last that can in any way add to their safety and efficiency.

The following will, perhaps, explain the cause of the rapid filling of one of a ship's compartments when the bottom of it has been cut into:—

The theoretical velocity in feet per second with which water is discharged through an aperture is given by the rule:—

$$V = \sqrt{H} \times 8.$$

In which H = the head of water in feet, or depth from surface to centre of opening. Now, if we suppose an opening 30″ diameter, and 20 feet below the water-line of a ship, the theoretical initial influx per hour may be thus found:—

The square root of 20, or $4\frac{1}{2} \times 8 = 36$ feet velocity per second, or 129,600 per hour, and as the area of a 30″ circular opening is 4·9 square feet, this gives $129{,}600 \times 4{\cdot}9 = 635{,}040$ cubic feet, or 18,144 tons at 35 feet per ton.

Inasmuch, however, as the opening is in a thin plate, instead of one scientifically constructed, the true initial influx will be at the rate of $18{,}144 \times {\cdot}615 = 11{,}158$ tons. This, however, will be gradually reduced as the ship fills, the outside pressure diminishes, and the inside resistance increases, unless the full pumping power of the vessel is able to discharge the water overboard as fast as it comes in, as no doubt it has often done most effectually in a time of danger.

CHAPTER XXI.

MINOR DETAILS OF MARINE MACHINERY.

Value of good Tables of Proportions—Their System of Construction—Examples from Practice — Table of Bursting Pressures of Cylinders—Covers of various kinds, and their Bolt Fixings—Proportions of Joints and Flanges — Steam Pipe Explosions — Subsequent Experiments — Results of Overheating — Curious Discoveries—Opinions of Engineers—Lapwelded Steel Pipes—Wire Lapping Process—Pipe Arrangements, and their fitting on board ship—Copper Pipe Table—Sheet Copper, &c., Table—Pipe Bending Process.

PEOPLE engaged in marine designing who value the tranquillity that arises out of labour wisely expended, will do well—as previously remarked—to provide themselves with *Tables of Proportions* of even the smallest details most generally in use. Such, for instance, as those that come under the head of "Valves," "Cocks," "Pipes," etc., and all their fixings, for the simple reason that, although the heavier portions of an engine may be more or less diversified, there is an enormous amount of repetition work of a smaller class that requires extra consideration on account of the saving thus produced in material and workmanship, not to mention time in the drawing office. Hence, we may reasonably add a little metal to parts that are only made by the dozen, whereas in those—especially of brass or copper—that are manufactured by the hundred, or the thousand, every thing should be cut down as far as possible. And although economy in the arrangement of works, in their machinery, in massive engine details, and in all the manipulative processes connected with them, are conspicuously visible, it is in the multitude of small things, similar to those now under consideration, that the principle may be still further extended.

In all these matters the drawing office takes the lead, as usual, by providing elaborate tables on an extensive scale. For instance, a type of feed, discharge, stop, safety, or any other valve that is in general demand for large and small engines and boilers, should have a thoroughly matured specimen shown exactly on a drawing either half size or full size. Block letters placed upon it should be used for reference to an accompanying list of dimensions of every part, for all the diameters of valves generally employed. And here, the latest and best experience ought to be utilised, so that a trustworthy set of dimensions may be obtained.

For all round calculations of the strength of circular boxes such as those referred to, or cylinders of any kind, tables of the bursting pressures of pipes in cast iron and brass, etc., ranging say from 2″ to 48″ diameter for the former, and to about 18″ for the latter, will prove very serviceable. The tensional strength, however, of the metals must be fixed at so many pounds or tons per square inch, according to circumstances.

The annexed quotation from a table originally used for water pipes, and also one for engine brass work, will illustrate these remarks, the breaking strain of cast iron being taken at 15,000 pounds, or about $6\frac{3}{4}$ tons, and that of brass at 18,000 pounds, or 8 tons per square inch. Upon these strengths full tables have been calculated which may be variously modified to suit other conditions.

As the bursting pressures of straight and solid pipes only are given, and as it has been proved by numerous experiments that those having branches are not so strong, it follows that valve boxes, as generally constructed, should have extra thickness given to them.

CAST IRON PIPES—BURSTING PRESSURE.

Diameter.	Thickness.	Bursting Pressure.	Diameter.	Thickness.	Bursting Pressure.	Diameter.	Thickness.	Bursting Pressure.
3	½	5000	7	⅝	2678	11	¾	2045
	⅝	6250		¾	3214		⅞	2386
4	½	3750	8	⅝	2343	12	¾	1875
	⅝	4687		¾	2812		⅞	2187
5	½	3000	9	⅝	2083	15	⅞	1750
	⅝	3750		¾	2500		1	2000
6	⅝	3125	10	⅝	1875	18	⅞	1458
	¾	3750		¾	2250		1	1666

BRASS PIPES—BURSTING PRESSURE.

Diameter.	Thickness.	Bursting Pressure	Diameter.	Thickness.	Bursting Pressure.	Diameter.	Thickness.	Bursting Pressure.
3	¼	3000	7	7/16	2250	11	½	1636
	5/16	3750		½	2571		9/16	1841
4	⅜	3375	8	7/16	1968	12	½	1500
	7/16	3937		½	2250		9/16	1687
5	⅜	2700	9	7/16	1750	13	9/16	1558
	7/16	3150		½	2000		⅝	1731
6	⅜	2250	10	½	1800	14	9/16	1446
	7/16	2625		9/16	2025		⅝	1607

Having found the bursting pressures as above, for pipes or cylinders, we have a scientific basis to work upon and utilise in very many ways to suit the greatly varied pressures of steam and water usually employed. The next movement is to provide suitable flanges, covers, and joints, and here we are thrown at once upon the bolt fixings for guidance. As the ends of the main connecting rods take their proportions from the bolts, so also do the flanges, etc., just referred to, and although Theory indicates that if 20 bolts $1\frac{1}{4}''$ diameter are sufficient for a cylinder cover, 40 bolts having the same total area at the bottom of thread will do quite as well; practice not only decides that the former arrangement is much better, but fixes the *pitch* of the bolts at about $\frac{1}{2}''$ to $\frac{7}{8}''$ for every "eighth" of diameter according to pressure, or from $4''$ to $7''$ for a $1''$ bolt, and this in turn gives the total number.

When the diameter has been thus settled, the *thickness of cylinder cover flanges*, when of cast iron, may be made $=$ D, of wrought iron bolt $\times$ 1·33, and the *width of joints* $=$ D $\times$ 3. Everything in this respect concerning the low pressure cylinder remains pretty much as it was before compound engines came into use, when boiler pressures rarely exceeded 25 pounds. And as the power given out by all the cylinders of triple engines is fairly balanced, notwithstanding their various diameters, it follows that the strengths of parts for the L. P. C. are largely utilised in the other two. Hence, although the diameters of the stud bolts, thickness of flanges, and width of joints remain the same in each case, the number of the bolts is increased to suit the intensified steam pressures, or, what is the same thing, their pitch is diminished. That is, in a set of triple expansion cylinders having $1\frac{1}{8}''$ studs in the covers, the joints will be $3\frac{1}{2}''$ wide, flanges $1\frac{1}{2}''$ thick, and pitch of studs in L. P., Intermediate, and H. P. cylinders $7\frac{1}{2}''$, $5\frac{1}{2}''$, and $4\frac{1}{2}''$ respectively, while the distance from centre of studs to outside of flange is $1\frac{1}{2}''$, and so on in proportion for other sizes of fixings.

While *Cylinder Covers* are made extra strong on account of the severe shocks through priming, etc., to which they are liable, multitudes of others which are not so strained, and which permeate the whole domain of mechanical engineering, admit of lighter proportions. Those of the ordinary single plate rectangular form, however, are too often badly designed, that is, if the body of the cover is of $\frac{7}{8}''$ metal, and the bolts $\frac{3}{4}''$ diameter, the flange will be about $1\frac{1}{8}''$ thick. They will also be made square at the corners, thus producing an unsightly and unnecessarily heavy casting. The best plan is to make them equal to the thickness of the body all over, and with rounded corners that give the joint the same width throughout, and greatly improve the appearance of the covers, thus making them a striking and ornamental feature in all engines. When of large size, and exposed to high pressure steam, these details are generally box shaped, and substantially strengthened with numerous ribs to enable them to withstand heavy loads. They should also be fitted with eye bolts for slinging purposes, and screwed pins for easing them off their joints.

In all bolts above $\frac{7}{8}''$ diameter, subject to shocks such as those in cylinder covers, the strain is usually taken at about 5,000 pounds per square inch at bottom of thread for the best steel, and about 4,500 pounds when below $\frac{7}{8}''$ but when iron is used this allowance should be one fifth less. If, however, covers are exposed only to steady loads, strains of 6,000 and 5,000 pounds respectively, for steel and iron, may be used. Doors and covers as a class, such as those for valve boxes, etc., are now most irregularly loaded by high, medium, and low steam, and by water pressure of similar nature. They are also diversified in material, that is to say, wrought iron and cast iron, steel and brass, are used in such a way that their once simple question of proportion has become complicated.

A standard width of faced and steady pressure joints is about $2\frac{3}{4}''$ times the diameter of the bolt, and this, as well as the pitch of studs and thickness of flange, etc., for, say, 30 pounds pressure, is shown in the following Table. The distance from centre of bolt to edge of flange being $D + {}^{1}/_{16}''$, and to the body of pipe, etc., $D + {}^{3}/_{16}''$, when the diameter of the studs is less than $1''$.

PROPORTIONS OF FLANGES.

Diameter of Bolts.	Pitch of Bolts.	Width of Joint.	Thickness of Flange.	A.	B.
$\frac{1}{2}$	3	$1\frac{1}{2}$	$^{9}/_{16}$	$^{9}/_{16}$	$^{11}/_{16}$
$\frac{5}{8}$	4	$1\frac{3}{4}$	$\frac{3}{4}$	$^{11}/_{16}$	$^{13}/_{16}$
$\frac{3}{4}$	5	$2\frac{1}{8}$	$\frac{7}{8}$	$^{13}/_{16}$	$^{15}/_{16}$
$\frac{7}{8}$	6	$2\frac{1}{2}$	1	$^{15}/_{16}$	$1^{1}/_{16}$

The joints of cast iron *pipe flanges* must necessarily be a little larger than those given in the above table, as their width and diameter are independently governed by the thickness of metal in the barrel, and by the distances of centres of bolts from the outside of flange and from the body of the pipe, both of which are respectively given in columns A and B. Hence the width of a joint for pipes, or for any similarly constructed castings or forgings becomes A + B + thickness of barrel or web. It may be added that the four sizes of bolts noted in the table permeate the whole domain of ordinary jointing up to about 30 pounds pressure; above this, however, extra strength must be given in some form or other.

Up to the year 1887, hundreds of thousands of *Copper Steam Pipes*, were made and used for all pressures, upon the old and well known lines, and with complete success. In later times, however, disasters occurred that caused a much greater loss of life than if nearly the whole of the engines to which they belonged had suddenly collapsed; thus creating, for a time at least, a loss of confidence in this important branch of industry. What would "Alexander the Coppersmith" have said, if he could have revisited the earth, and seen how his craft had been endangered by the advance of engineering science? Happy man! he had no high pressure steam to contend with in *his* time, or the results might have embellished history.

The loss of confidence referred to was brought about very simply. In the above mentioned year a steam pipe explosion took place on board the S.S. *Elbe*, which caused the deaths of ten people. Other similar disasters followed, including one in the S.S. *Lahn*, thus clearly indicating the presence of hidden evils of an unusual character. The former vessel had just had her old compound engines tripled by a very celebrated firm, thus involving a new boiler and steam pipe arrangement which had most successfully passed the hydraulic test of 300 pounds on behalf of the builders, and another of 350 pounds to please the owners. Notwithstanding this, however, one of the main pipes burst while the vessel was on her trial trip. A most rigid examination of all the facts connected with the case was subsequently made by Mr. William Parker, Chief Engineer Surveyor to Lloyd's. He also inquired into the cause of the *Lahn* disaster, and then combined the results of both investigations in a valuable paper which was read before the Institute of Naval

Architects, in 1889, and formed the basis of the few following remarks.

It was only natural to suppose that the bursting of the pipes, although fitted by eminent firms, would be found attributable to occult defects in the workmanship or the material, and that possibly due care had not been exercised in their manufacture. The investigation referred to, however, went to show that the elements of serious danger entered into the ordinary methods of making brazed pipes, especially when intended for high pressure steam, and this became more apparent as the inquiry proceeded.

The new engines of the *Elbe* had cylinders 33″, 53″, and 88″ diameter, by 4′ 0″ stroke, with a working steam pressure of 150 pounds per square inch, the main steam pipe to the H.P. cylinder being $9\frac{3}{8}$″ bore by ·276″ in thickness, the joints of which were lapped and brazed in the usual way. As the pipe in all its lengths was proved to be of the best copper, and had passed the most severe tests, it was only fair to conclude that it was perfectly safe, and therefore its rupture was a matter of astonishment to everyone.

Mr. Kirkaldy, of London, made numerous experiments with the exploded pipe, and also its adjacent pieces, with the object of ascertaining their tensile strength, and these to a large extent formed the foundation of the official Report, and also the paper to which reference has been made, both of which exhibited masterly reasoning on the part of Mr. Parker in a somewhat novel field. Test pieces, cut from the unbrazed portions of the damaged pipe, were found to have a tensile breaking strength of 33,000 pounds per square inch, with an elongation of 33 per cent. before fracture. So that the bursting pressure in its cold state should have been 1,940 pounds per square inch, or 13 times the working pressure. Or, taking $^3/_{16}''$ as the actual thickness of the copper at the point of rupture, the pipe should not have burst with less than 1,220 pounds pressure.

A portion of the uninjured part of the exploded pipe, and also two similar pieces cut from the adjoining length, all of which were about 30″ long, were fitted with flanges and tested hydraulically to destruction, and it was then discovered that, while the former burst with 780 pounds per square inch, the two latter gave way with 600, and 1,440 pounds respectively. This great and unexpected diversity in the bursting pressures, under the same apparent conditions and similarity in the character and position of the fracture in each case, seemed clearly to indicate that the material had been injured in the vicinity of the seams by the operation of brazing.

Some very careful experiments were made many years ago by the Franklin Institute of America to ascertain the effects of increased temperatures upon sheet copper, and from these we learn that at 360° Fahrenheit the *Elbe's* fractured steam pipe would have been 15 per cent. weaker than when it was cold, as we shall endeavour to show.

Out of nine specimens cut from the *brazed joint* and heated to 360°, the tensile strengths ranged from 8·59 to 12·32 tons, having a mean of 10·53 tons per square inch. In the same manner, 148 strips cut at points clear of the brazing, gave way with strains varying from 10·19 to 13 tons, the mean being 11·81 tons. Other experiments made at the same time by Mr. Parker, upon fair samples of sheet copper, at temperatures ranging from 300° to 370°, showed a mean tensile strength of 9·93 tons. From these as well as from other similar experiments, it appeared that not more than a 10 ton breaking strain per square inch could be allowed for ordinary sheet copper at the temperature of 150 pound steam, apart altogether from the uncertainty arising from inferior brazing. After reviewing all the circumstances of the case, and all the elaborate experiments and practical reasoning that had been brought to bear upon it, Mr. Parker said in his Report :—

"*From this it will be seen that should a copper pipe be overheated during the brazing operation, and seeing that the metal becomes perfectly brittle at not much above the brazing heat, the pipe might be accidentally cracked while in this condition, and although the section of metal still remaining intact might be sufficient to sustain the cold water test pressure, yet hot steam and accompanying strains might develop and deepen the crack, and the pipe ultimately give way at the working pressure. This I consider to be the true explanation of the explosion of the 'Elbe's' steam pipe, and also that of the S.S. 'Lahn.' A serious element of danger is thus shown to exist in the present practice of brazing large, heavy copper pipes intended to be subjected to the high pressures now so common.*

"*It is generally admitted that welds or brazed joints in any material must possess certain elements of uncertainty, and the above experiments show this uncertainty to be greatly increased in the case of copper worked over a fire. How to eliminate these evils becomes an important question.*"

The disaster on board the *Jumna*, in 1890, was very easily explained on account of these discoveries. In this case, however, the explosion took place at the bend of a branch steam pipe close to a stop valve on one of the boilers. The diameter of this pipe was 6″, and the thickness of the copper sheets from which it had been made was about ·238″, whilst the scarphing and brazing of the joints was accomplished in the usual way. The engines having cylinders 30″, 42″, 60″, and 84″ diameter, × 5′ stroke, were constructed by a very well known firm with a 160 pound steam pressure, the ruptured pipe being made of the best material by coppersmiths of the highest reputation. Notwithstanding this, an explosion occurred at 150 pounds pressure while steam was being raised, previous to the departure of the ship for Australia.

In the opinion of the Board of Trade Commissioners, the accident was due to extra thinning of the copper at the part that gave way, and also to the overheating and partial cracking of the metal during the process of brazing. The bend had, therefore, very little margin of strength, and this ultimately vanished in consequence of the strains originated by the expansion and contraction of the pipe when exposed to various degrees of temperature. Tests were made as usual, and, although these showed the good quality of the copper, they also indicated tensile weakness next the brazed joint, which was all the more apparent as an exact duplicate of the burst pipe, fitted to the starboard boiler, was hydraulically fractured at a pressure of 1,200 pounds per square inch.

At the conclusion of a lecture subsequently given by Mr. Parker on the *Elbe* and *Lahn* disasters, Dr. Kirk spoke somewhat feelingly regarding "the very extensive and able services rendered by brazed steam pipes, which he thought should not now be thrown away. He also added that experiments made by Dr. Sinclair for his firm showed that ordinary brazed copper pipes, when carefully made, were quite trustworthy. And further, seeing that out of the immense number of high pressure engines supplied with these pipes only two notorious cases had arisen, their usefulness was not by any means exhausted. Much, however, depended on the skill of those who did the brazing."

Dr. Kirk further observed, that "*it had long been known that in a length of, say 12" pipe, there was a variation of strength that might perhaps be as much as 30 per cent. To meet this, however, a very large margin of thickness had been constantly employed, which had arisen out of the results of very extensive practice. Hence the allowances made by engineers were intended to cover all irregularities that might possibly exist.*"

The remarks of this gentleman have been fully confirmed by the fact that, in spite of the existence of the dangers referred to, so very few steam-pipe accidents have occurred, when compared with the extensive monthly list of breakdowns of shafts, propellers, etc., in steamers. Had it not been, however, for the great loss of life which these apparently unimportant disasters entailed, hardly any notice would have been taken of them, and possibly the scientific facts thus revealed would even now have remained in obscurity. It may be added that one of the results of the late disastrous steam-pipe explosions has been the successful introduction by Messrs. A. & J. Stewart, of Glasgow, of lap-welded *Main Steam Pipes*, which have been critically experimented upon both in a hot and a cold state, and also supplied in iron and steel to many of the principal engineers.

With the object of getting the latest particulars on this most important subject, we paid a visit to the works of Mr. Ellis Marsden, of Liverpool, whose establishment bears the date of 1792. This gentleman kindly explained his own method of manufacturing the steam-pipes in progress for H.M.S. *Royal Oak*, and other ships then building at Messrs. Laird's, and gave general information concerning his productions, with which I had long been acquainted. Mr. Marsden knew everything about the latest scientific discoveries, but in his opinion there was, after all, nothing like good brazing, such for instance as his own, which for a whole century had never failed, even with 200 pound steam pressures. At the same time, he considered the application of the strong wire lapping, now so popular, would remove the bare possibility of a serious accident under any circumstances, since even if a fracture *did* occur, the steam would only filter harmlessly through the small interstices of the lapping, instead of rushing overwhelmingly through a large rent in the body of a pipe.

This lapping consists of three or four consecutive wires laid on side by side under a severe tension, which is not relaxed until they are permanently fastened. It will therefore be seen that the pipe is very securely bound throughout, and further, that if a wire should give way from any unforseen cause, the others will be sufficient for all safety purposes.

After the diameters of the pipes have been calculated, they are shown in full in the ship, engine, and boiler *General Arrangement Plans*, as they are intended to be when the vessel is finished in every respect. With the view, however, of reducing drawing office designing of this nature to a precise system, and also of producing the most skilful economy in pipe construction and brass fittings, various tables have been prepared, which are much used for naval and mercantile ships, one of which, for water services up to 25 pounds pressure, is given on the next page.

TABLE OF EXHAUST, WASTE WATER, SEA AND BILGE INJECTION, BILGE PUMP AND CIRCULATING PUMP PIPES, UP TO 25 POUNDS PRESSURE PER SQUARE INCH.

Diameter.	Thickness in Pounds.	Diameter of Bolts.	No. of Bolts.	Diameter of Bolt Circle.	Diameter of Flange.	Thickness of Flange.
2	4	½	4	3⅝	4¾	5/16
½				4⅛	5¼	
3			5	4⅝	5¾	⅜
½		⅝	4	5⅜	6¾	7/16
4	5			5⅞	7¼	
½			5	6⅜	7¾	
5				6⅞	8¼	
½			6	7⅜	8¾	
6				7⅞	9¼	½
½				8⅜	9¾	
7	6		7	8⅞	10¼	
½				9⅜	10¾	
8				10⅛	11½	
½			8	10⅝	12	
9				11⅛	12½	
½				11⅝	13	
10	7		9	12⅛	13½	
½				12⅝	14	
11				13⅛	14½	9/16
½			10	13⅝	15	
12				14⅛	15½	
13			11	15⅛	16½	
14	8			16⅛	17½	
15		¾	11	17⅜	19	⅝
16				18⅜	20	
17			12	19⅜	21	
18	9			20⅜	22	

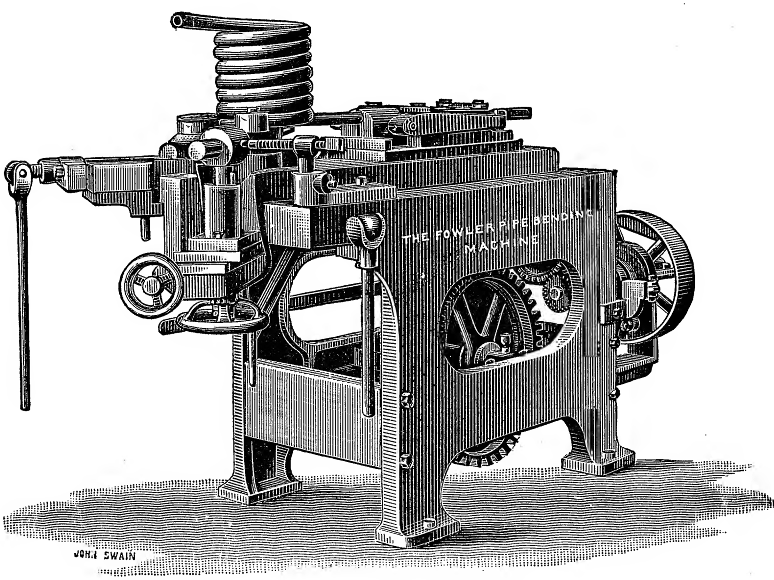
When the dimensions and arrangements of the pipes have been thoroughly matured, working tracings are taken direct from the plans, carefully figured and noted in every respect, and copies of them sent to the coppersmiths for execution. The specified thickness of the sheets, out of which pipes of all kinds are made, is given either by the Birmingham Wire Gauge, or by decimals of an inch, or by weight in pounds per square foot of metal. The annexed Table will give full information on this point, as the decimals have their equivalent fractions of an inch, either "*bare*" or "*full*" attached.

WEIGHT AND THICKNESS OF A SQUARE FOOT OF SHEET COPPER AND BRASS IN POUNDS.

No. B.W.G.	Thickness.	Copper.	Brass.
1	·300 = $^5/_{16}b$	13·740	13·170
2	·284 = $^9/_{32}f$	13·007	12.468
3	.259 = $\frac{1}{4}f$	11·862	11·370
4	·238 = $\frac{1}{4}b$	10·900	10·448
5	·220 = $^7/_{32}f$	10·076	9·658
6	·203 = $^{13}/_{64}$	9·297	8·912
7	·180 = $^3/_{16}b$	8·244	7.902
8	·165 = $^5/_{32}f$	7·557	7·243
9	·148 = $^5/_{32}b$	6·778	6·497
10	·134 = $\frac{1}{8}f$	6·137	5·883
11	·120 = $\frac{1}{8}b$	5·496	5·268

As many of the pipes in the engine and boiler departments require to be more or less curved, we give adjacently an illustration of an improved *Bending Machine* by the Fowler Patents Co., which is made in sizes capable of operating upon iron, brass, copper, steel, lead, &c., pipes, up to about 8″ diameter, without undergoing the usual processes of heating and filling. Its special advantages include uniformity of work produced, simplicity of action, which renders skilled labour unnecessary, and great economy in the manipulative process. When the machine is in operation the pipes are passed between grooved rollers, and as the position of these is altered, so also is the radius of the bend. For hand-power purposes, Mr. Kelly has devised an extremely simple apparatus that will be a valuable acquisition in places where work is of an intermittent character, and not too large for bending in this manner.

After the pipes have been made, and all lengths



PIPE BENDING MACHINE.

adjusted, and the loose flanges brazed on, the latter are faced and drilled for bolt holes. India rubber faced canvas is then inserted at water joints, and asbestos cloth at steam joints, and when all the separate pieces have been screwed together they are finished off in good style throughout the ship. In places where modern refinements are not available, the old canvas and red lead joints must still be used. These barbarous fixings did well enough in early days, but were very bad for disconnecting purposes, hence the new methods referred to became universal for steam and water joints of every size and description.

Owing to the very complicated nature of pipe arrangements in a ship, a little liberty in adjustment is given to the fitters, who, however, should be guided as closely as possible by the drawings. In all other details, however, the most rigid supervision is exercised upon foremen and workmen alike. That is, the plans are made perfect in every respect down to the smallest bolt hole, and with "Rights and Lefts"—"To be made to Templet," and "Length to be taken from Ship," added to them where needed, so that the workmen have nothing more to do than follow them. If, however, any alteration should become necessary, it has to be made in red lines on the drawing before anything can be done. By this means the work is greatly facilitated, a complete record of which is kept for reference for all future years.

The disasters previously referred to spread consternation amongst engineers on account of the exposure of a hidden danger, in which the action of heat upon copper played a conspicuous part. Now, however, confidence is restored, and as the means of preventing such calamities are fully understood, we anticipate renewed success for our old steam pipe friends, after having passed through a season of trial that magnified their virtues, while at the same time it threw light upon their vices.

CHAPTER XXII.

DETAILS OF ENGINES.—*Continued.*

Slide Valves — Equilibrating Appliances — Piston Valves and their Peculiarities—Modern Systems of Valve Gear—Application of Morton's Gear — Illustration of Joy's System — Joy's Steam Assistant Cylinder—The Link Motion—Innovations not always "Improvements"—Prejudice of Shipowners and Engineers—Usefulness of the Marine Governor—Engine Breakdowns—Evil Effects of Racing—Latest Improved Governors—Pistons as they are—Steam Cylinders—Their Detail Drawings—General Construction—Workshop Manipulation—Improved Triple Engines.

SINCE in all steamships the motive power is taken direct from the boilers, it is only natural that the greatest attention should be paid to its economical distribution in the cylinders of the main engines by means of valves and their connections. Details generally require careful consideration for the sake of good working and maintenance, and to avoid the possibility of fracture at any time. The most important of them all, however, is the gear with which the judicious development of power is so intimately linked, and for which at least five hundred "improved arrangements" have been invented. To these we need not refer, as Dr. Rankine and Dr. Zeuner have gone into the deep science aspect of the question, Mr. Seaton has taken in hand the practical science view of the case, and Mr. Burgh has provided us with a handy treatise on the *Slide Valve.* As other scientists have profusely and learnedly contributed books, etc., on similar lines of thought, we may perhaps be excused for unconventionally writing on such a dry-as-dust subject.

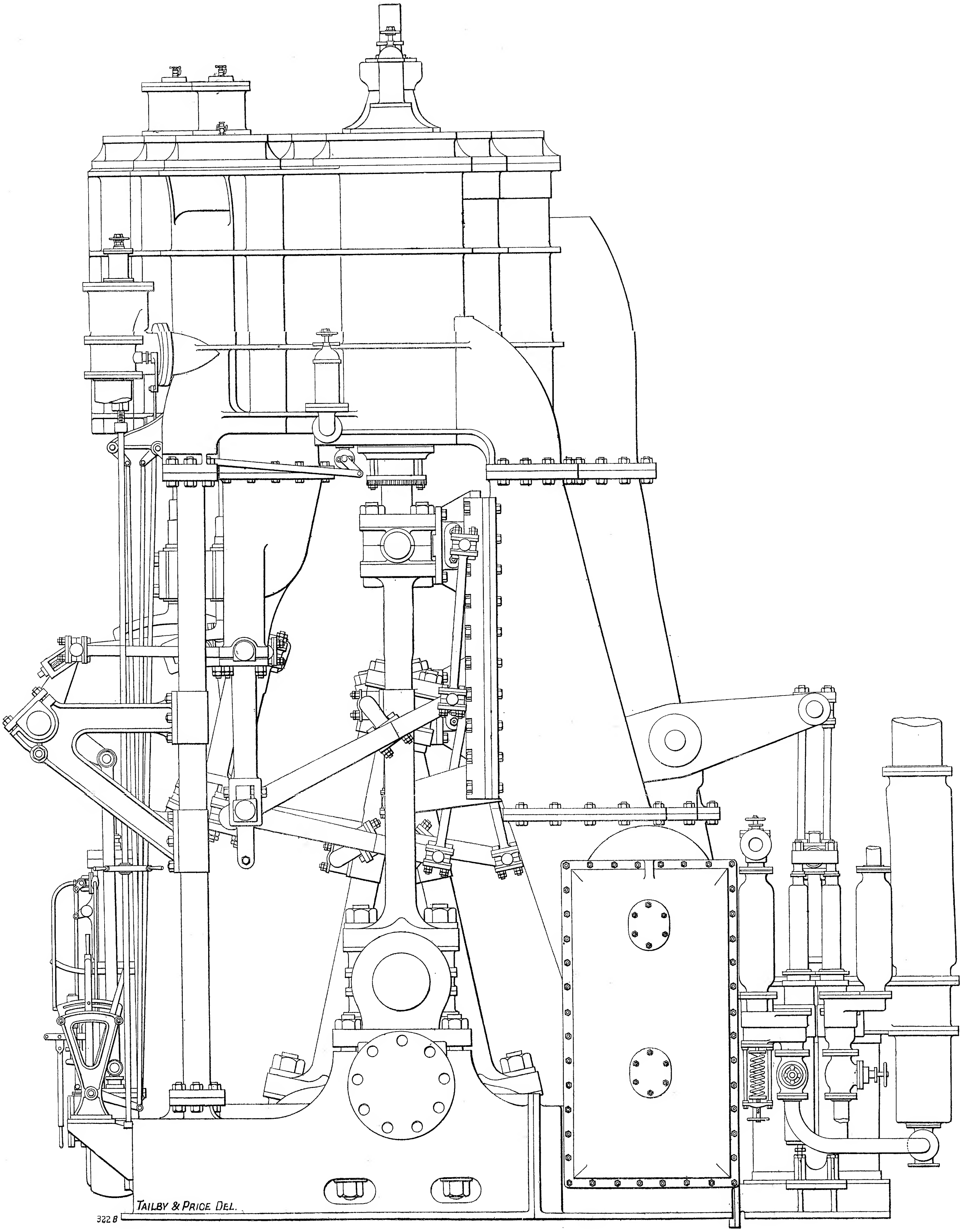
Of all the *Main Steam Valves* that have been devised, none has ever been so much appreciated as the ordinary slide, variously modified to suit the requirements of modern practice. Nor, indeed, is it likely to be superseded by any other for the medium and low pressure cylinders of engines. Mr. Corliss's rotating valve has long been very popular in America on land and water, but although much employed in our mill engines, it has not proved acceptable in British ships for practical reasons.

The valves almost universally adopted in marine machinery are of the ordinary single ported, and double and treble ported slide, and piston types, the latter of which has now become a necessity in many high pressure cylinders where the former are objectionable on account of their great frictional resistance. For lighter steam pressures, however, various methods have been utilised with the object of reducing the great waste of power involved in working the valves. By means of the double and treble ported valves the area of openings for steam and exhaust is twice and three times that of a single valve having the same stroke. Hence, by their use, either the area of the openings may be greatly increased, or the stroke of the valves correspondingly diminished.

In order to relieve the pressure on the working faces of large slide valves it is usual to fit to them some balancing apparatus, of which there are several varieties, notably that of Mr. Church, and for small engines that by Messrs. Payton and Wilson, both of which have been very successful. The latter is a circular double ported

TRIPLE EXPANSION ENGINES OF 4,000 HORSE POWER
FOR S.S. *CITY OF VIENNA*,

BY MESSRS. JOHN AND JAMES THOMSON, GLASGOW.



END VIEW LOOKING AFT.

slide valve of the simplest description, very easily moved, and capable of turning on its faces, whilst, at the same time, its weight and wearing properties are greatly reduced.

Piston Valves have had many detractors, not perhaps without good reason, but improvements have been made by Messrs. MacLaine, Mr. Thom, and others, which have caused them to become indispensable for the high pressures of triple and quadruple engines, where their splendid equilibrating qualities are now fully appreciated. The same principle is sometimes applied in a much simpler form to steam stop valves, but no equilibrium valve ever invented has had such a magnificent reputation as Harvey and West's " double beat," which is still employed in the cylinders of Cornish pumping and other engines, and in the rising mains of waterworks and mines, where at the outset it greatly benefitted the former, and proved invaluable to the latter.

The 'tween cylinder valve and Stephenson link motion arrangement has often been adversely noted on account of the additional length of engines thus entailed, and the extremely contracted spaces for overhauling the working parts. Here we have two good reasons for adopting excellent and well tried modern systems, such as the plan of putting the valves on the *sides* of the cylinders, which considerably reduces the fore and aft space, and gives much greater convenience for their examination and repair. To enable this to be done, however, new valve gears were introduced by various well-known engineers, who tried more or less successfully to remedy the defects of the old system. Mr. Morton's arrangement will be clearly seen in the Plate of the engines made by Messrs. J. and G. Thomson for the S.S. *City of Vienna.* After examining the machinery of this ship, with the kind assistance of her chief engineer, and learning what he had to say on the subject, we can only conclude that the above gear possesses admirable valve working as well as space saving qualities that have been fully tested in many other vessels similarly fitted. In this instance, the total length of engine room was four feet less than it would have been with the ordinary link motion, which, from a shipowner's point of view, is a very important advantage.

Another most excellent modern system of valve gear is that by Mr. Joy, which has now been successfully employed in about 1,700 locomotives, and in marine engines having a total of at least 380,000 H.P. The latter comprising paddle and screw machinery of every description, and also naval ships from 20,000 H.P. down to torpedo boats, etc. The advantages claimed for the invention are as follows :—

It is simple and inexpensive, and gives the nearest approach to a perfect distribution of steam.

It also favours an arrangement of machinery that shortens the engine room, thus leaving more space for cargo, and allowing complete accessibility to all the working parts.

Further, by its adoption, existing two crank link motion engines may be altered to Triples without increase of length, and this has been abundantly proved in very many ways.

Mr. Joy subsequently made another advance by introducing his "*Steam Assistant Cylinder*," which not only does the work of the original balance cylinder for relieving the weight of large valves, but by a very simple arrangement, cushions their inertia and assists to any desired extent in moving them, thus saving much wear and tear in the working parts. The appliance can be used for any class of engine, has nothing to get out of order, and is under the most perfect control.

The modern valve gears, as described, are more or less acceptable according to circumstances, but notwithstanding the disadvantages of the old link motion it overshadows them all in popularity when extreme compactness is not aimed at. The cause of this is easy to discover.

Amateur "inventors" are often unpractical in their ideas, and devise things that may be in some respects very good and in others very bad. The engineer may also be an inventor, but his own superior all-round knowledge gives him an immense advantage, which is clearly evident from the history of the past. Even at the best it is extremely difficult to introduce anything new, but one good method of accomplishing this is primarily to study the characters of shipowners—the peculiarities of their superintending engineers—and also the manners, customs, and idiosyncrasies of the sea-going hands, who live and move by day and by night amongst what are sometimes erroneously termed "*Improvements.*"

The shipowners are naturally averse to innovations until well tried, which was very apparent at the time Mr. Elder made the Compound engine a practical success. For many years the Pacific Steam Navigation Company had it entirely to themselves, but in 1868 orders for the re-engining of old vessels and fitting of new ones with the more economical machinery began to pour continuously into the various works throughout the country, until eventually the Triples slowly superseded their predecessors, and at last reigned supreme.

The prejudice referred to originated in the dread that every owner has, not so much of mere breakdowns, but of the danger, delay, and loss otherwise incurred by them at sea, which tempts them to bear the ills they have rather than fly to those they know not of. The superintending engineers hold the same opinions, and are additionally averse to untried improvements, in case *they* get into trouble by adopting them. The sea-going engineers also dislike them if their use involves extra responsibility and trouble that should be avoided. Hence, inventors would much more profitably solve the question of "How to do it," by studying the surroundings of those who employ their gear, and by producing things that are the essence of simplicity in arrangement—non-liability to get out of order amidst the rough usage of ocean service—and do not entail unnecessary overhaul or repair during the very limited time that vessels have now to remain in port. This will perhaps explain the reason why shipowners and engineers have such regard for the link valve motion they have known so happily all their days, and so frequently prefer to the best modern systems.

Whilst one day examining one of the new valve arrangements in a ship of the advanced type, I said to the "chief" in the usual tentative style—"Fine gear?"

"Very fine," he replied, "but there are *too many joints about it*," the drift of the observation being that a multiplicity of slackened bearings had sometimes either vitiated the action of the valves, or given too much trouble to adjust.

"Could they not have made the pins larger?" I remarked.

"Oh yes, it could easily have been done."

These faults, I have since discovered, form the main objections to some of the modernised valve gears, thus indicating that their designers had paid more attention to theoretical strength than to practical wear or allowance for friction, the last of which is so essential to good working in the smaller details of machinery, and can at all times be easily provided for.

The life-giving food supplied to the engines by the boilers has to be regulated by primarily making the main steam pipe large enough to deliver a sufficient quantity of steam into the high pressure cylinder at a mean velocity of about 8,000 feet per minute. The size of the pipe may thus be found :—

8,000 : Speed of piston : : Area of Cylinder : Area of pipe.

The net opening in the steam ports due to the motion of the valves is generally allowed to give a mean speed of 10,000 to 12,000 feet, and for the exhaust 5,000 to 6,000 feet per minute. These, however, are varied to suit circumstances. As the valves must perform their part with the utmost nicety, it follows that great responsibility rests upon the various kinds of gear above described, which they bear more or less satisfactorily according to the manner in which they are treated.

Although a stop valve on the H. P. Cylinder admits the full supply of steam from the boilers, it is regulated by means of a throttle valve in the usual way. The latter, as well as its connections, are shown in position in the *Vienna* drawing clearly enough to indicate their application. Formerly, when a ship was pitching heavily, one of the engineers had to stand continuously by the regulating lever, and thus by instantaneously diminishing the flow of steam to the cylinders the danger of overstraining the whole of the machinery by sudden racing was usually averted. Now, however, the *Mechanical Governor* has been so much improved that it can automatically perform the same operation under all circumstances.

The importance of this movement may be gathered from the fact that, in the British Mercantile Marine, during a recent period of eighteen months, 217 accidents happened to crank and screw shafts and propellers, exclusive of fractures discovered in port. Out of these 127 were broken shafts, in all of which the safety of the ship was more or less imperilled. And in addition to these we might also include some, at least, of the steamers lost every year throughout the world with all on board, perhaps through a broken tunnel shaft tearing a hole in the bottom, thus causing them to founder.

From the expressed opinions of various sea-going engineers we may select those of Mr. T. G. Barron, who says that "*When engines suddenly attain a speed of double the number of revolutions per minute at which they are intended to run, the strain upon the machinery, caused by the extra resistance to the propeller as it dips in the water, after being partially or wholly out of it, must necessarily be transmitted through the whole length of shafting to the engines themselves. If the governor is quick enough to check the racing before the propeller is again immersed, the severely irregular twisting strain upon the shafts will be avoided. So also will it be with the pumps and their attachments, as they will then be able to deliver their contents fast enough to prevent choking and consequent damage to the gear. The feed pumps especially, and also the main crosshead that works them, may indeed receive a very severe shock owing to their rams quickly coming down upon only a partial charge of water in the barrels, thus causing undue vibration to the surrounding machinery, which may in time produce a serious disaster.*

"*In addition to this, extreme racing will cause considerable agitation of the water in the boilers, materially facilitating, if not* *actually causing priming, thereby incurring the risk of fracture of a steam pipe by water hammering, and also smashes in the cylinders, not to mention the damage inflicted upon pump valves, doors, etc., and even the ship herself in various ways, by undue vibration. In short, it would be difficult to say where the evil ends, and in this respect, it is only necessary for a shipowner to know the effect of even a small portion of it, in order to see the benefit of having thoroughly efficient governors on board his steamers.*"

Since the introduction of the Triple Compound engine, many engineers have been of opinion that a governor which controls only the High Pressure cylinder is not enough, in consequence of the large amount of steam contained in the passages and casings, which, in conjunction with the vacuum, is sufficient, in very heavy weather, to cause excessive racing, even after the high-pressure steam is shut off by the throttle-valve. Many devices and suggestions have been brought forward with a view of obviating this difficulty, but as they proved ineffectual, Messrs. Durham, Churchill & Co. designed and perfected a more complete system for controlling multiple-cylinder engines, which the Court of Inquiry into the *City of Paris* disaster practically recommended. By means of this system, any engine can be held under perfect control without setting up unusual strains, the high-pressure steam being completely shut off, and the low pressure piston simultaneously thrown into equilibrium.

The "*Universal*" *Governor*, to which these observations refer, is very simply constructed, and is so placed as to be easily accessible from the starting platform. It is driven by a cotton belt from the forward end of the crank shaft, and is so delicate in its action that the slightest acceleration of speed will begin to check the high-pressure steam by means of the throttle valve, whilst the low pressure cylinder is operated by suitable connections with the same valve.

Mr. D. J. Dunlop, of Port Glasgow, has also invented a very ingenious *Combined Steam and Pneumatic Governor*, which consists of a small air vessel, placed as far aft in the ship as possible, and connected at its bottom end to a sea cock through which water can be admitted. From the top of the air vessel a small pipe is led along the screw shaft tunnel to the underside of an elastic diaphragm contained within an apparatus in the engine room, on the top of which there is a spindle with balance spring attached. When the chamber, piping, etc., are full of air, and the sea cock is opened, the contained air is compressed to a density corresponding to the head of water in which the propeller is revolving, and, if the spring is screwed into a position to balance this pressure, its spindle will remain inactive as long as a uniform draft of water is sustained, but as soon as the stern rises through the pitching of the vessel the air pressure decreases, the spring expands, and, drawing down its spindle, opens the steam passage to the small governor cylinder, which in its turn closes the steam valve of the large engines in exact proportion to the immersed depth of the propeller.

These governors have been fitted to some of the largest and most powerful steamers afloat, including the new gigantic Cunarders *Campania* and *Lucania*, their steam cylinders being proportioned so as to give instantaneous action. There is a still later governor by Messrs. Aspinall and Johnston that owes its action to a law of nature which in this case has been utilised in practice. Its principle may be thus explained:—If one's extended arm has a heavy ball placed in the hand, and the latter slowly lowered, the ball goes with it, but if the depression is suddenly accelerated, the weight is left in the air to descend less quickly by the force of gravity. With this in view a simply arranged governor has been devised that works successfully at sea.

The simplest, and perhaps the most easily adjustable, *Piston* ever made was designed by Mr. Ramsbottom, of the London and North Western Railway, which is too well known to need comment. Numerous inventors have tried to obtain success in this respect, and amongst the most notable are Messrs. Lockwood and Carlisle; MacLaine; Durham, Churchill and Co.; Buckley; Cameron; Mather and Platt, etc., who have unitedly supplied countless thousands of first-rate pistons for marine and other purposes. Mr. Mudd has also invented an admirable piston packing ring that suits equally well the whole of the cylinders of triple engines. Where extreme lightness is desired, single webbed, cone shaped steel pistons are preferred to those of the box type, but whatever their shape may be, the most exact fitting at all times to the walls of the cylinders is absolutely necessary, the accomplishment of which in various ways is due to the persistent efforts of the above engineers.

The *Steam Cylinders* for a set of engines are so diversified in arrangement that here we enter upon a profound theoretical and practical branch of science which has been endlessly discussed. Their detail drawings, say, for a set of large triples, require several elaborate and clearly expressed views, which are usually shown to an inch and a half scale. These views involve the accurate delineation of everything internal and external, including cylinder liners, facings for slide valves, and working barrels for piston valves, steam and exhaust ports and passages, boring bar apertures, facings for auxiliary, escape, etc., valves, and also for pipes and general fitting together purposes.

The successful preparation of the original drawings primarily depends upon a certain knowledge of Foundry Work, and of the necessity for avoiding unnecessary complications or any irregular thickening of the metal that may cause defective castings. An intimate acquaintance with the machining operations to which the cylinders will be subjected is also most important, as it clearly indicates their possibility or impossibility, and the extravagant or economical manipulation of the castings from beginning to end. These remarks, however, are applicable to *all* engineering work, small as well as great.

Steam cylinders are made of hard and close grained iron, but for various practical reasons the working barrel or liner is generally a separate attachment, flanged at the lower end, and secured to the bottom of the cylinder by countersunk bolts. In the merchant service these liners are made of still harder metal, but in the navy they are usually of steel for lightness. For jacketing purposes, there should be a space of at least one inch between the liner and the cylinder, which the fitting strips on both at each end will naturally allow, and in the bottom of the latter there should be a boring bar aperture of, say, one-fifth of its diameter. In any case, however, this opening ought to be at least 15″ diameter to permit of interior examination of the cylinder. Removable slide valve faces are often employed for the sake of using a harder rubbing material, and for easy rectification when worn. Here, however, as in numerous other instances, we expose a principle that permeates the whole realm of dynamical engineering—one that, by simple methods, protects heavy and expensive machinery by throwing the evil effects of wear and tear, or even accidents, upon parts that cost comparatively little either to make or to renew.

It may appear somewhat irrational to say that marine machinery should never be proportioned throughout with theoretical exactness. If it were so, the result might not merely be the failure of *one* detail, but an utter collapse of the whole fabric, the heavy upper portions of which might crash through the bottom of the ship and sink her. Fortunately, however, skilled designers make ample allowances for *everything*, from a thoroughly practical point of view, and thus much danger is avoided to which the travelling public would otherwise be exposed.

After the cylinder castings have been carefully trimmed, cleaned, and painted for protection from rust, they are bored in a large vertical mill, or in a horizontal boring machine, or in the lathe, according to circumstances. The first-named is specially adapted for cylinders up to 120″ diameter, but in the two latter a great deal of medium and small sized work can be easily executed by bolting the cylinder either to a fixed table or to a sliding saddle, while the boring bar and cutter blocks slowly revolve, first rough cutting, and then smooth cutting the interior until completed. When this is done, the planers do their parts, also the radial and other drilling machines, which subsequently bore all bolt and stud holes, screw the latter and fix the studs in position.

These operations are not only very interesting, but require the utmost nicety in their performance, as the vertical centre line of each cylinder must be dead true every way with the centres of the crank shaft and crank pins when the latter are placed in a top or bottom position, all the other working parts being treated in similarly accurate style. It is here that the benefits to be derived from the use of first class constructive machines become clearly apparent, as any want of truth on their part will show itself conspicuously in such costly details, and cause much trouble to rectify.

After the cylinders have been machined and finished off, the whole of them are rigidly bolted together, securely slung by chains, hoisted by a powerful overhead crane and placed on the tops of the columns prepared for their reception, to which they will be securely fixed. When this is done the pistons, and piston and connecting rods, valve rods, air, etc., pumps, and all other working gear are set up and linked to each other, thus giving the engines in a short time a very handsome appearance. The cylinders are then lagged in the usual way, but here the history of the past rises to view.

Early engineers seem to have overlooked the fact that the enormous consumption of coal in marine boilers was caused not only by their faulty design, construction, and management, but also through loss of heat in the cylinders of the engines, owing to their want of non-conductive coverings. This was painfully, and even dangerously evident during the experimental trip of the P.S. *Enterprise* on her voyage from London to Calcutta in 1825, when her unprotected engines and boilers radiated such intense heat that the men sometimes could not work them, and eventually the latter set fire to the coal bags that had been carelessly placed over them to economise space.

Since those days, lagging, in both of the above, has become universal, and has involved the application of various materials, including hair felt, fossil meal, asbestos, etc. After these substances have been carefully put on, they are covered with sheet iron for boilers, and well finished sheet steel for engines, as the latter has a handsome metallic appearance, and is so easy to keep in good order when compared with mahogany or teak, which soon become irrecoverably dirty.

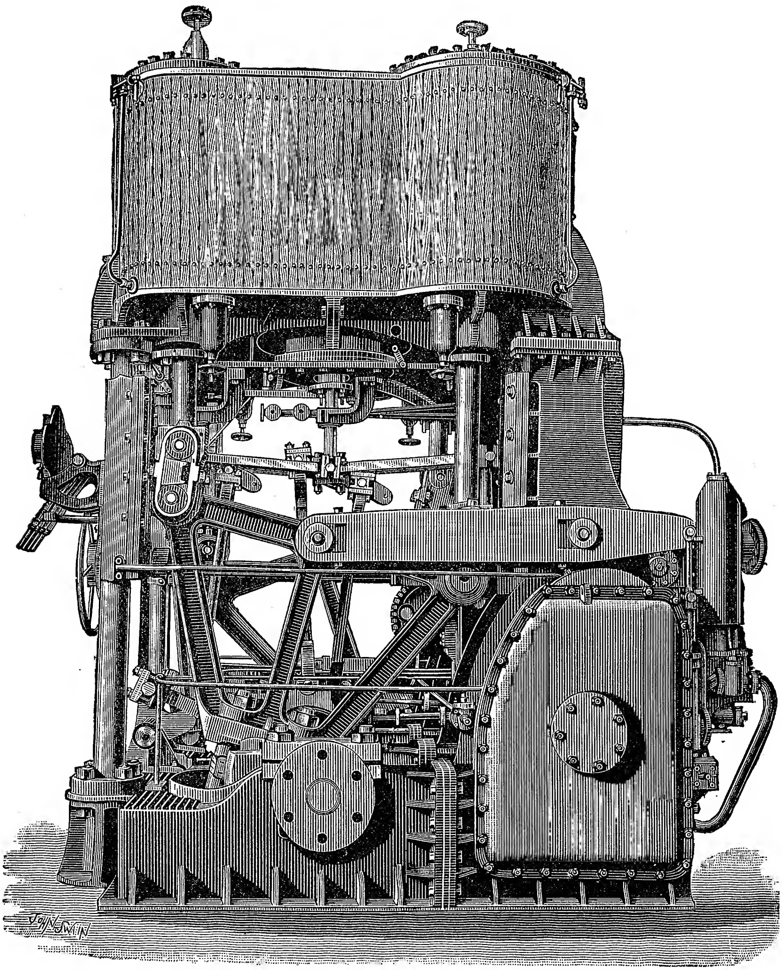
Besides the numerous heavy details previously referred to, there is a large quantity of light or hand gear about engines that has finally to be shown on the general drawing. To save, however, a vast amount of unnecessary erasure and re-production of lines that have already been approved, a sheet of tracing paper is spread over the drawing, and on *this* all the additional designing can be done without touching what is below. After the arrangement of these minor parts has been finally settled, sketch tracings are made of them, to enable the working details to be proceeded with as usual.

Another notable feature in connection with the engineering plans is that while single or combined details are shown in black, any surroundings that help to indicate their connection with the ship, or with anything else, are drawn in blue lines. Centre lines, however, are invariably in full red, and dimension lines of similar colour, but in the dot and dash fashion. Sometimes, too, in drawings of large cylinders, condensers, etc., having many surfaces that require planing, a wash of crimson lake over them will show at a glance their position and extent.

Since the year 1870, a more intimate knowledge of the action of steam in the cylinder of an engine has resulted in the employment of higher pressures in order to obtain a greater saving in fuel. At that time, boiler pressures ranged from 50 to 70 pounds per square inch, and a single cylinder land engine expanding this steam four or five times, proved so efficient, that an additional cylinder was not considered necessary, but with the augmented pressures that soon followed, economy was expected from an increased number of expansions. It was discovered, however, that with these pressures a greater number of expansions than five or six in one cylinder was not advantageous, and as marine Compound engines were already in use, their adoption in a modified form for land purposes at once dispelled the difficulty.

From these results it appeared that, in the first place, steam should be expanded only a limited number of times in each cylinder, and secondly, that the range of the temperature should be similarly restrained in order to produce the greatest efficiency. With still higher pressures, a third cylinder was employed to permit of a greater number of expansions, and eventually *Quadruple* engines were introduced, to which we have now to refer as the latest source of economy on land and sea.

The adjacent Plate of these engines by Messrs. Fleming and Ferguson, of Paisley, gives a good idea of their arrangement, the cylinders being placed in pairs on each side of the crank shaft, with the two pins of which they are connected by the triangular framed rods that allow of no dead centres at any point. As will be noted in the view, the cross-heads of both cylinders are never at the ends of their respective strokes at the same time, hence the turning effort on the shaft is the same as if they were attached to cranks set nearly at right angles to each other. And as the strains around each crank pin are gradually changed from one side to the other, thus being incapable of sudden reversal, it naturally follows that very high speeds may be employed without any observable vibration. This will be clearly seen from the fact that while the power of triple cylinders is transmitted



QUADRUPLE ENGINES OF S.S. "*UPOLU,*" 1000 I.H.P.

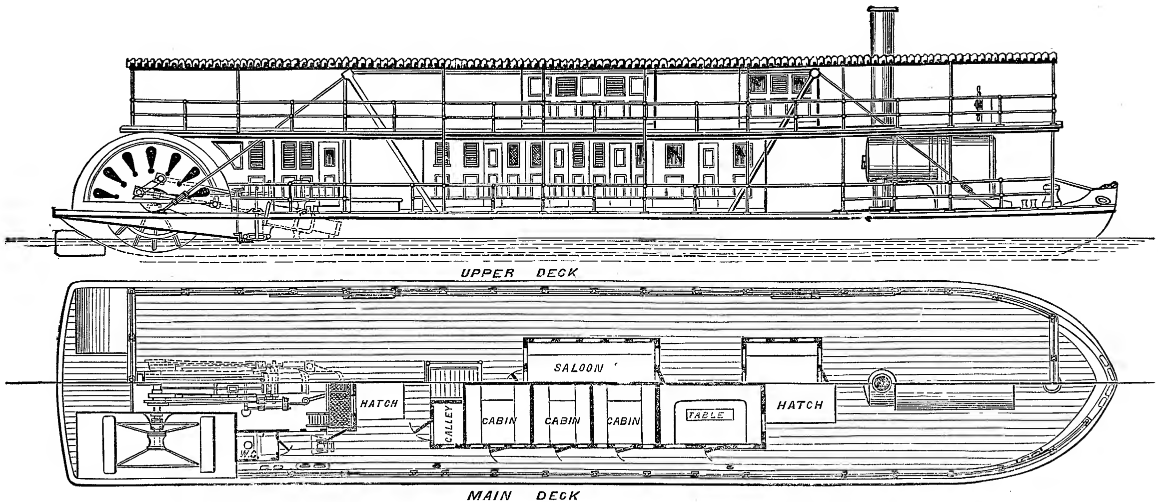
to the main shaft at *three* points 120° apart, that of the Quadruples under consideration similarly acts as if there were *four* cranks placed at an angle of 90° with each other.

The machinery is very compact, as the space occupied by the cylinders in a fore and aft direction is about the same as it is transversely. By means of the peculiar motion of the connecting rod, the side pressure on the guides is much reduced, and for the same reason, the end of the air pump lever can be attached to the former direct, without the intervention of the usual links. In marine engines of this description two piston valves only are required, and these fit compactly into the spaces between the four cylinders. The engines shown in the view were recently built for the Union Steamship Company of New Zealand, their leading proportions being:—

Diameters of Cylinders ...	15″, 23″, 30″, and 45″.
Stroke	33″.
Condensing Surface ...	1,021 sq. ft.
Diameter of Propeller ...	11′ 6″.
Mean Pitch...	14′ 0″.
Total Surface	38 sq. ft.
Diameter of Tunnel Shaft	9″.
Boiler Diameter	14′ 6″.
Boiler Length	10′ 6″.
Fire Grate Area	63 sq. ft.
Working Pressure... ...	200 pounds per sq. in.

This type of machinery has generally proved so successful that Messrs. Musgrave and Sons, of Bolton, have extensively adopted it in their mill engines up to at least 1,600 horse power in one set.

Another very admirable type of Quadruple machinery is manufactured by Messrs. Simpson, Strickland & Co., of



LIGHT-DRAUGHT STERN-WHEEL STEAMER, 110 FEET LONG— LONGITUDINAL VIEW, AND UPPER AND LOWER DECK PLANS.

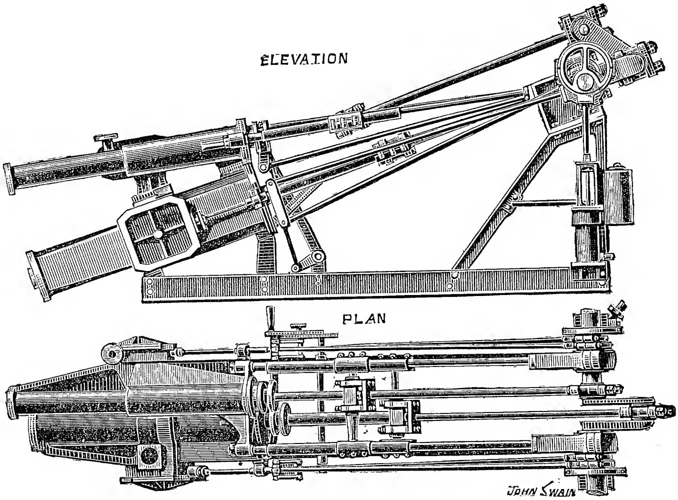
Dartmouth, who have fitted it in yachts and launches of every description, for naval and mercantile services at home and abroad. These engines are on the "Kingdon" tandem principle, and have the advantage of being surface condensing, instead of high pressure, as was recently the case in launches. They are also so arranged that the necessity of carrying a fresh supply of water for feeding the boilers is entirely obviated.

The Plate of 70 ton *Steam Yacht* shown at page 112, clearly illustrates the arrangement of the engines and boilers, and also the bunker spaces, which are capable of carrying sufficient coal for 2000 miles steaming.

The same firm has recently applied this type of machinery to electrical purposes, and to the propulsion of light draught *Stern Wheel Steamers*, one of which, 110 feet long, is shown in the annexed Plate. The Longitudinal Section, and Upper and Lower deck Plans, so clearly explain themselves that further reference is unnecessary. For shallow rivers this has proved a very useful type of vessel, since when fully loaded it only draws about two feet of water, whilst the position of the machinery and boilers at the extreme ends not only balances the vessel, but provides an unobstructed space for cargo.

In general design, these Quadruple, as well as the Compound diagonals made by the above engineers, are in accordance with the most approved type of modern Paddle Wheel Machinery, and are extremely simple and easy to get at, as shown on the following page.

The weight per I. H. P. and the coal consumption are very much less than has generally been required, consequently the engines referred to have entirely superseded the High Pressure type for small marine work, and will no doubt continue to do so for light draught purposes, especially where minimised fuel expenditure is of importance. Taken in the aggregate, a very compact arrangement has resulted, that can be used equally well for stern and side wheel steamers, and may be easily adapted to the combustion of inferior coal, or even the wood fuel that in many places can alone be obtained.



QUADRUPLE DIAGONAL PADDLE ENGINES.

For Royal Mail, and other ships, whose engines may be some thousands of horses power, those of the Quadruple expansion type, by Messrs. Denny Brothers, have been found very serviceable, as they possess novel and excellent features, which simultaneously combine elegance of design with compactness of arrangements.

CHAPTER XXIII.

MARINE BOILERS, AND THEIR DESIGN.

Generation of Steam in Boilers—Recent Experimental Discoveries—Value of highly Expanded Steam—Coal Consumption in Steamers Past and Present—Advantages of High Pressures—Constructional Practice—Cause of Superiority of Triple Engines—Useful Expansion Tables—Empirical Proportions of Boilers—Rational Science Rules Exemplified—Forced Draught System—Its Practical results in various Ships — Table of Boiler Averages from numerous examples—Working Drawings of Boilers—Special Considerations affecting them.

WHEN referring to the generation of steam in marine boilers of the present day, we approach a subject that has been most ably discussed from every point of view by many of the most advanced scientists of the age. The wonder is that in the interior of a plated shell—in the chemistry of the water that partially fills it—in the heat that evaporates this fluid—and in the mechanical and structural peculiarities of the whole fabric, including its management at sea, there should have existed so much that was profound and perplexing. So immensely important is this subject, that although the engineers of a ship supervise the machinery in a general way, the "chief" takes the boilers under his own critical observation at all times. Many valuable facts have thus been discovered during recent years, and especially by the elaborate experiments upon the S.S. *Meteor*, *Fusi-Yama*, *Colchester*, *Tartar*, *Iona*, etc.

Special interest is attached to these trials as the *Meteor* and *Tartar* had triple engines; the *Fusi-Yama*, ordinary compounds; and the *Colchester*, twin screw compounds; whilst the *Iona's* engines were similar to those of the *Macduff*. All the experiments were conducted at the instigation of the Research Committee on Marine Engine Performances, and under the active and skilful guidance of Professor Kennedy and his colleagues, the valuable results thus obtained being due to a desire on their part to meet every difficulty in the most practical and unprejudiced manner. To these trials we need not further refer, as the Reports given of them are to be found in the *Proceedings of the Institution of Mechanical Engineers*, and also in the Technical Journals for the year 1890, all of which will prove most instructive.

Whilst designing boilers in accordance with the usual allowance of fire grate and heating surfaces, area through tubes, steam space capacity, and contents of shell, etc., there is much that requires very careful consideration. And if, at this initial stage, the results of the latest experience are not sufficiently utilised, the engines will suffer more or less in efficiency. The object of engineers for a long time past has been to reduce the consumption of fuel, and this has been accomplished partly by the employment of improved boilers, but chiefly by the adoption of triple and quadruple engines, worked by highly expanded steam, the advantages of which may be thus described:—

If an engine required full steam in the high-pressure cylinder throughout a *whole* stroke, or say, 40 cubic feet, at boiler pressure, it is evident that if the steam were cut off at *half stroke*, only 20 cubic feet would be needed, and this quantity would gratuitously give out during the rest of the stroke a large amount of useful effect by means of its expansion. If, moreover, the steam were cut off in the cylinder at *one fourth of the stroke*, the demand on the boiler would be correspondingly reduced, and so on for other degrees of expansion.

Perhaps the greatest obstacle that beset steam navigation at the outset was the enormous quantity of coal required for firing boilers. Up to the year 1838, the ordinary consumption per horse power per hour had dcereased from 10 to 6·5 pounds, and the speed of ships had increased from 6 to 8 knots. Hence it will be seen what gigantic fuel difficulties confronted those who in 1838 successfully started the *Sirius* and *Great Western* on their first voyages to New York.

From 1840, when the Cunard P.S. *Britannia* began to run on her station, the coal expenditure slowly diminished, but although it was still very high, the great prosperity of the Company was no doubt partially due to very high freights, and also to handsome passenger rates. Valuable improvements were gradually introduced by Maudslay, Penn, Napier, Caird, and others, until in 1852, Mr. Elder made an entirely new departure by putting into really practical form what had for some time previously been known as the *Compound Engine*, the recent developments of which have been of the most sweeping description, for as matters now stand, we have ships of 10,000 to 13,000 tons, averaging 21 and 22 knots at sea, upon a consumption of 1 to $1\frac{1}{4}$ pounds of coal per hour.

After having tried to explain how the expansion of steam in the engines affects the size of the boilers, let us now see how the increase of pressure improves the economy of both. So far as the latter are concerned, the saving produced by their agency is, in at least one respect, due to the small additional amount of fuel required to raise steam from a low to a high pressure, hence its efficiency rapidly increases with the pressure. That is to say, when water in a boiler is at 212° Fahr., the steam pressure is the same as the atmosphere—at 228°, it is at 5·3 pounds above the atmosphere; at 240°, 10·3 pounds; at 302°, 55·3 pounds; at 324°, 80·3 pounds; at 353°, 125·3 pounds; at 401°, 235·3 pounds per square inch, and so on.

Constructional practice, however, seems to indicate that with ordinary tubular boilers it is not safe to exceed 200 pounds, on account of the difficulty of making them strong enough without inconveniently limiting their diameter, or increasing the thickness of the plates beyond 1½″. With the object of reducing the diameter of boilers, those of the locomotive type have been tried, but when of large size they have occasionally failed, partly because they were liable to prime in rough weather owing to the limited steam space, but chiefly on account of the difficulty of keeping their interiors in order unless the purest water was employed.

The superiority of the Triple Engines over two-cylinder Compounds is therefore mainly due to the higher steam pressures of the boilers being used more expansively in the cylinders, while at the same time considerable variations of temperature in these cylinders, and also in the receivers, etc., are avoided. Another advantage is created by the distribution of the total load amongst three cranks, thus diminishing the initial strain on each, and allowing scope for lightness in design, more regular strains upon the crank pins, and more steady running, with correspondingly reduced wear and tear in the working parts. The efficiency of the boilers upon which so much of the superiority of Triple machinery depends, is also due to the forced draught system which has now become popular, and which, upon Mr. Fothergill's system, was found very serviceable during the trial of the S.S. *Iona*, referred to in Chapter XIV.

The benefit derived from the use of expanded steam will be clearly observed when it is stated that, up to the point of its cut-off in the high pressure cylinder, the shipowner has to pay for the energy thus created by the boilers. When, however, the flow of vapour from the generators is stopped at any part of the stroke of the piston, the rest of the work is done for *nothing*, and with more or less liberality, according to the manner in which the engine is supplied with the motive power, which the accompanying tables will show at a glance.

TABLE OF STEAM USED EXPANSIVELY.

Initial pressure in pounds per square inch.	AVERAGE PRESSURE IN POUNDS PER SQUARE INCH FOR WHOLE STROKE.					
	PORTIONS OF STROKE AT WHICH STEAM IS CUT OF.					
	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
100	96·6	91·9	84·6	74·4	59·6	38·5
110	106·2	101·1	93·1	81·8	65·6	42·3
120	115 9	110·3	101·5	89·3	71·5	46·2
130	125·6	119·4	110·0	96·7	77·5	50·0
140	135·2	128·6	118·5	104·1	83·4	53·9
150	144·9	137·8	126·9	111·6	89·4	57·7
160	154·6	147 0	135·4	119·0	95·4	61·6
180	173·9	165·4	152·3	133·9	107·3	69·3
200	193·2	183·8	169·2	148 8	119·2	77·0

TABLE SHOWING THE THEORETICAL POWER DUE TO THE USE OF THE SAME QUANTITY OF STEAM WHEN USED UNDER DIFFERENT RATIOS OF EXPANSION.

POINT OF CUT-OFF.	Number of Expansions	Horse-Power.
Full Stroke	0	100·0
1/2 ,, ...	2	169·3
1/4 ,, ...	4	238·6
1/6 ,, ...	6	279·1
1/8 ,, ...	8	307·9
1/10 ,, ...	10	330·2

From this it will be noted that by working the steam under ten expansions, an advantage equivalent to 330 per cent. is derived from the same steam above the result obtained during the full stroke of a non-expansive engine.

In general practice, the *Dimensions of the Boilers* for a certain size of engines are regulated by an allowance of so many square feet of firegrate and heating surface per horse power, and this old and simple rule does very well, provided the designer knows how to adapt it to the changing circumstances involved by the application of natural, induced, and forced draught, otherwise the boilers may be made unnecessarily large, or too small.

The *Rational Science* rule, however, is to treat a steam engine as we would a horse, that is, to find out how much food and water per day is required to keep him well and hearty. And although these quantities may be approximately ascertained by weighing the noble animal, and allowing him so many pounds of food and drink per hundredweight, the first method is certainly the best, and one that in principle can easily be applied to all engines with the best results.

For example, after the diameter and stroke of the High-pressure piston have been settled, and also the number of revolutions per minute with a boiler pressure of, say, 160 pounds, calculate in the first place the number of cubic feet of steam used in the cylinder at each stroke before the supply is cut off. In other words, if a cylinder 40″ diameter with an area of 8·726 square feet, has a 5′ 0″ stroke, piston speed of 800 feet per minute, and the boiler supply is cut off at half-stroke, we may thus ascertain directly how much steam and water and coal will be used per hour by the engines under consideration.

8·726 × 400′ × 60 minutes = 209,424 cubic feet of steam to be used per hour, and as this quantity at the above pressure is to the water that produced it as 159 to 1, therefore: 209,424 ÷ 159 = 1317 cubic feet or 82,312 pounds of water at 62·5 pounds per foot, and taking the evaporative power of the fuel at, say, 10 pounds of water per pound of coal, we shall require 8,231 pounds of black diamonds to change the whole of the above into steam. By the use, however, of Messrs. Galloway's Table, on page 76, a simpler method of calculation may be adopted, which gives similar results. That is, for a 40″ cylinder carrying 160 pound steam, 205·46 × 400, as above, = 82,184 pounds of water.

With good stoking and natural draught, 20 pounds of coal per square foot of firegrate may be burnt per hour, but in the merchant service, 15 pounds is usually considered a sufficient allowance. Therefore 8231 ÷ 15 = 549 square feet of net grate surface. From this it will be seen that in ships using good fuel the evaporation may be taken at 150 pounds water per hour per square foot of grate; but on stations where bad coal is most likely to be had, 100 pounds is a safer allowance. It will be well to note, however, that in practice, these calculations have to be extensively modified to make up for waste, deterioration of heating surfaces, etc., and for supplying motive power to all the auxiliary machinery of a ship. When forced, or induced draughts are employed, the question simply becomes one of respective evaporative efficiency, but when this is known, the rest may be easily discovered.

After the required boiler power has been thus ascertained, and the diameter, length, and number of boilers decided upon, all the resources of modern science have to be utilised to enable every part to resist the severe strains to which it will be subjected, either from the pressure of the steam or from expansion by heat. When these have been fully considered, and when the materials have arrived in the Works, the *manipulative* processes described in the Galloway chapter occupy the executive in the boiler department from first to last.

For very many years it was considered that *moderate* combustion in good-sized boilers was more economical than forced firing in those of smaller dimensions, which would thus become prematurely worn out. This was confirmed by the sea-going engineers themselves, and so we jogged along quite content with the extremely popular system of construction and management to which we had been educated. Mr. Howden, of Glasgow, tried to produce a better method of firing, and in this he admirably succeeded, judging by the numerous and extended long voyage results, and also by the evidence of many leading firms who are increasingly adopting his *Forced Draught* system in their ships.

Leaving theory out of sight, and turning to actual performances, we find that by the employment of this system the boiler capacity for equal powers is from two-thirds to one-half of that required for natural draught, while its use secures much greater economy in fuel, and decreased wear and tear. The reduced space thus required for boilers, and also their proportionately diminished weight, necessarily make this system vitally important for ocean steamers. In proof of this we have only to examine the records of many ships belonging to the Cunard, White Star, P. & O., Inman, City, Clan, Allan, and other companies, some of whose vessels make round voyages up to 22,000 knots. From these we learn the true value of Mr. Howden's method of firing, which has enabled highly satisfactory results to be obtained with only two square feet of heating surface per I. H. P., at rates of combustion giving from 20 to 24 I. H. P. per square foot of firegrate; whereas, with natural draught, the usual 2½ to 3 feet of heating surface produces from 10 to 12 horse power for each square foot of fire grate.

In the S.S. *Clan Fraser*, for instance, the average of 1183 H. P. was maintained on a consumption of 15·8 tons per day, or 1·25 pounds per hour, thus giving 75 horse power per ton of coal, or 23·66 per square foot of fire-grate, over a distance of 3,405 knots. It is in the great ocean racers, however, which have adopted the above system, where its value becomes most conspicuous, and where not only may a considerable saving be effected in the first cost of a ship, but additionally of many thousands a year in the management and maintenance of the boiler department alone.

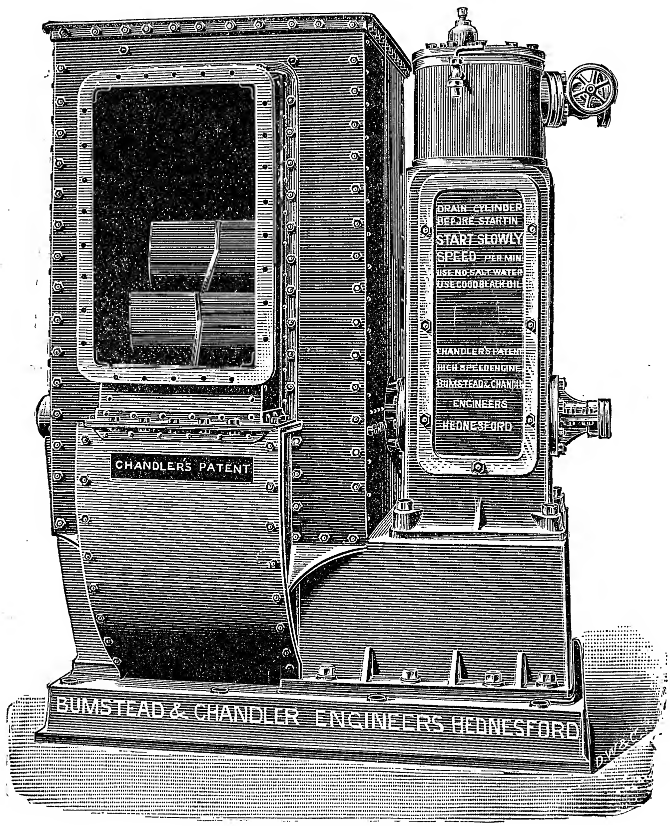
Forced Draught, or the mechanical method of supplying air above atmospheric pressure for economically improving the steam-raising powers of marine boilers, was for some time a much-disputed question. As far back as 1830, John Ericsson applied a fan draught to the Liverpool and Belfast steamer *Corsair*, but without success, and although the idea was subsequently modified and experimented upon, it is only within recent years that any true progress has been made.

The employment of forced draught does not involve any new principles in chemistry, but enables us with greater certainty to carry out those conditions which chemistry shows are essential to produce perfect combustion, and thus obtain a higher efficiency per pound of fuel than can be obtained by natural draught. Especially is this the case with the ordinary type of marine boilers, where, for repairing purposes, the new arrangement must be made capable of easy removal, and strong enough to bear continuously severe treatment during long voyages. It also must not affect the original system of firing, so that a ship may steam under natural draught without stopping for alterations in the event of the apparatus breaking down.

The air pressure in the ashpit ranges from $\frac{1}{2}''$ to $\frac{3}{4}''$ on the water gauge in the merchant service, to 2″ in the Navy, and the supply is regulated by means of a rapidly-revolving fan. Although this in itself is of the utmost importance, there are attendant *mechanical* advantages which render perfect combustion independent of weather or climate, and particularly so during light following winds and in hot climates, when, under natural draught, the firemen are unable to get steam, and coals are inefficiently consumed. With forced draught we are also better able to maintain steam with the inferior coal occasionally supplied at foreign ports, and to regulate the pressure very evenly whilst cleaning fires, thus preventing the speed of the engines from going down during the process, owing to the blast which is shut off from any particular furnace increasing the pressure in the rest, and compensating for the loss that would otherwise be incurred.

Amongst the subsidiary benefits derived from the use of this system may be mentioned the improved ventilation and cooling of engine and boiler rooms in hot climates and when the fan is placed at the bottom of the former, this department is kept cool owing to the down draught through the skylight. Under any circumstances, however, the air, in passing through the casing on the boiler fronts on its way to the ash-pits, absorbs the radiated heat of the plating, and thus the temperature of the stoke-holds is greatly reduced. As the success of the invention greatly depends upon the excellence of the blowing machinery, so much attention has been paid to the design and construction of the latter, that it has now been perfected. The annexed view illustrates one of Messrs. Bumsted & Chandler's *High Speed "Silent" Engines and Fans* for Ventilation and Forced Draught, which have been extensively used by many leading Companies, especially the White Star, who have fifteen similar sets in each of their ships *Teutonic* and *Majestic*, for supplying all the air to the boiler furnaces, and for ventilating the ships throughout by drawing it in at the top and discharging it at the bottom.

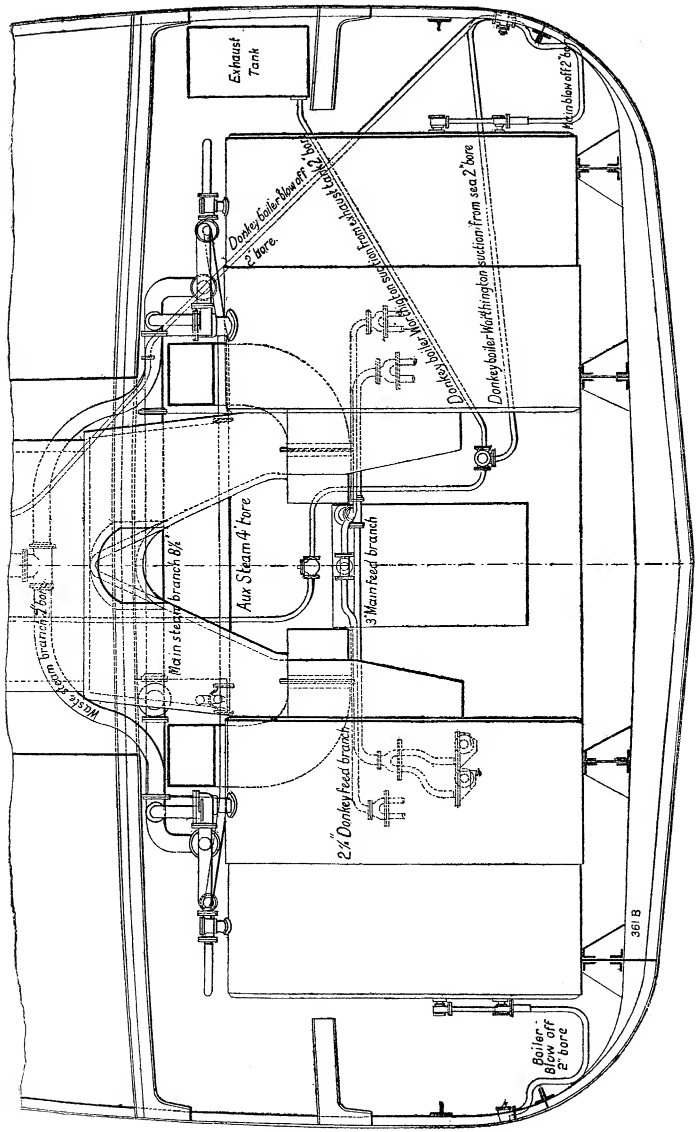
These engines are made for a variety of purposes in many different sizes, either in single form, or as double and triple compounds up to 350 H. P., and have proved very economical and trustworthy. Owing to their unfailing automatic lubrication, the "enclosed" method of construction has been adopted, and this not only prevents waste of oil, but ensures external cleanliness, and protects all the working parts from dirt and grit, while at the same time the interior can be easily examined by removing one or both of the large doors placed at the sides.



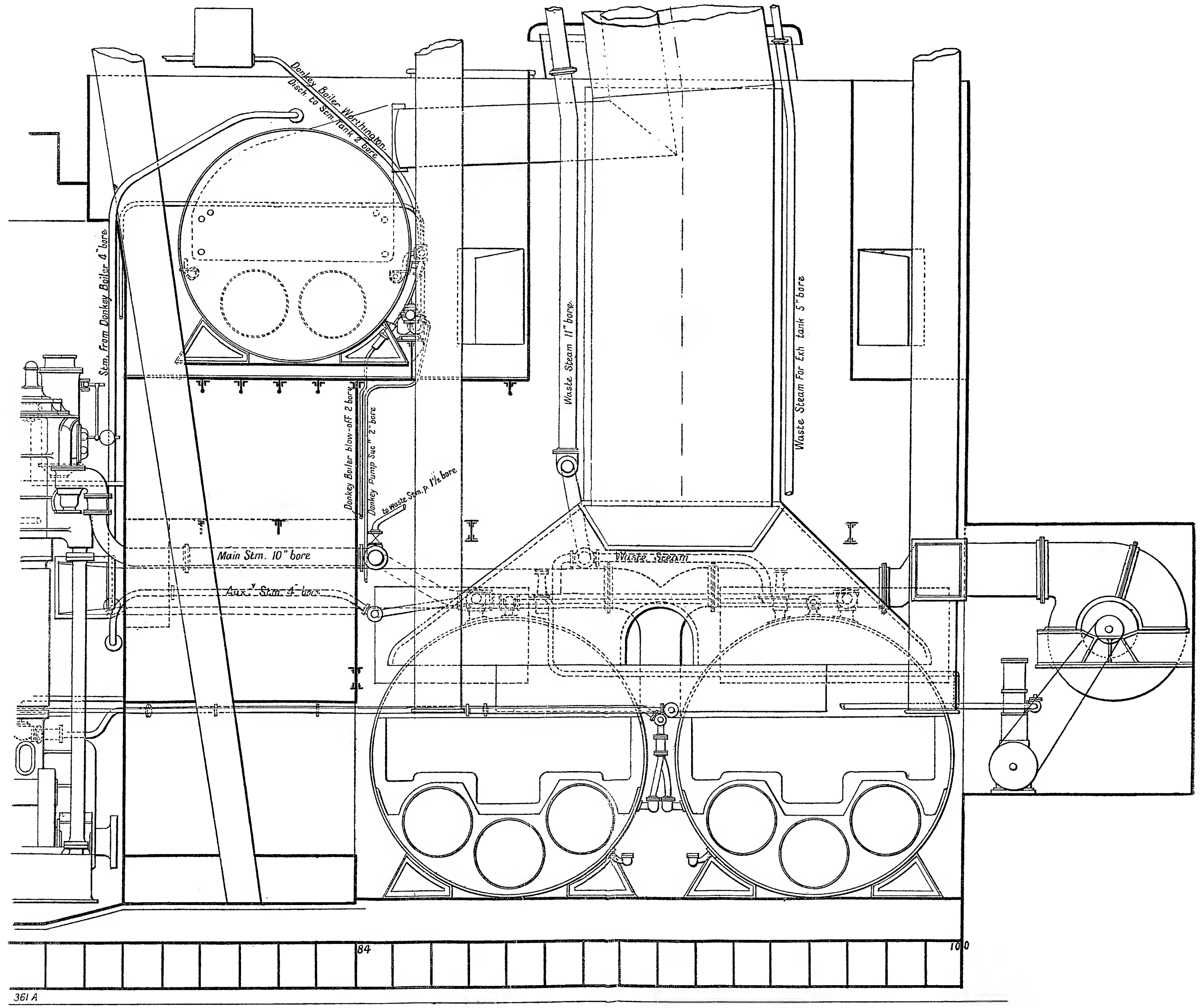
HIGH SPEED ENGINE AND FAN.

The Forced draught system may be partially understood on reference to the adjacent ship plans of boilers of the S.S. *City of Vienna*, and thus a good idea may be formed of its application in steamers of similar tonnage.

BOILERS, WITH HOWDEN'S SYSTEM OF FORCED DRAUGHT, FOR S.S. *CITY OF VIENNA*.



TRANSVERSE SECTION.



LONGITUDINAL SECTION

The furnaces shown in this and other vessels are worked on the quick gasifying and complete combustion principle by the following means:—The air in the ash-pit, with a given area of air space through the fire bars, and a fixed average depth of fuel, is maintained at a pressure designed to pass a quantity of air through the fuel sufficient to gasify it and bring it to the surface largely in the form of carbonic oxide. The atmosphere in the casing between the furnace doors is maintained at a considerably higher pressure than in the ash-pit, and is thus received by the distributing boxes inside the furnace plate and inner furnace-door. It then, at a considerable temperature, and at a high velocity, issues in minute streams from small holes in the interior side of the boxes, the aggregate area of the former being proportioned to the normal work of the furnace, and their position arranged so that the air will forcibly strike the fuel equally over the surface.

By means of these differential pressures, the quantity of air required for the complete combustion of a given weight of fuel can be made much less than is necessary in an ordinary furnace, while, with the stage of complete combustion chiefly on, or above, the surface of the fuel, a clear white flame and intense heat is generated where it is most effective for radiation, and least hurtful to the furnace bars.

The importance of the forced draught system may be gathered from the fact that the Inman and White Star Companies expended many thousands of pounds in preliminary trials with smaller ships before they decided to adopt it in their gigantic ocean racers, and as inventors are often one-sided in their ideas, the independent reasoning and appreciation of others should thus prove of great value. The difficulties that beset forced draught in its initial stages have been so effectually overcome as to have induced Mr. Parker to express his opinion of it most favourably, and to show how the shipowners could be greatly benefited by the new system of firing boilers, the advantages of which are now so widely known.

We are indebted to Mr. Blechynden, of the Naval Construction and Armament Works at Barrow-in-Furness, for a valuable *Table of Leading Proportions* of the triple engines and boilers of twenty-two natural draught and six forced draught steamers from 900 to 4,295 horse power, whose boiler averages are given below.

RESULTS OF TRIAL OF TWENTY-EIGHT STEAMERS.

VARIOUS AVERAGES.	Heating Surface.		I. H. P. per sq. ft. of Grate.	Coal burnt per sq. ft. of Grate per hour in lbs.	Coal burnt per I. H. P. per hour in lbs.
	Per I. H. P. in sq. feet.	Per lb. of Coal per hour in sq. feet.			
Average of 28 Steamers ..	3·275	2·14	11·22	17·08	1·522
,, Natural Draught	3·560	2·25	8·91	13·92	1·573
,, Forced Draught	2·412	1·72	20·98	28·15	1·336

Where rapid approximations are desired, a very simple rule is to allow 2·5 cubic feet of total boiler shell content per horse power. With forced draught, however, Mr. Howden considers 1·75 cubic feet sufficient, and for naval boilers much less than this. When the total content and number of the proposed boilers have been thus found for sketch designing purposes, and the more exact methods employed for ascertaining their *true* dimensions to suit the ship as well as the engines, the working plans may be proceeded with.

These include a *Longitudinal Section*, with *End View*,—one half of which is internal and the other external, also an *End Elevation* showing furnace and smoke box doors and outside fittings. Two or three enlarged scale riveted joints are needed in addition, besides a *Plan of the Shell Plating* laid flat, showing the rivet and other holes complete. All these views must be carefully dimensioned and have notes appended to the general drawing containing a variety of particulars concerning steam pressure, heating and grate surfaces, etc., for reference.

From the above, a list of the various plates is made out for the Rolling Mill people, whilst the working details of valves, cocks, pipes, and other gear, follow on lines similar to those for the engines. *Skeleton outside Views* of the boilers, giving the position of the mountings, are used for fitting purposes, and these are to some extent shown in the *Vienna* plans. From the main *General Arrangement of Engines and Boilers* a tracing is taken showing the *Connections* between the latter and the ship's side and bottom, and similarly, and much more extensively, one from the *Engine Room*, besides others from various plans showing the *Tunnel Shafting*, etc., and *Auxiliary Engines* and their connections throughout the vessel. Tracings of *Arrangements of Keelsons*, ladders, ventilators, uptakes, funnels, ship gear, etc., also follow, as well as the complete *General Arrangement of everything in a consolidated form.* Thus not only full sets of plans as described, but working drawings of every detail relating to them will be provided for the purpose of carrying on in the most exact and rapid manner the whole interior work of the ship.

The fire room arrangements for the *Vienna* are very simple, but in ocean racers and great ironclads, with many boilers and numerous auxiliary engines, extensive complications are unavoidable. In the former, the application of Mr. Howden's forced draught system, with its attendant high speed engines and fan blast may be noted. The air pipes leading to the fronts of the boilers may be easily followed, but are lost sight of at the top of the smoke box. From this point, however, the air supply is led inside it, and after being heated by the escaping gases, is delivered into the furnaces through apertures in their doors as previously described.

It may here be noted that as many of these plans are on a small scale, they should be lightly washed with colours suited to the various metals to make everything clear at a glance. And further, that *single* colours only should be used for each metal; those most suitable being *Prussian blue* for wrought iron—*neutral tint* for cast iron — *violet*, or *purple lake*, for steel — *yellow ochre* for outside brass—*gamboge* for sectional brass—*crimson lake* for copper—*burnt sienna* for wood, and *Indian ink* for backgrounding or shading recessed parts, all sections being of much darker tints, streakily put in, of course, when of a dotted nature. Detailed drawings, however, only require full and dotted sectioning, whilst boiler plans have the tube openings jet black, and furnace and other openings of lighter shades. By these simple means engineering drawings can have a very artistic and expressive finish given to them with little labour. In addition to this, general plans should have every pipe numbered consecutively, and a corresponding list with their names and diameters appended for reference.

Boiler details do not offer much scope for variation, but a few improvements have been made from time to time. Amongst these may be mentioned the *Parallel slide Blow-off Cocks* of Messrs. J. Hopkinson & Co., which prevent the possibility of an accident happening under the high pressures now employed, a result, with ordinary cocks, sometimes difficult to prevent.

In third and forth rate establishments, working tracings are very sloppily got up, the lines and circles being most irregularly drawn, the figures more or less disreputable, the colouring laid on raggily, jaggily, scraggily, cloudily, and messily throughout, thus causing one to think that if such productions were sent abroad, or even to strangers at home the results would be unsatisfactory. *First* impressions are very strong, and hence the wise take care that their excellent manufactures will not suffer by the unfavourable criticisms bestowed upon their plans by outside people. None, perhaps, know this better than private practitioners, whose designs are seen by non-professional "Committees," "Commissioners," etc., who may so greatly admire high art in this respect as to award the prize to the most artistic, instead of the most practical designer, as many disappointed ones can testify.

Some years ago, an architectural firm, in conjunction with myself, prepared the plans for an iron pile pier and landing stage, with large bowstring connecting bridge, into which we threw all our talent. The drawings were beautiful specimens of good practice, the lining, figuring, and printing were perfection, and the washes of colour, sectioning, and dark recessing beyond all praise. When the Commissioners had carefully studied them, our arrangement was considered the best, and we were requested to carry out the undertaking. No doubt the examiners were right, but we ourselves thought that the very clear, simple, and finished manner in which the drawings had been treated somewhat influenced the gentlemen of the Board, which of course was very gratifying.

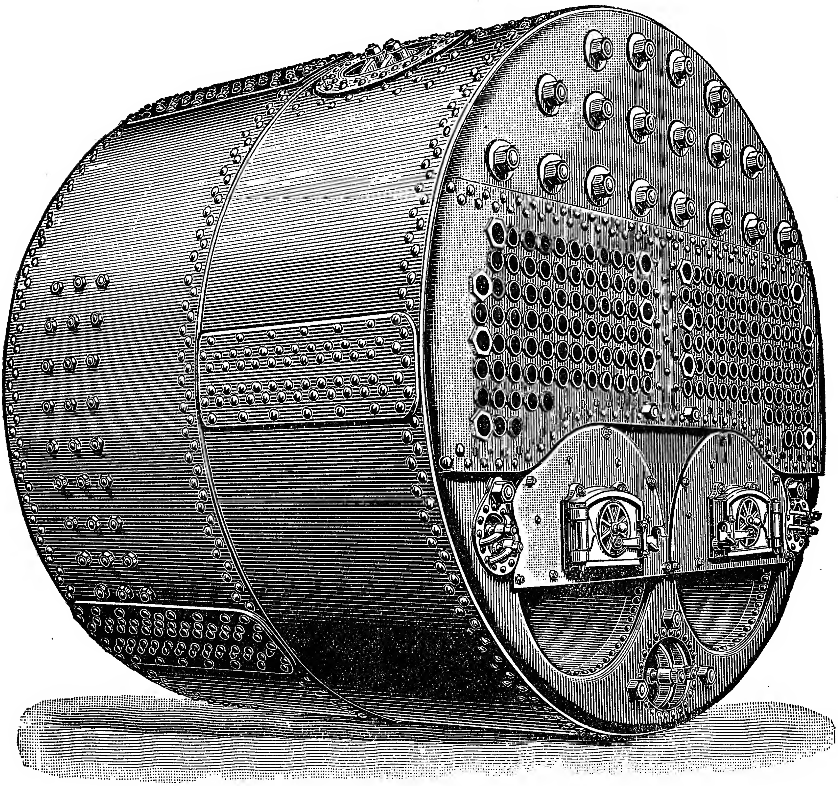
CHAPTER XXIV.

MARINE BOILERS—*Continued.*

Single and Double-ended Boilers—New Style of Furnace—Latest Scientific Discoveries—Peculiarities of Steel when exposed to Heat—Ribbed Boiler Tubes—Destructive Impurities of Condenser Feed Water — Its Initial Purification — Feed Water Heaters—Connections in Ship—Section of Twin Screw Steamer—Automatic Evaporator and its Uses—Donkey Boilers—Management of Boilers.

THE *Cylindrical Tubular Boiler* of to-day has practically resolved itself into the single-ended and double-ended classes, the former of which is usually made to about 16′ 6″ diameter by 10′ 6″ long, and the latter to at least 19′ 0″ in length. These dimensions, however, are governed entirely by the available space in ship, engine power, number of boilers, workable length of fire grate, thickness of shell plate to withstand high pressures, and other considerations to which we need not refer. The views of the single-ended boilers shown on the *Vienna* General Plans, give a good idea not only of their skeletoned outside appearance, but also of the manner in which they are bedded upon the keelsons. Structurally, few alterations have been made during recent years, but the system of manufacture has greatly changed, as described in Chapter V.

The annexed Plate of a *Single-ended Marine Boiler*, by Messrs. Lindsay Burnet & Co., of Glasgow, shows the approved type of steam generator for pressures up to 200 pounds per square inch, such as those employed for triple and quadruple engines. The boiler has been engraved without any of its brass mountings, valves, and fittings, but amongst the visible details may be mentioned the usual arrangement of tubes and stays, furnace fronts, corrugated flues, and riveted shell. This, however, need



SINGLE ENDED MARINE BOILER.

have no intermediate circumferential joint, if longitudinally plated, and may even be made in *one* piece throughout, if required.

From a practical point of view, a furnace should have a uniform evaporative efficiency, thus causing equality in the thickness of the scaly deposit. It should also have no receptacles for the undue formation of scale, and no projections towards the fire that may become unduly heated, and it ought to be of such a section that the expense of scaling is minimised, whilst at the same time its form provides the greatest amount of strength, all of which requirements have been successfully met by the *Suspension Furnaces* of Mr. D. B. Morison, of Hartlepool, which are now extensively made by the Leeds Forge Company. Some idea may be formed of their resisting power, when one of them, of mild steel, 37″ outside diameter, and $^7/_{16}$″ thick, stood an official test collapsing pressure of 1140 pounds per square inch before deformation took place. For calculating the Working Pressure, Lloyd's Registry allows the following formula :—

$$\frac{1000 \times (T - 2)}{D} = \text{W.P. where}$$

T = Thickness in sixteenths of an inch, and D greatest Diameter of furnace.

As an example of the manner in which engineers incidentally ascertain the peculiarities of metals, it may be stated that from 1882 to 1888, the Leeds Forge Company manufactured 28,000 Fox flues of steel, having a 24 ton tensile strength, without a known casualty of serious nature happening to one of them. Since 1890, however, the average strength of the steel employed by this firm for the Mercantile Marine was raised to 28 tons, but, as Mr. Morison has shown in his recent valuable paper on *Marine Boiler Furnaces*, the per centage of failures had been thus so much increased, that general opinion was in favour of a return to the 24 ton mean standard of the English and Foreign Governments.

The advantages of the latter quality of steel are as follows:—It is better able to stand the rough usage of the boiler shop, and is less liable to develop imperceptible cracks in manufacture that may afterwards extend. It is also more able to bear continued expansion and contraction in steam boilers, and to retain its ductility for a longer period than the high tension and harder metal. In short, although the first cost of furnaces of 28 ton steel is slightly less than at 24 tons, the material is neither so trustworthy nor so lasting. This, however, is due to the influence of *temperature*, as indicated by a valuable set of experiments made in the United States in the year 1888.

These have shown that the tensile strength of steel diminishes from zero Fahr., to about 300°, and then increases until from 400° to 600° is reached, but after this the strength falls away rapidly. And although the ultimate tenacity increases between 200° and 600°, the elastic limit steadily decreases from zero upwards. That is, if this limit is 35,000 pounds per square inch at zero, it becomes reduced to 20,000 at 600°. Various other important features were likewise discovered; compressed, however, into the traditional "nut shell," they amount to this:—With a thick furnace, the temperature of the plate will be higher than with a thin one, hence its elastic limit will be lower, and a greater margin of safety become necessary.

Thin furnaces on the other hand, of $\frac{1}{2}''$ to $\frac{5}{8}''$ metal, with 180 pound steam pressure, have, when clean on the water side, a temperature on their inner surface of 470°, which is about the brittle temperature. Hence it is necessary to guard against this by employing steel of *low* tensile strength, as we have endeavoured to show from the results of the latest practice, that will no doubt clearly indicate the difference between two distinctly marked qualities of of the same material, in which "mild" or soft steel holds a most conspicuous place.

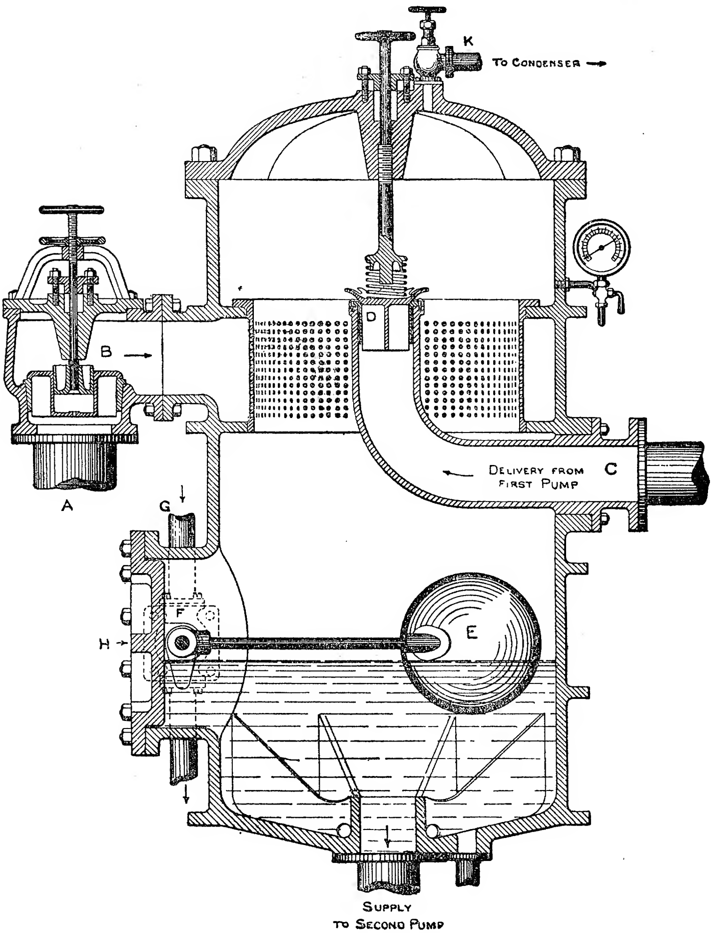
Although considerable economy has resulted from the use of the plain tubular boiler, it has not been so great after all, owing to the amount of wasted gases that pass into the funnel. This is owing to the central portion of these gases not coming in contact with the tubes and transmitting their heat to the surrounding water as they ought to do. With the object of remedying this defect, M. Serve invented a tube that has proved very efficient in many ships during the last few years. From numerous experiments made by the French Admiralty with ordinary 3″ diameter brass tubes, and Serve's Ribbed tubes of the same material, under identical circumstances, we learn that the extra quantities of steam produced by the latter were 15 per cent. with natural draught, and 20 per cent. with forced draught, the average reduction of heat in the smoke box and funnels being at least 200° Fahr. with natural draught, and fully 300° with forced draught. Although the main object of the interior ribs is to penetrate the columns of hot gases passing through them and thus communicate their heat to the water, an incidental increase of strength is obtained, while for internal cleaning purposes a wire brush or suitable scraper have been found quite sufficient.

The destructive peculiarities of condenser feed water have long received close attention from engineers and others, so much so, indeed, as to have given rise to very important recent discoveries through the experiments of accomplished Chemical scientists. The analytical investigations of the late Dr. Norman Tate unmistakably showed that the amount of impurities of a greasy and corrosive nature passed into the feed water from the engines was almost beyond belief. Professor Lewis, and others, have also proved that the burning and collapsing of furnaces is, in most cases, traceable to oil or grease settling upon them, and that the scaly deposits on the surface of the metal include oxides of copper, iron, etc., and other substances of a highly injurious nature.

With the object of neutralising their destructive effects, various anti-corrosives have been successfully used, but their employment, *after* the feed water has been taken into the boilers, is just as irrational, we should think, as drugging away the diseases engendered in our own systems through drinking bad water when pure fluid would have entirely prevented them. With this in view, Mr. Edmiston invented a *Feed-water Filter* that most effectually removes all the impurities at the outset, and as the remedy is very simple, the apparatus has naturally become popular in many naval and mercantile ships, and is also being usefully employed in land boilers.

When marine boilers are fed with water at high temperatures, the result is not only economy of fuel but considerable relief from the strains due to expansion and contraction. The ordinary method of heating the feed water by live steam secures only a small economy, as the main engines are thus robbed of it while still capable of performing useful work, and therefore the utilisation of of this vapour after it has exhausted its power is of great importance, especially when the heat that would otherwise be lost in the condenser can be beneficially saved.

With the view of advantageously employing the heat in the exhaust from the auxiliary engines, Messrs. Worthington especially designed the *Marine Feed Water Heater*, shown in the annexed view, for use in connection with triple and quadruple machinery. It is equally suitable for live steam, but is only thus recommended when there is



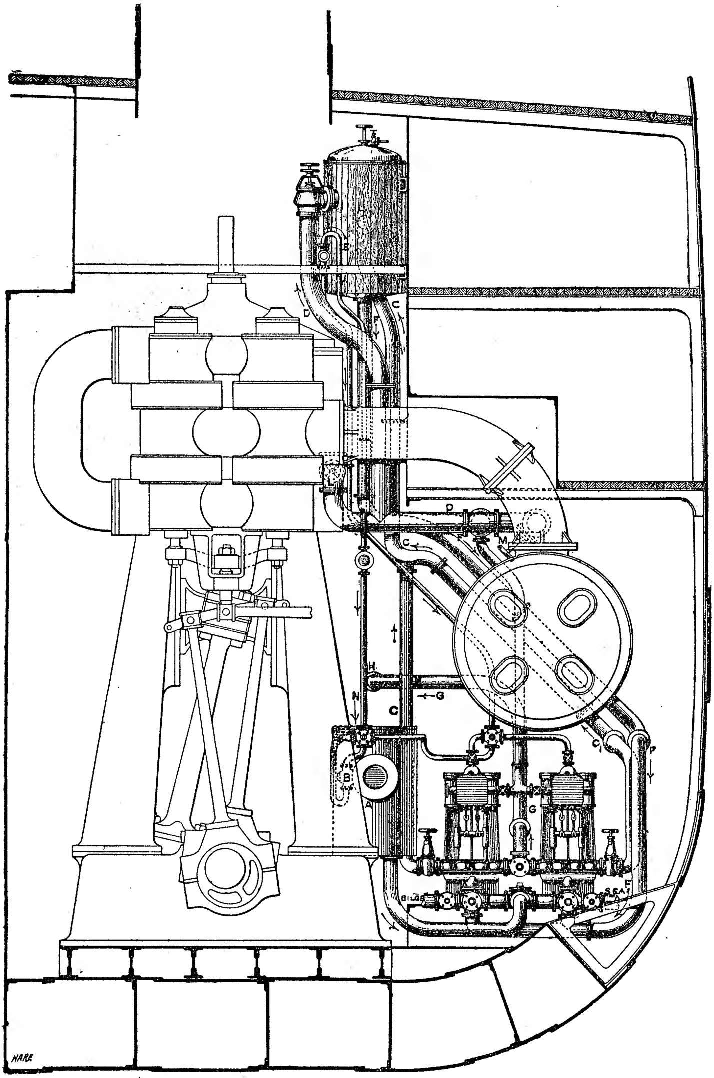
FEED WATER HEATER.

not sufficient exhaust vapour to be had for raising the feed water to the required temperature. In many ships, however, where only the latter is used, the temperature is raised from about 135° in the hot well to 210° or 215° Fahr. by means of this apparatus.

In the above Heater, steam of either description, as required, passes through the pipe A and specially constructed valve B into the annular chamber, and then through the perforated cylinder into the interior. On the other hand, the feed water from the hot well is forced by a pump through the pipe C to the valve D, and is then sprayed while passing this valve which is loaded by an adjustable spring to open at any desired pressure. This spray mixes with and absorbs the heat of the vapour as it enters from the annular passage, and causes it to fall in a condensed state to the bottom of the chamber.

As the water collects, it lifts the float E and opens the valve F, thereby admitting steam through the pipe G to another pump, which forces the heated fluid into the boiler. The float is made of copper, electrically deposited to avoid joints, the Heater being fitted with safety valves and other accessories in the usual way.

The *Application of the Apparatus* in a complete form to a ship is adjacently shown. In the first place, the surface condenser water is delivered by the air pumps into the hot well A, and, as this delivery is intermittent, it is necessary to regulate the working of the feed pumps so that they may be always filled with water. In the hot well, therefore, there is a float that operates the steam valve B and controls the working of one of these pumps by gradually opening the valve as the water rises, and shutting it in case the fluid is not delivered as fast as it is taken away. The pump in connection with the hot well delivers the water through the pipe C or C^1 into the heater, through the spray valve, and as the exhaust steam from the various auxiliaries flows into the main pipe



SHIP ARRANGEMENT OF FEED WATER HEATER.

D, it is conveyed to the annular chamber as already described. As the water accumulates in the heater, its internal float opens the steam valve E controlling the second pump, and passing from the heater through the pipe F to this pump, the fluid is forced by it into the feed supply pipe G leading to the boilers.

On the exhaust pipe D, is a valve L, leading to the low pressure casing, and any steam not utilised by the heater passes into the low pressure cylinder, and again does useful work. Or, if there is not enough exhaust steam from the auxiliaries to sufficiently heat the feed water, this valve can be used to regulate the amount of live steam admitted to the heater to increase the temperature of the feed water to the desired degree. By means of the valve M, exhaust steam from the auxiliaries can be turned into the condenser if required. These pumps are perfectly automatic, and either of them can be arranged by the valves shown to work in connection with the hot well, or the heater, or can be worked independently of the controlling gear by means of the three-way valve N. They can thus be used for pumping from the sea, or for any other service, as described on page 331.

Feed Pumps and Heaters, as above, have been adopted in many of the largest ships with eminently satisfactory results, such as, for example, in connection with a 10,000 horse power set of triple expansion engines. Without any method of heating the feed water, its temperature in the hot well would probably not be above 120°, whereas, by means of the above apparatus, the temperature might be raised by exhaust steam to 210°, and considerably higher with live steam from the intermediate casing. With, however, an increase of 90° only, the saving in coal will be about 13 tons per day.

The Plate showing the arrangement of the pumping machinery, etc., in a ship, also illustrates the method of double bottom construction now so popular in large vessels, on account of the protection it gives when the outer shell is damaged, and forming at the same time a convenient water ballast space that can be filled or pumped dry at any time. The *Half Section* shows how the engines and their keelsons are placed in a twin screw steamer—also the central bulkhead with gangway and skylight above, the left-hand portion of the vessel being an exact duplicate in every respect.

Since the introduction of very high pressure steam, it has not been considered advisable to take any water from the sea to make up the waste in the feed pump delivery to the boilers. This caused many vessels to carry a large fresh supply in their ballast tanks, or otherwise. Inasmuch, however, as the fluid not only contained large quantities of lime and other substances that created a hard scaly deposit on the furnaces, etc., but was too expensive and weighty, various distilling apparatus were invented by Mr. Weir and others, which effectually overcame the difficulty.

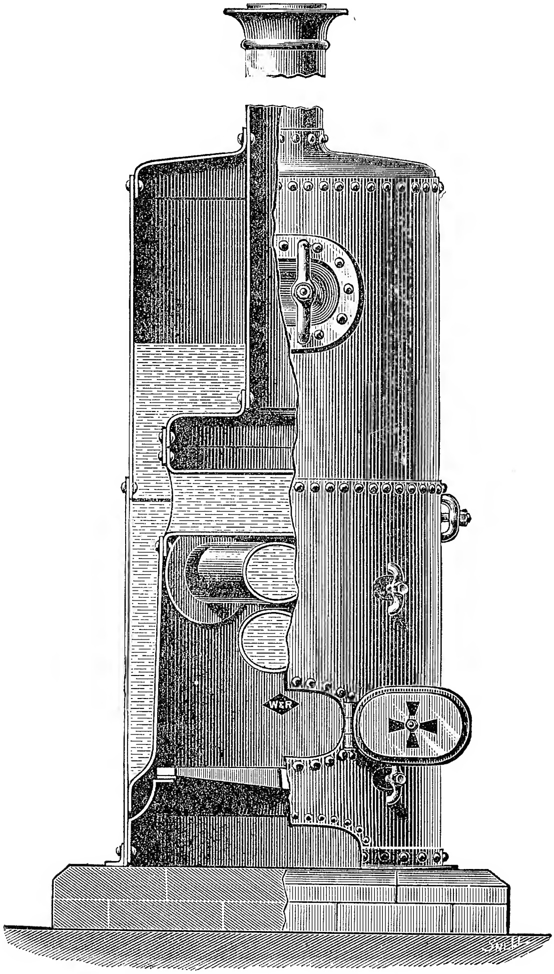
Mr. Hocking's Double Surface *Corrugated Stay-tube Feed Water Heaters* are so well known and appreciated that we need only say that they have undergone the most severe tests in very many of the finest ships working under pressures up to 200 pounds per square inch. His *Fresh Water Condensers*, for distilling purposes, are perhaps quite as popular, having proved themselves worthy of all confidence ashore and afloat.

One of the latest improvements has been introduced by Messrs. Musker & Webster, whose *Automatic Evaporator* possesses important features. It consists of a vertical cylinder with domed ends, having a large hinged door at the side, to which is attached a number of internal coils of pipe capable of being easily examined at any time. With the cylinder full of sea or other impure water up to the required level, steam under automatic control is admitted to the coils. The vapour thus formed is allowed to enter the main or other condenser, and then, in the form of pure water, passes into the hot well or tank, from which it is pumped into the boilers, or used for drinking, etc., purposes.

Amongst the most popular of steam generators is the well-known vertical *Donkey Boiler*, which in large sizes, under the name of "Haystack," has always been a favourite in Clyde river steamers on account of its general excellence and compactness. It is employed to do all the work of a ship while the main boilers are at rest, and is therefore made, fitted, surveyed, tested, and maintained in good order, under the supervision of the Board of Trade officials, as in all other cases.

The illustration on the next page gives a good idea of an improved *Vertical Cross Tubular Boiler* of this nature, made by Messrs. Woodhouse and Rawson, of London, in sizes from one to twenty-five horse-power.

The *Management of Boilers* is a most important feature, since, without proper care on the part of the attendants, heat may be lost in various ways, and accidents incurred that should have been avoided. At the end of a long voyage every boiler is examined internally and externally, scaled, and cleaned, etc., and thus they are enabled to give out their full powers during many years of hard service, as some of the Mail Companies can abundantly testify. The subject of boiler design, construction, and maintenance at sea in perfect condition, involves innumerable considerations, a few only of which have been sketchily noted in this chapter.



VERTICAL BOILER.

CHAPTER XXV.

THE SCREW PROPELLER—PATTERN SHOPS—FOUNDRIES.

Peculiarities of the Screw Propeller—Its Successful Application—Materials of Construction—Extraordinary Corrosion—Methods of avoiding it—Alteration in shape of Blades—Vicissitudes of Screw Propulsion Machinery—Designing of Propellers—Intricacy of the Subject—The Sirius Works again—Pattern Shop and its Machinery—The Foundry—Cause of a Broken Axle Epidemic on a Railway—Moulding by Machinery—Modern Plant and its Improvements—Heavy Castings—Foundry Appliances—Very old Establishments still in operation—Foundry Scenes by day and by night.

THE first thing that strikes the uninitiated who gaze at the propeller of a colossal racer in dry dock, is its utter insignificance compared with the ship to which it is attached and to the work it has to perform, and all the more so as sailing ships and paddle steamers display such enormous power when in rapid motion. Probably there are no paddle vessels in Europe that for speed and magnificence combined can excel the mail liners *Queen Victoria* and *Prince of Wales*, built by the Fairfield Company to run between Liverpool and the Isle of Man. Hence no better examples can be found to illustrate the difference between two distinct classes of ships of the highest order.

To judge from the prodigious splash of their wheels and their heavily surging wake, coupled with a speed which enables a full complement of 1,800 passengers to traverse the 75 mile distance from the Mersey to Douglas in three hours, one would fancy the engines must be immense. And so they are, since during the trip from 7,000 to 8,000 horse power is developed in the most strikingly *visible* manner. With screw vessels, however, there is nothing that can give any true indication of the energy put forth, as the propeller is an imperceptible agent, and as the velocity of a steamer is only about one tenth less, and has in some cases been even greater than that of the screw which drives it, there is additional cause for astonishment.

The small size of the propeller is primarily due to the high speed of modern engines, which increases the reactionary resistance of the water to the screw as the squares of the number of revolutions. And secondly, to the very fine lines, or "run," of the after body of the ship, which enables a small propeller to work in more solid fluid than it would do if the vessel were a tubby cargo carrier.

If we were to suppose a screw to act without any slip, or in other words, if its number of revolutions × pitch equalled the speed of the ship, we would have the same result as if the screw revolved in a cast steel nut instead of water. But even this becomes more astonishing when, with *negative* slip, a steamer actually over-runs her propeller, thus introducing a marvel which at one time ranked with the greatest of modern mysteries. In well designed propellers, however, there is always a certain amount of positive slip, ranging say from 8 to 10 per cent. in ordinary practice. Or, otherwise expressed, while the screw travels 100 knots the ship runs 90 to 92 knots.

So important are good proportions in this respect, that if there is any mistake it will be sure to vitiate the efficiency even of the best engines and boilers, hence it is only natural that the subject should have been discussed until threadbare by philosophers and practical engineers during the last fifty years. As the matter now stands, calculations only carry one so far, whilst practical or experimental knowledge does the rest. One of the most useful contributions on this subject is Mr. Drewry's paper recently read at the Institute of Marine Engineers, London. As a chief engineer in the Peninsular and Oriental Company, he had many opportunities of acquiring an amount of special knowledge that can never be obtained by pure scientists, nevertheless, *Theory* holds the light, while *Practice* does the work.

Although the *Paddle Wheel* was used by the Chinese ages ago, and the *Screw Propeller* was similarly known to them, it is to Mr. Patrick Miller of Dalswinton that we owe the successful introduction of the former in 1788, when he caused the first vessel that could be termed a "steamer" to run five miles an hour on his own loch. This subsequently popular method of propulsion, however, has been almost entirely superseded by the screw, owing to the advantages of the latter. Its first practical success dates back to the year 1836, but after the S.S. *Dwarf* experiments of 1846, some headway was made which gradually increased until at last the invention became a ruling power throughout the world, and the foundation, we may say, upon which the whole of the complex machinery of a ship is now built.

Propellers are chiefly formed of steel, cast iron, and manganese bronze, the latter of which is the best for the purpose on account of its non-corrodibility, toughness, and smooth surface, which gives about half a knot more speed to a ship, and also owing to its value as old metal. Of course good steel is much less costly, but its corrosive powers are worse than those of cast iron, as we have noted in hundreds of cases where the blades have been perforated, pitted, nibbled, bitten, honeycombed, etc., in the most irregular and destructive fashion, invariably within nine inches or so of the tip.

With the view of ascertaining the cause of this, we have firstly to remember that the evil was little known in the fan-shaped and stiff pointed blades of early days, which maintained their soundness for 12 or 13 years, whereas now they are sometimes destroyed by 4 or 5 years' service. The Griffiths screw, made of gun metal, was much used in the Navy long before it became popular in merchant ships, but when it was introduced to the latter it was made of cast iron, and brought with it the plague of pitting to which we have referred.

The origin of the mischief, therefore, may be thus explained:—If a broad-pointed or fan-shaped blade lasted for so many years unimpaired, and the now genteelly fined-off points are rapidly destroyed, may we not conclude that the latter have been the direct cause? We learn emphatically, from Sir William Fairbairn's experiments, that large beams, severely tested with a *pulsating* load, have actually broken down from this cause alone in an incredibly short period. Can we be wrong then in supposing that the narrow points of modern propellers have not sufficient rigidity to bear a few million tremors while working—that these movements loosen irregularly in a short time the fibres of a casting perhaps deficient in homogeneity—and that exposure to air, etc, destructively does the rest?

The subject has been ably and exhaustively discussed by many engineers, but the reasons given have often seemed to be the true ones as we contemplated from a dock wall the prematurely dreadful effects produced upon our propellers, which we are powerless to avert in iron and steel without returning to a discarded practice. The best remedy for the evil is the adoption of manganese bronze blades, when first cost is no object, but a less expensive method is to homogeneously coat them, when of steel, with some non-corrosive metal. This has already been done in Delta metal, which gives great transverse strength when upon the principle invented by Messrs. List and Dick.

Mr. Griffiths worked out the proportions of his screws very carefully, and won his fame by completely altering the shape of the blades, and by greatly increasing the diameter of the boss, which thus prevented the wasteful churning of the water when the blades attached to a small centre ran closely parallel to the shaft. He also made them capable of easy disconnection at any time. Various inventors have subsequently tried to run successfully on new lines, and amongst the number are Mr. Thorneycroft and Mr. Wrench. The former by making his propeller scientifically adaptable to quick running Torpedo boats, and the latter, by skewing the blades well aft, to obtain the best results with vessels having full lines and light draught.

As there are still many vessels that have good engine power, but nevertheless use their sails as frequently as possible when not under steam, it is only natural that the dragging of an ordinary screw through the water must be a serious impediment. To obviate this, Mr. Bevis designed an excellent arrangement by means of which the blades of a propeller can be angled so as to alter the pitch if required, or they can be feathered in a fore and aft direction, and thus enable a ship to proceed under sail to the best advantage. The utility of the invention may be gathered from the fact that it has been fitted to very many naval vessels of various nationalities up to at least 4,000 horse power, and also to numerous steam yachts down to 80 horse power. The gearing is very simple, and can be worked either in the engine room or from the deck above with little trouble, thus forming a striking contrast to the cumbrous system that once existed of lifting the screw into an aperture in the stern.

The vicissitudes of screw propulsion and its machinery have been peculiar. Amongst the "fifties" and "sixties," ships had low speed but full powered engines and large sail area to help them along. These engines were extremely varied, as already described, but this was owing to each firm having its own favourite types, in whose general and detailed design there was a manifest desire to avoid even the suspicion of copying from each other, and hence every kind of novelty was introduced. The next move was to have full rigged ships with auxiliary engines, good examples of which were to be found in the Navy, and in vessels of the *Great Britain* type.

In the latter, the screw was carried in a vertically sliding frame, which enabled it to be easily disengaged from the shaft and hoisted out of the water. The two-bladed screws thus employed were superseded by three and four bladers, which worked with greater steadiness, but as these could not be housed when not required, much power was lost by dragging when a ship was under full sail. Although very many vessels were thus built, other changes were introduced which involved the cutting down of the handsome masts, until they gradually became mere flag staffs, and thus the whole of the propelling power of a steamer was eventually thrown upon the engines.

The position of a screw in the water, especially at load draught, is sufficient, one would think, to keep it from being damaged at any time, nevertheless, steamers are sometimes delayed from this cause alone through sudden shocks in stormy weather. If the propeller is a single casting, fracture of one or two blades will necessitate the removal of the whole, but, strange to say, ships have sometimes had their speed increased by such accidents. This, however, was at the risk of injury to the vessel owing to the vibration caused by such unbalanced distribution of strains. In high class ocean steamers, the usual practice is to cast the blades separately and bolt them to the boss, hence a fractured blade can easily be disconnected and a spare one fitted, even at sea, by means of Mr. Boulton's vertical sliding tube arrangement.

The design and proportions of propellers require so many considerations that no reference need here be made to them, especially when so much has been ably written already from every point of view, including the records of numerous steamship performances. From these it may be gathered that the design of a screw is not so much a matter of calculation as of precedent and experiment, hence we find that ships have frequently been fitted with propellers that had to be reduced in size, or altered in shape, or pitch, before the best results could be obtained. One of the most successful engineering firms thus worked out the proportions they now employ, and although the superintendents of steamship lines are supposed to have somewhat uniform ideas on leading points, they nevertheless vary considerably in this respect.

Neither philosophers nor mathematicians have yet been able to solve the question satisfactorily, and it now appears that constructors at the building yards are the only people who can do so in their own way with the greatest success. It is commonly believed that the maximum efficiency of a screw does not exceed 56 per cent. of the engine power; dynamometer experiments, however, have shown that this in some cases has reached fully 77 per cent, but here again the question becomes perplexing on account of so many disturbing causes. At any rate it may be said that those who design steamships seem to avoid theoretical reasoning as much as possible, and trust to their own matured judgment with results which have become fully apparent.

So far as the mere drawing of a propeller is concerned, any artistic young lady could easily produce a highly finished sketch from a graving dock stand point, but a correct series of geometrical views is an impossibility to any but those who are in the secret, hence it will be necessary to find out from the best sources how the thing is done.

While describing rational science, our good friends at the Sirius Works may appear to have been forgotton, nevertheless, we have had them continuously in view. What has been said, however, in previous chapters, refers to every-day practice in the best establishments, of which Messrs. Baxendelle and Farquharson's is only a type.

With this in view, we shall revisit the Works with a few friends, have a general survey of everything connected with the machinery of the *Vencedora* and her sisters, note the various methods of construction and completion in a somewhat sketchy style, and finish the volume with a chapter illustrative of ocean racer performances at sea.

Since we left the two principals they have been so busily occupied inside and outside that the results of their labours will soon be prominently visible. On entering the *Pattern Shop* we find a number of hands preparing the patterns for large and small sets of engines, orders for which have recently been received, and as in new establishments the stock supply has to be gradually acquired, the activity in this department becomes intensified. It was at one time supposed that machine labour could not be profitably employed on account of the great irregularity in form and size of engine patterns, so many easily adjustable wood-manipulators, however, have recently been introduced, that much can now be accomplished by their aid that formerly was done by hand. Patterns require great nicety in formation to enable easy moulding and sound castings to be obtained from them. The former operation, however, depends upon the skill of the workman, and the latter upon the practical knowledge of the drawing office staff.

The machines in general use are very simple, and chiefly include wood-turning lathes, planers, and circular and band saws, etc, which have already been described in Chapter XI.

Large patterns are made of well seasoned pine timber, small and delicately formed ones, however, are of hard wood, but when frequently used cast iron is preferred. Good firms as a rule pay great attention to elegance in design, and hence lines of beauty are very prevalent in their productions. These lines, however, are made to give additional strength, and therefore all interior corners in castings are hollowed out, or "filleted," and general outlines swept by parabolic or circular curves, as will be seen in many of the plates. This filleting of castings and forgings has a very important practical bearing, insignificant as it may appear, since with the former it causes the fluid metal to cool in such a way as to avoid initially injurious local strains, and with the latter it becomes a source of strength, owing to the absence of sharp angles, or, virtually speaking, incipient cracks that may afterwards extend.

Many years ago an epidemic of broken axles burst upon the railway world which was perplexing, as plenty of strength had been given to them. Nevertheless they invariably failed at the point where a sudden change of diameter occurred for the purpose of giving a shoulder for the naves of the wheels to bear against. This had hitherto been made square; after being rounded, however, the evil vanished.

As another example, it may be mentioned that when, on a recent occasion, the axle of a dock omnibus broke at the same place, and caused a man to be thrown off the top and seriously injured, I was invited to give scientific evidence in Court.

"Take this axle into your hand," said the judge, whilst gazing at the broken end, "and tell us what *you* think was the cause of the accident."

I immediately pointed out to him an old crack in a *sharp* corner next to the wheel, which had eventually destroyed the shaft, and accompanied my remarks with the aforesaid reasoning, which proved conclusive. We may add, that a very practical way of utilising this principle when an iron or steel bar has to be broken, is to notch it all round with a chisel so that it can be easily snapped like cast iron on the edge of an anvil. The granular nature, however, of the fracture, is delusive for test purposes, as it will indicate material of a brittle or inferior nature, even if it should be of the best quality.

In locomotive works, and other places where castings of moderate dimensions are much used, the *Foundry* forms part of the establishment, but in marine works it is generally a separate business, for reasons already given. The latter thus becames a centre for many neighbouring firms to whom it owes its prosperity. All kinds of heavy castings are moulded by hand more or less elaborately, but when there is much repetition work of small size, Mr. F. G. Leeder's Sand-Moulding machine proves invaluable, since through its use from 400 to 600 complete moulds for each machine can be made with ease every day by means of boy labour alone.

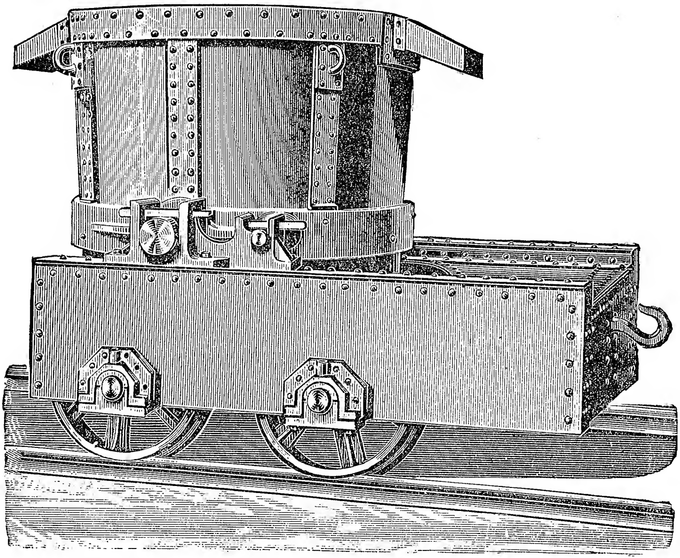
The main working parts consist of two hydraulic rams—one within the other—which act in concert with a swinging plate carried by one of the columns, and capable of being raised or lowered on it. This plate has half of the pattern projecting from each side ready to be brought into position at once, and above and below it are the moulding boxes, the under one being first filled with sand and then covered by the pattern plate. The upper sliding box is now lowered down to it and similiarly filled, when the valves at the side are successively opened, thus causing the outer and inner rams to compress the sand and finish the moulds, which are now taken out and brought together ready for receiving the melted metal.

The *Foundry Plant* and *Machinery* come next in order, and here great improvements have been effected by Messrs. Thwaites Brothers, of Bradford, who have produced an admirable system, supplied in the most complete form, amongst others to the New South Wales Government, at Sydney. This installation comprised a built up *Casting pit* 16′ 0″ square, by 15′ 0″ deep, a *Core drying Stove*, *Loam carriages*, and three *Cupolas* of Stewart's "Rapid" description, a self acting *Loam Mill*, and a *Roots' Blower* of considerable power.

The *Cupolas* are each capable of melting one, five, and ten tons of metal per hour, according to requirements, and the advantages attending their use are so conspicuous as to have won for the apparatus a remarkable amount of appreciation from numerous firms at home and abroad. In addition to the above, all the necessary *Lifting* gear, *Brass* furnaces, *Moulding* boxes, etc., *Tools*, and everything necessary for executing the work in the most complete and effective manner were provided.

Iron castings for engines or machines are made of the strongest quality of metal, and have a very smooth and clean surface, which is well represented on a drawing by neutral tint. Upon arrival at the works, the massive parts receive a coat of paint for preservation, but in some places this is dispensed with. After being carefully lined off according to the plans, and marked with a centre punch for distinctness, the machining operations are at once begun, and continued without intermission until the details are ready for finishing by hand and erecting in position.

As gigantic castings are frequently made in some of the great establishments, powerful overhead travelling cranes are used, but for ordinary work, the "jib," or "foundry crane" is still much employed. Many dreadful accidents have happened whilst passing large quantities of fluid metal from the cupolas to the casting pits, and to avoid this danger many excellent arrangements have been devised. Amongst these may be mentioned Messrs. Henry Berry's *Hot Metal Carriage* and centre-crane *Casting Ladle*, adjacently shown. The former is made in sizes up to a capacity of 100 tons; in this case, however, a 65 tonner is represented, but for lighter purposes the Ladle

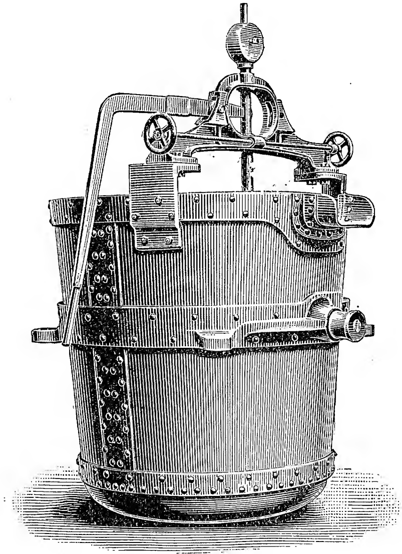


HOT METAL CARRIAGE.

of 20 tons, illustrated on the next page, is sufficient. As will be seen in the views, the gear for swinging and canting are clearly delineated.

Amongst the most recent improvements relating to Foundry Work is the apparatus invented by Mr. Boulton for the production of steel, or other ingots, in the most perfect state, and with a saving of 30 per cent., owing to the rapid and efficient manner in which the operation is performed.

The quality of castings depends upon the mixtures of the various brands of pig iron out of which they are made. These qualities may be indicated by the fact that while the tensile strength of the metal ranges, say, from 5 to about 15 tons per square inch, the compression extends from nearly 40 to 50 tons. Hence its great value for constructive purposes, and especially for columns, etc., that have to sustain heavy crushing loads.



20 TON CASTING LADLE.

The term "Foundry" is of comparatively modern date, and was originally applied to the early works where castings were chiefly produced. Messrs. Fawcett & Preston's Phœnix Foundry, in Liverpool, for instance, is a good example of this, as it was similarly employed upwards of 100 years ago upon small gear. Mr. Fawcett then began to make carronades, to which the still more ancient *Carron* Foundry, on the Forth, had given its name. After this, he undertook the construction of land engines, sugar mills, etc., and as the firm advanced in years the manufacture of marine engines was added, and is continued to the present with great success.

Very naturally the grand old establishments still retain the name under which they became famous, even after modern improvements had caused their original casting business to be given to specialists. New places, however, generally adopt such titles as "Sirius *Works*," "North Shore *Iron Works*," and so on, which should be in all cases as briefly expressive as possible, for reasons already given.

On account of their gloomy and uninteresting appearance, Foundries are seldom visited by strangers, nevertheless, they hold the same relation even to the most magnificent machinery departments, as the unseen foundations of a vast cathedral do to the superstructure. In the day time the men are busy preparing the moulds, and towards evening, the cupolas, cranes, and other gear we have mentioned get into full play, whilst the receptacles prepared for the melted metal are being filled. The scene thus becomes picturesquely dangerous to visitors, who might be seriously injured by treading incautiously upon miniature volcanic territory. After these remarks we shall, in the next chapter, take our accompanying friends into departments where marine engineering practice begins to unfold itself in the most comprehensively attractive manner.

CHAPTER XXVI.

MACHINING AND ERECTING SHOPS AT THE SIRIUS WORKS.

The Light Machine Shop—Increased Productive Powers of Machinery — Engine Fitters and their Work — Panoramic View of Erecting Shop, &c. — Engines in Progress — The Foreman and his "Hands"—Overhead Travelling Cranes—"Swell Apprentices"—Various useful Machines—Erection of Engines as it was, and is—Bolt and other Fixings—Electric Motor in Ships—Screw Shafts and their Failures—How Originated—Construction of Built Shafts—Repairing Broken Shafts at sea—Artistic finish in Ships—Engine Turning Gear—Simple Method of altering Compound Engines into Triples—Results from Practice.

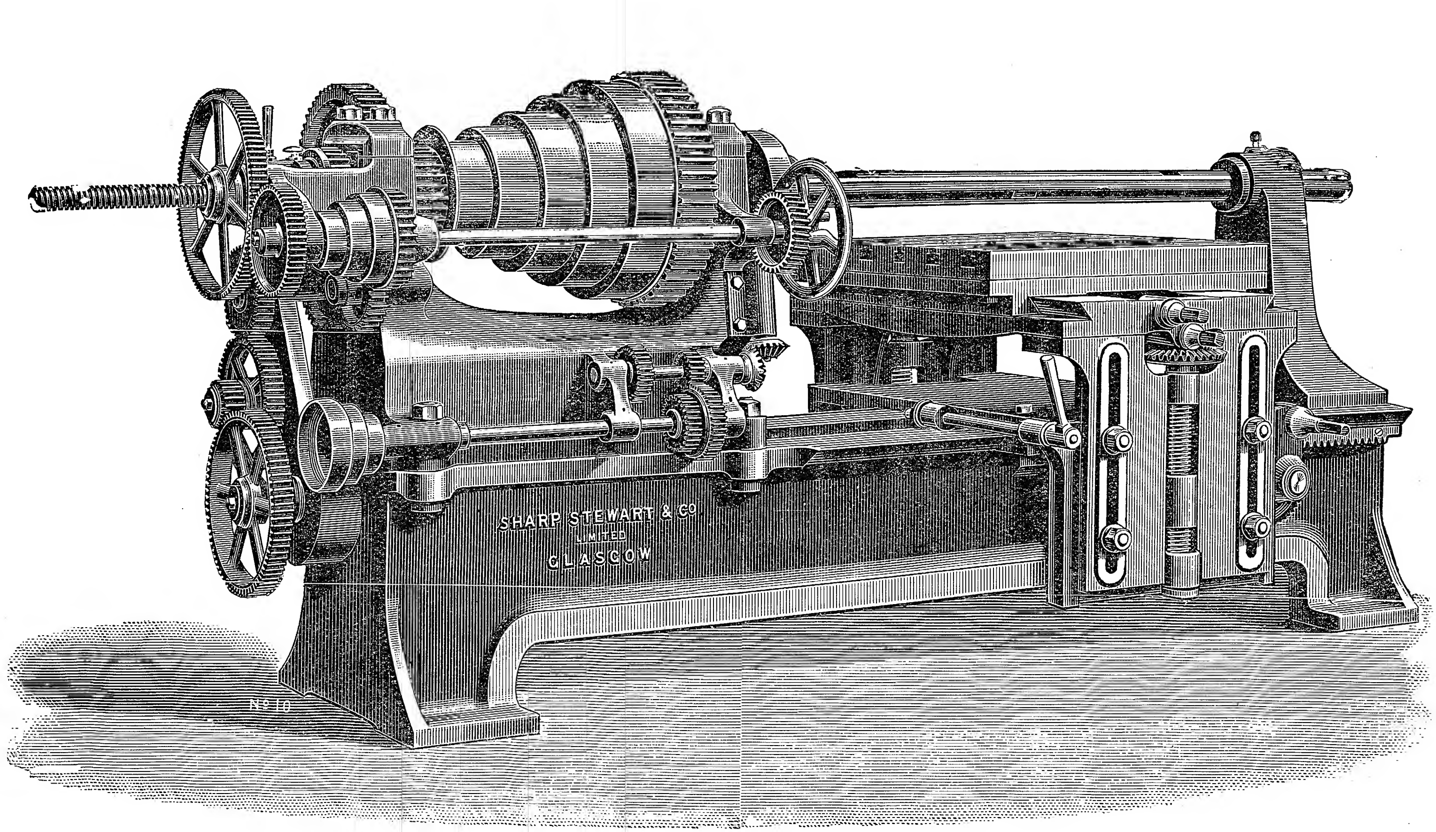
LET us now visit the *Light Machine Shop*, where much previously mentioned will be seen in operation, and from which, owing to its elevated position between the bays of a vast building, a very animated and picturesque view will be obtained.

Upon entering the first named department at the Sirius Works, we find all the machines fully occupied with a great variety of small and medium sized details for engines, boilers, etc., which are being turned, planed, slotted, drilled, milled, and so on, with great smoothness and steadiness. As the class of machinery now around us has already been described, we shall only add what may be desirable, whilst referring to a region where many most important minor operations are performed.

In large engineering establishments, bolts and nuts, from $\frac{5}{8}''$ to say 6″ diameter, are used up by the thousand in a very short period, as one might reasonably expect. For bright work the sides of the nuts and bolt heads are smooth finished, and this can be accomplished by planing or slotting; but one of the best methods is to use *Special Nut Shaping Machines* that operate upon a number of them at one time. *Quick Speed Drilling Machines*, which can be instantaneously regulated by means of a foot lever arrangement, are also most useful, as the innumerable oil holes, small pin holes, and those for set screws, etc., can be very rapidly bored with the least amount of trouble. In these, as in many other instances, the patented and apparently insignificant devices of certain firms prove highly advantageous, as they so greatly facilitate workshop operations.

Amongst the innumerable varieties, sizes, and combinations of marine details, are many that cannot be conveniently operated upon either by the lathe or by vertical drillers. To remove these difficulties, the *Horizontal Boring and Drilling Machine* was invented, but as this was originally of an imperfect type, improvements were gradually made by different firms, until at last Messrs. Sharp, Stewart & Co., of Glasgow, introduced the excellent arrangement shown on the next page. This machine was recently designed for the purpose of dealing with a large variety of work with the least amount of trouble, all the motions and adjustments being under the direct control of the attendant. It is also fitted with a guide screw, change wheels, and other arrangements for screw cutting, sliding, etc.

The main spindle is bored throughout its entire length to allow the steel boring bar to work in it and thus



HORIZONTAL BORING MACHINE.

economise space, whilst at the same time the latter is made capable of independent driving, automatic feeding, and quick hand motion, by means of special gear attached to the fast headstock. This bar is provided with apertures for fixing cutters of different kinds and sizes for boring and facing purposes, and along its front side may be seen the longitudinal key seat for the attachment of cutter blocks to suit a variety of work. The table can be adjusted quickly by hand, longitudinally, transversely, and vertically, and it can also be swivelled completely round. Hence a piece of work can be bored, drilled, or faced at one end, and afterwards moved into any other position to be similarly treated at one setting.

As we proceed, rows of vice benches rise to view, and rows of fitters, too, at least what is left of them in days when planed, slotted, etc., details only require a little toshing up here with a file, and a little titivating there with a flat scraper, so that every part shall have the most exact adjustment. As the forgings and castings arrive some of them are passed to the iron marking table, whose smooth and level surface forms a splendid basis for such operations. Crossheads, forked joints, valves, rods, levers, and so on, are here chalked, draw-point-lined from the plans, centre-punched for permanent distinctness, and sent to the various hands for execution; thus providing much that is highly instructive to the non-professional as well as to the engineer, on account of the insight it gives into the machines themselves, their methods of working steel, iron, and brass, and also into some of the engine details lying about in every direction, that may unitedly help to drive a ship at a speed of twenty to twenty-three knots an hour.

Upon reaching the outside railing of the floor we are now upon, a grand panoramic view is obtained of the building and its contents. Underneath, and on both sides, are to be seen some of the magnificent heavy machinery, and also the spacious, lofty, and well arranged *Erecting Shop*, which is now well stocked with the handsome engines of the *Vencedora*, *Voltinia*, and *Vipsania*, the first of which is nearly ready for launching.

The machinery of other ships is in a more or less forward state, and from our present standpoint we can see Mr. Hulse's colossal Side Planer trimming up a condenser for one of them, whilst cylinders, connecting rods, and other gear are lying about in every direction. There is Mr. Burton, the foreman, slowly revolving the *Vence's* engines by the turning gear, to see if the various "clearances" are all right, and also if the valves are properly set. You may depend upon it, kind reader, that all these movements will be executed to perfection, as the above gentleman runs exactly upon the lines of one with whose character and abilities we were long acquainted, and whose carefulness we often noted.

There, too, is Mr. Ogden, who has come for something he wanted relating to the *Vencedora's* sea connections. Yonder are numerous erectors putting things together, whilst the cranes overhead are picturesquely conveying heavy gear from one place to another. There, for instance, is the *Malacca's* bedplate balanced in mid air by means of careful chain-slinging, also one of the *Vipsania's* connecting rods similarly well poised, and so on in a variety of other ways.

Intermingled with the crowd of people and things, we discover numerous apprentices performing their varied parts in their own way, and amongst them is Reginald De Courcy Camperdown Plantagenet — the very *last* of his race, whose father is one of Mr. Baxendelle's best friends. Sir Alberto expects his son to rank as an eminent some day through the excellent training he will have at the Sirius Works; Mr. B., however, thinks otherwise. What a contrast there is between Mr. Reginald and William Frederick Colin Campbell working beside him, who, with all the ambition of his clan, is industriously trying to climb the ladder of engineering practice at the very outset. 'Pon my word! there is Mr. Baxendelle himself having a look round in the satisfied manner of one who finds his plans coming out all right and everything doing well. We must go down to him after we have had a final inspection of our high level surroundings.

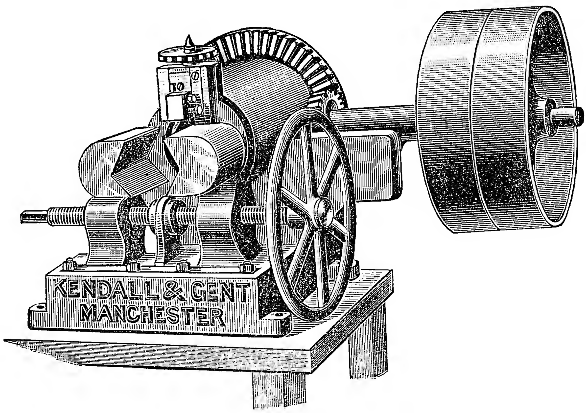
One of the numerous practical accomplishments left to the writer from early days, is the art of cutting a square hole with a round file, which can easily be done to perfection by a skilled hand, as some of my contemporaries well know. The usual method of performing the same operation is, first to bore a hole, then chip out the corners with a diamond pointed chisel, and finish with a *square* file, all of which involves considerable labour. Modern times, however, have produced the Ainley-Oakes *Square Drilling Machine*, which in an extraordinary and rapid manner, bores square, rectangular, hexagonal, and other variously shaped holes, and can also be used for ordinary drilling when required. For establishments where such apertures are in demand, this invention should prove invaluable.

In apprentice days we used to do many little things, as well as those of a more extensive character, and amongst the former were the cutting of key seats in levers, etc., by hand, which was done firstly by chipping them out with a ripping chisel, and then filing them to a hair breadth finish. The most barbarous operation, however, of this nature was that of excavating a sunk key bed in the body of a crank shaft for securing the eccentrics in position. As the former could not even be partially drilled, they had to be ripped, and chipped, and filed without any approach to accuracy, as the recess was closed at both ends.

Now-a-days, the last named operation can be most admirably performed by means of the *Slot Drilling Machines* previously mentioned, and the former by the special machines of Messrs. Smith & Coventry, and Messrs. Harper, which have proved highly advantageous.

In large establishments scores of thousands of boiler and condenser tubes are used up in the course of a year, all of which have to be cut to dead lengths, whilst very many stay tubes for the former require to be screwed at the ends as well. The first named operation was at one time variously performed, as the tube ends could be sawn off with a hand bow-saw, if nothing better was obtainable, or a machine saw, or notched with a chisel all round, and snapped off and filed true, but at great cost. Engineers noted these defects, and hence Messrs. Kendall & Gent introduced their specially designed portable *Bevel-geared Tube Cutting Machine*, adjacently illustrated, which can be either belt or hand-driven, as desired. The tube is firmly gripped by the vice jaws, and as the tool head-stock is hollow, it can be held in any position for cutting, which is rapidly performed by the revolving tool box shown in the engraving. It is now the custom in the navy to stretch boiler tubes so that when their ends are damaged by burning they may be taken off, and thus enabled to be still further used, but by the latest process scarph cutting and welding may be employed instead.

We have been constrained, for two reasons, to refer to the old and new systems of performing some of the minor operations which are now most extensively required. Firstly, because the younger race of engineers have few opportunities of learning the manual processes of doing work with which their elder brethren are so well acquainted, and which must still be adopted when suitable machinery is not employed. And, secondly, because



BEVEL-GEARED TUBE CUTTING MACHINE.

by comparing the two systems we are enabled to see at a glance the extravagance of using costly general machinery for doing things that can be performed much more rapidly by those of an inexpensive special character. It is here, therefore, where the difference lies between profits on the one hand and losses on the other, especially when, as in some establishments, 1,000 to 1,500 machines are employed for every possible purpose.

Having sufficiently noted the peculiarities of the high level machinery, and re-surveyed from lofty ground the scenes around us, we may now descend to the floor below. Amongst other things, the system of erection employed requires explanation, here, however, we must give some of our own experiences in this respect.

A flash of thought raises to view the year 1855, when at Messrs. Denny's, I had my small share in helping on the engines of the Allan screw liners *Anglo-Saxon* and *North American* we were then building. The bedplate for the former has just arrived from the adjacent foundry, and Mr. William Campbell, the foreman of the erectors, is having it slung into position on the prepared timber blocks by means of the jib crane of the period, and soon afterwards the heavy casting is adjusted by the application of a long wooden straight edge and spirit level.

The main bearing and air pump seats, were now tightly fitted with pieces of plank about three inches in width, chalked as usual, so that the principal centre lines of the engines could be distinctly drawn in. The *lowest* corner of the fitting strips for the column bases was next found, and then chipped and filed as a true datum level for all the other corners, whilst the intervening irregularities were gradually reduced by the same process. The air pump seats were similarly treated, and by gently rubbing them with wooden face plates, lightly smeared with red lead, all inequalities were so clearly indicated, as to enable them to be touched up with a file and flat scraper, until a perfect surface was at last attained.

After bedding the columns carefully in position, the bolt holes were drilled by ratchet braces, rhymered true with each other, and faced for the nuts by portable cutter bars. The bolts were then turned to a tight driving fit, and after the nuts had been screwed hard up the whole fabric was as solid as if cast in one piece. The air pump barrels were fitted to circular openings chipped and filed as above, the stud holes drilled with crank braces and screwed by hand, and when the pumps were fixed, the hot well and other gear were proceeded with.

The seats for the main bearing brasses were prepared by chipping and filing as usual, and when the latter had been properly fitted and bolted down, to enable the shaft circles to be drawn upon them, they were bored separately in the lathe. This vicious practice entailed considerable trouble when the crank shaft, previously smeared with red lead, came to be lowered into position, as the brasses had in some places to be heavily filed and scraped before they could be truly adjusted. Then, as now, the flat scraper and ground half round file were invaluable, the former giving a beautifully true finish to all flat bearings such as valve faces, machine slides, etc., and the other a similar finish to curved surfaces.

When the jet condenser columns and outer framings, etc., were fixed in position, the cylinders were placed upon them, and all the rest of the gear set up by degrees, until the engines were completed upon a perfectly level and perpendicular system which was insured by the use of the spirit level and plumb line. My highly esteemed and in some cases eminent contemporaries, who were "all on the job" at that period, will remember these interesting events in engine building, and they will also recollect that their own performances were quite equal to the best machine work, though not so rapid in execution. The *principles* involved in the above system remain unaltered, but the manipulative processes referred to have been so entirely changed by the use of machinery, that they threaten to become a lost art. Nevertheless, they must still be used when nothing better can be had.

Naval engines are now very frequently built upon an iron floor foundation, sufficiently large to accommodate the different sizes, whose cylinders, condensers, framings, etc., after being planed on the bottoms, are at once laid in position, and the rest of the work proceeded with, almost without the aid of a spirit level. This, however, can easily be done, as shown on page 219, when everything is carefully marked off, and as carefully machined.

The *Bolt Fixings* of machinery are not only elegantly simple and efficient, but are of vital and universal importance, and chiefly include those with heads for ordinary work, and "stud bolts" which are screwed at both ends for convenient and very compact attachments. The former comprise those that are turned to an exact and tight fit for shaft coupling and all rigid constructional purposes, where their full shearing powers must be given out. The next class consists of similarly exact but easy fitting tensional bolts, which allow all working gear, such as connecting rods, eccentric rods, etc., to be perfectly rigid and yet easy of disconnection. Then follow the unturned bolts in their thousands for pipe flange and other jointing, and the ordinary fixing of parts in the engine, boiler, and ship departments. All these should fit loosely and have their nuts forged or machined to the size, according to circumstances.

"Studs" are not only extremely useful for all sorts of covers, boxes, etc., but actually indispensable where the others cannot be employed. The former are usually made of iron or steel rolled to the size, cut to the length, and screwed at both ends with a plain part between, which makes them more able to stand severe straining. Where this, however, does not exist, a less costly method is to get long rods screwed throughout, to cut as required. By screwing the holes for their reception only with the medium tap, the necessary tightness is insured. These holes should have a depth equal to D of stud when in steel, wrought iron, or brass; in cast iron, however, $D \times 1 \cdot 5$ is allowed, because this metal is naturally weaker, and also because the threads are slightly deteriorated by the action of the tap.

The other indispensable fixings of, however, only a special nature, comprise *Gibs* and *Cottars* for rods whose bearings are exposed to wear; to allow for which, the latter should have a driving taper of $\frac{3}{4}''$ per foot, and be protected from vibratory slackening, as with main bolts, by means of a set screw and cross pin.

Cottars for securing rods and cross heads, etc., immovably to each other, should have a taper of $^3/_{16}''$ per foot, and also a cross pin for the above reason.

Single Keys for fastening levers on shafts are usually D of eye $\div$ 4 in width, and two-thirds of this in depth—one half of which should be in the lever and the other half in the shaft. Amongst other fixings may be mentioned Mr. Geddes's *Safety Flanges* for copper pipes, which have proved most useful, especially for high pressures.

Electric Motors are now extensively used in driving small portable tools that in modern practice have proved indispensable in the works, and promise to be in a short time equally so in large ships. This is due to their extremely handy nature, and to the ease with which power may be transmitted to them in every possible direction, and into the most tortuous and confined spaces. One of these motors for launch driving is shown in Chapter *XXVIII*, and another is now employed in *Electrical Drilling Machines* by the Electrical Company of London.

The numerous advantages of the latter include the absence of belting, convenient transportation from place to place, and facility in drilling holes up to $1\frac{3}{8}''$ diameter, vertically, angularly, or invertedly. The easy adaptability of this machine to steamers having electric light apparatus is clearly apparent, especially when the motive power may be had at nominal cost. An indication, however, of its usefulness for ship purposes, may be gathered from the fact that *drilling* at all times forms one of the most indispensable operations, not only on account of the circular holes thus produced, but also aided by hand tools, those of every possible form that could not otherwise be accomplished, of which the repairing of the S.S. *Umbria's* main shaft at sea and in port is an excellent example.

A recent innovation now used in shipyards, is the *Improved Drilling Machine for Counter-sinking rivet holes*, which traverses a large area of a plate at one setting, thus abolishing the cumbrous system of shifting the latter for each hole. As the various movements are instantaneously accomplished by means of hand gear its great value will be readily appreciated.

It may appear strange that after all that the most skilful designers, and metallurgists, and constructors have done to secure absolute safety to the *Main Shafts* of steamers, they should break so frequently as they do.

In view of this, the question will naturally be asked how it happens that during three very recent years no less than 228 steamers were disabled by broken shafts, the average life of which was only about four years. Various reasons have been assigned for these and other similar failures, but the one above all others that now seems to create the greatest mischief is the long continued vibration due to the high speed of marine engines. *Galvanic agency* is another power we have to contend with; fortunately, however, its ravages are confined to the stern tube shaft, where the evil is sometimes caused by improperly jointed brass liners. So much indeed has this been the case that shafts have actually been thus cut to destruction all round as by a saw.

The difficulties that once existed through imperfect alignment, and its consequent evils, are now almost impossible, owing to improved systems of erection in the works, and fitting in the ship. A marked cause of trouble, however, arose out of insufficient bearing surfaces, as pressures of more than 200 lbs. per square inch squeezed out the lubricant and brought the dry metals into such abrasive contact as to induce severe cutting and heating. As an example of this, one of the P. and O. ships in 1864, had so much wear thus created in her crank shaft bearings that they had to be lined up every five days or so, whilst the later vessels of this fleet can run their 25,000 mile voyages for many years without giving any trouble. This, as in other similar ships, is partly due to the employment of longer bearings well lined with "Magnolia" metal, or Parson's white metal, thus reducing the pressure upon them to about 120 pounds per square inch, which Mr. Manuel, the superintending engineer to the Company, considers sufficient to avoid the cooling application of sea water with its attendant evils.

The efforts that have been made to diminish the chances of *fracture* are very instructive. As steel gradually superseded iron for such purposes, it sometimes proved untrustworthy, nevertheless the Steel Companies eventually succeeded in producing a mild and tough material that has been successfully employed in large fleets of steamers for many years.

Shafts above 12″ diameter are now of the built-up description, and in interchangeable and reversible sections, so that one length only is sufficient for spare gear. As the fitting process is liable to error, the greatest possible care is exercised so that not only may the shaft be perfectly true as a whole, but equally so in each independent part, when placed in any position. This, however, is an operation of considerable difficulty, but, at the same time, it most effectually avoids the risk of vitiated alignment, and the consequent heating and other evils that may eventually create fracture.

Those who remember how enormously large lathes used to be loaded between the centres and counterbalanced on the face plate, when turning the crank pins of a gigantic shaft, will fully appreciate the change that has taken place in this respect, each length alone for its own engine being now constructed from five separate pieces, all of which are made from steel ingots.

The usual system of manufacture is as follows:—When the two rough pieces of flanged shaft, and also the crank pin and crank slabs, arrive at the machine shop, the three former are turned to within ·25 inch of the finished sizes, so that if any imperfections appear the forgings may be rejected. At the same time, the slabs are planed to the required thickness, and the shaft and pinholes bored in them separately a little under the finished diameter. The slabs are then bolted together in pairs, slotted to the correct outline, and after the above holes have been smooth-finished to the exact gauge, the key seats are cut in them.

The crank ends of the shafts, and also the pins, may now be prepared in the lathe for the shrinking on process, and here lies the critical point, because if they are made too small, dangerous slackness will follow, and if too large, the excessive strain upon the metal around the eye may split it, the usual extra allowance, however, is from D ÷ 500 to 750. When the operation is finished, the other similarly treated lengths of shaft are temporarily fastened together in an exact position by their previously drilled coupling flanges, whose bolt-holes are rhymered to gun barrel truth. The bolts are now turned to a sledge hammer driving fit, and when the nuts are screwed hard up, a powerful lathe gives the final touches to the shaft while suspended between the centres, its total weight of 40, 50, or even upwards of 70 tons, being relieved by a bearing bracket placed between each pair of cranks.

One of the best modern arrangements of built-up shafts is that of Mr. John Dickenson, the construction of which is as follows:—For triple engines, it consists of four short interchangeable lengths, having the ordinary coupling flange at each end, each pair of cranks with their accompanying pin forming a single steel casting, into the shaft end of which the couplings are recessed. These are fitted with bolts as above, which bind the whole structure rigidly together, and yet allow of easy disconnection at every point.

The thrust and tunnel shafts are plain forgings throughout, the former taking upon numerous adjustable collar bearings the whole thrust of the propeller upon the ship, but in such a way as to entirely relieve the engines of end pressure. As all these shafts are liable to fracture at sea, it is usual to have one of Mr. Thomson's couplings at hand, as this simple contrivance will enable the repairs to be easily effected.

In addition to this and other heavy appliances and spare gear, the engine store room is furnished with a good assortment of hand tools for general purposes. Hence, it may be noted that the machinery of a vessel is fully protected at all vital points, and provided with everything that should enable it to be continuously kept in the most perfect order.

The love of the beautiful in some form or other prevades the minds of most people, and it is only natural to suppose that when they are gratified in this respect good results should follow. How, we may ask, do Mr. Macbrayne and Mr. Hutchison, of Glasgow, run their Royal Yacht like steamers *Columba* and *Lord of the Isles*, etc., to the delight of the inhabitants of the world? Why have the United States Fall River Company been recently placing new and magnificent 5,000 horse power floating palaces on the above river? For what reason does the immensely famous Baldwin Locomotive Company adorn their engines and tenders with high art pictorial decorations when we do not? Why do the ocean Mail Companies generally embellish their ships in exquisite style? And why do agricultural firms gaudily paint in blue, and scarlet, and green, and yellow, the machinery that is to be worked by country labourers?

Simply because, in all these cases, highly gifted commercial and engineering practitioners have a critical knowledge of the tastes of their various patrons, without which the above embellishments would be considered unnecessary, as they do not in any way affect the working capabilities of vessels or their engines.

To put the matter in a nut-shell. Induce passengers to admire your ships, and they will flock to them. Give your sea-going engineers well finished engines, and their exquisite maintenance will become a *pleasure* instead of a labour, on account of the pride they will take in their beautiful machinery, and so on in many other ways.

"The worm, you see, drives the wheel," replied Mr. Baxendelle to a lady who wished to know *everything*, and who wondered how the engines could be made to move without steam.

This observation surprised most of the visitors to the erecting shop whose ideas of crawling animals were not of an exalted nature. The mechanical "worm," or short piece of widely pitched screw, however, is extremely useful, as it provides great power in little space and in numerous ways, without the intervention of cumbrous and unnecessary spur gearing. A worm, for instance, as above, having its threads 3″ pitch, acts directly with a power of 60 to 1 over a wheel having 60 teeth, because sixty revolutions of the former are required to give one revolution of the latter, and so on for others.

Were we to say that *living* worms can eat steel rails, it would appear incredible. It is, however, a fact that so many accidents happened recently at Hagen, in Germany, from this cause alone, as to create consternation amongst the railway authorities, as well as a prolonged and critical series of investigations by Government officials, before their labours were rewarded.

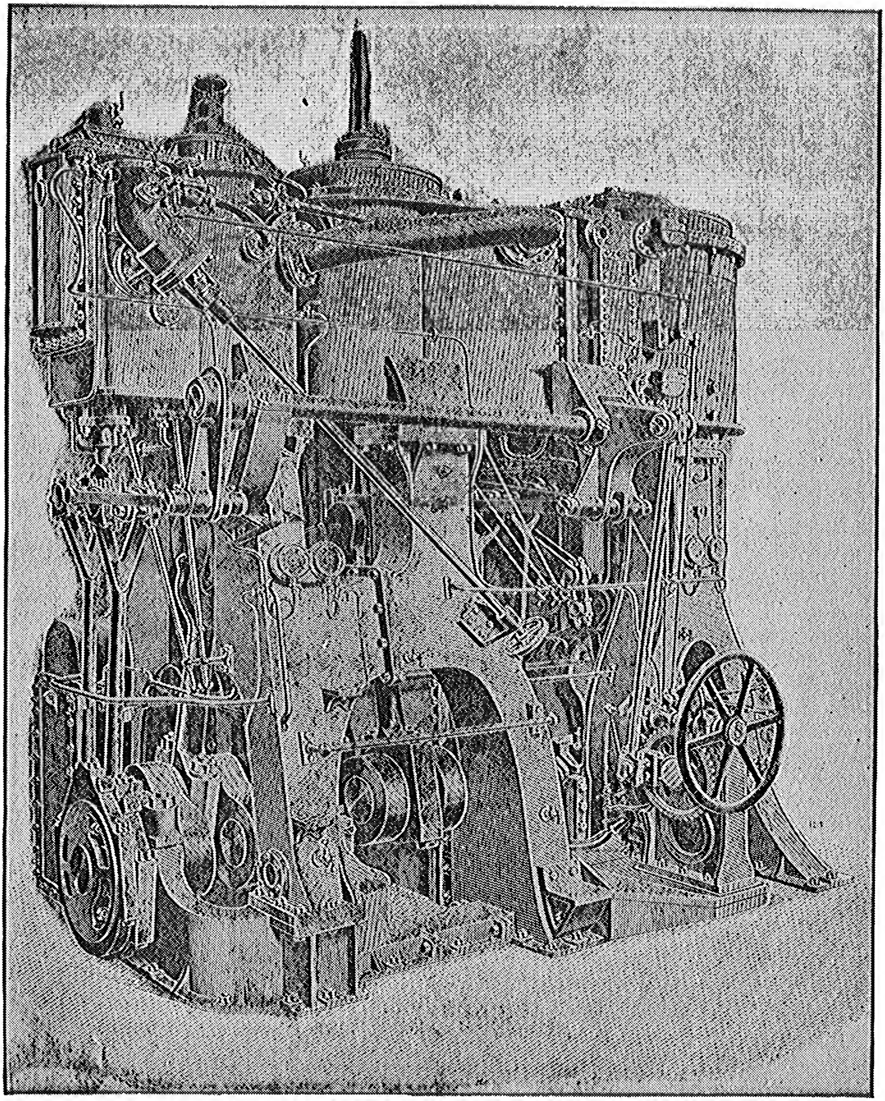
Whilst Mr. Baxendelle has been explaining everything, Mr. Burton has been slowly revolving the engines for his own satisfaction, because if any insufficient clearance, or improper valve setting existed, it would now be discovered. Hence, when the engines have passed this critical operation, all will be well, and after a few final touches have been added, they will be taken down previous to re-erection in the ship. This, however, includes a great many things which form connections either with the engine room or with the vessel herself throughout, but which cannot now be put in place.

As there are many Compound engines still in service that may yet be altered to triples, we here give a good example of what has been done in this respect by Messrs. T. Richardson & Sons, of Hartlepool, with sets of the former that were originally fitted in the S.S. *Pallion* and *Stranton*, built by the above firm in 1880, the diameters of whose cylinders were 33″ and 61″, and stroke of pistons 2′ 9″, the working pressure being 75 pounds per square inch. These engines have been converted to triple expansion by the same firm, as follows :—

The original boilers were replaced by two new ones, 12′ 9″ diameter and 9′ 9″ long, the steam pressure being 170 pounds, whilst each of them was fitted with Morison's suspension furnaces of large diameter, minimum thickness, and shortened grate bars, thus producing more perfect combustion and easy management of the fires. The old engines were utilised as far as possible, the original cylinders being retained for intermediate and low pressure purposes. The latter, however, was reduced from 61″ to 56″ by means of an independent liner. The condenser, bed-plate, and main pumps were also retained, but new feed pumps were added to suit the increased pressure.

A new high-pressure engine complete was fitted to the forward end of the crank shaft, which was provided with an additional crank, the three cranks being set at angles of 120°. The original high-pressure column was replaced by a new one, and a casting was bolted to the condenser to form the back support of the high-pressure cylinder. The reversing shaft was lengthened to operate the high-pressure valve gear, and a new reversing engine of the all-round type provided.

The chief feature, however, is the novel arrangement of the high-pressure cylinder, the improvement being



CASSIER.

CONVERTED ENGINES OF THE S.S. "PALLION" AND "STRANTON" BY MESSRS. T. RICHARDSON AND SONS, HARTLEPOOL.

based upon the fact that the greater the circulation over a heat-giving surface the greater is the amount of heat transmitted. To obtain this desirable end the outside of the jacket is surrounded by the first receiver, which is provided with a number of peculiarly formed circulating channels that cause the steam to flow uniformly over the whole surface of the jacket on its passage to the intermediate-pressure engine. Thus, not only does it abstract a large amount of heat by means of its rapid flow, but the whole body of the steam, being continually intermingled, is thoroughly dried before entering the intermediate-pressure cylinder. Other features include the application of Morison's evaporator arranged to work in combination with the steam jacket. The evaporator is connected to the high-pressure jacket at its lowest part, and the steam passes through the jacket to the heating coils of the evaporator. The jacket is thus automatically drained, the circulation of steam therein is increased, and the steam generated in the evaporator is still further utilised to heat the feed water on its passage from the hot-well to the feed pumps. The value of these arrangements, which are from the designs of Mr. D. B. Morison, may be gathered from the fact that during a sea voyage of one of the ships named the former consumption of about 13 tons of coal per day, at 8½ knots, was reduced to an average of 8½ tons at 8·6 knots per hour.

As another example of a different class of ship, we may take the case of Sir Donald Currie & Co.'s Royal Mail steamer *Grantully Castle*, which was also "Tripled" by Messrs. T. Richardson & Sons. We learn from the official records that this ship, during her fastest voyage from Dartmouth to Cape Town with compound engines, burned 939 tons of coal, her engines indicating 2,371 horse power with 70 pounds steam pressure. The average coal consumption per I.H.P. per hour was 1·9 pounds, and the knots run per ton of coal 6·4, the speed of the ship being 12·93 knots on a mean draught of 19′ 4″.

With the tripled engines, however, the performance over the same route became as follows: Total consumption 725 tons, I.H.P. 2,430 with 146 pounds steam pressure, consumption per I.H.P. per hour 1·46 pounds, knots run per ton of coal 8·2, the speed of the ship being 13·13 knots, on a mean draught of 18′ 9″. The saving in coal, when compared with the average consumption over twelve former voyages, was 23·87 per cent. on an average speed of 12·46 knots, and the calculated diminution in fuel with the altered machinery, if reduced to this speed, amounts to 34·9 per cent.

The latest improvement in Triple engines is due to Mr. R. R. Bevis, who has introduced an arrangement which enables naval and other vessels to be propelled, either at full speed, or economically at a reduced velocity. For this purpose two low-pressure cylinders are employed, and the crank-shaft is made in two parts, connective or disconnective at will, the rest of the gear being so arranged that one portion of the engines may be used alone, while the other portion is at rest, or the whole of the power brought into operation if required.

CHAPTER XXVII.

AUXILIARY MACHINERY OF A SHIP.

Auxiliary Machinery of a Ship – Ordinary Steam Winches—Noiseless Winches—Hydraulic Winches and Capstans—Electric Winches—Steering Gear and it Latest Improvements—Value of a good Scientific Discovery exemplified—Description of the Freezing Process—Principle of Mechanical Refrigeration—Life Germs of the Air—Application of the System to Ships—Arrangement of the Machinery—Cycle of Operations—Fittings of Ships for Frozen Meat Trade—Building Yard of the Sirius Works—Preparations for Launching.

WHILST the engines of the *Vencedora* have progressed as described, the boilers have rapidly advanced under Mr. Ashton's careful guidance, and as the *Building Yard* operations have run very closely upon Fairfield lines, further description is needless. From what has been said, however, in earlier chapters, the reader can easily comprehend the methods of construction of our three Rising Sun liners, the first of which is to be launched next Tuesday in the presence of numerous visitors. In the meantime, let us have a chat about the *Auxiliary Machinery* of the ships throughout, and, firstly, upon the *Winches* that are to be fixed on their decks.

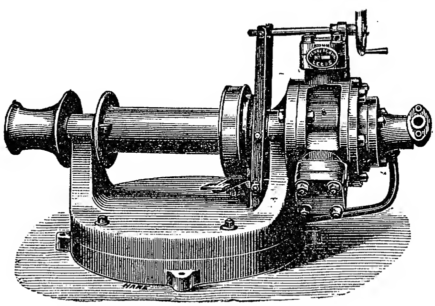
In early days the cargoes of ships were hoisted by means of hand-gear or tackle of the simplest form, but as this process was extremely slow, it occurred to Mr. James Taylor of the Britannia Works, Birkenhead, that steam power might be profitably employed for the same purpose. He therefore designed a winch that soon became extremely popular, until eventually the various plans of different people resolved themselves into the present type of horizontal machinery.

It is to be regretted, however, that so much that is excellent mechanically should be otherwise disagreeable. This will be obvious to those who visit a ship while one or more adjacent winches are rattlingly making more noise over a bale of cotton than a set of 20,000 horse-power engines at full speed. Of course, frictional gearing would get over this difficulty, but it unfortunately happens that grooved wheels are liable to slip if there is any water or oil upon them when lifting heavy weights or warping a vessel in or out of dock; hence in British vessels they are not much employed, although popular with the Americans and French.

To avoid the above most objectionable evil, Mr. Higginson introduced his extremely simple and smooth running winch, the arrangement of which involves the use of two oscillating cylinders coupled direct to the cranks, and capable of being economically controlled by means of a special valve gear. The design of the engines is based upon the fact that if a cylinder of, say, 40 inches area, requires a certain quantity of steam at 400 revolutions per minute, one of double the area and twice the length of stroke will use up the same quantity of steam at 100 revolutions. Hence, while on the one hand there is no loss of steam, there is, on the other hand, an entire absence of the friction and noise caused by spur wheels, which frequently receive very severe treatment.

In ships where water power is available, *Hydraulic Winches* may be employed, such, for example, as those by

Messrs. Henry Berry & Co., one of whose two-ton arrangements is shown below. It will be seen that the attached three cylinder engines drive the drum and capstan *direct*, in the simplest manner, and, it may be observed that engines of this type for working *vertical* capstans on Mr. Brotherhood's system, have been almost universally adopted by the principal Railway and Dock Companies, as they have very few working parts, and run smoothly, with the best results, for long periods, without needing examination or repair. They can also be started or stopped by means of a small treadle valve that admits the pressure to the cylinders or shuts it off at any moment.



TWO-TON HYDRAULIC WINCH.

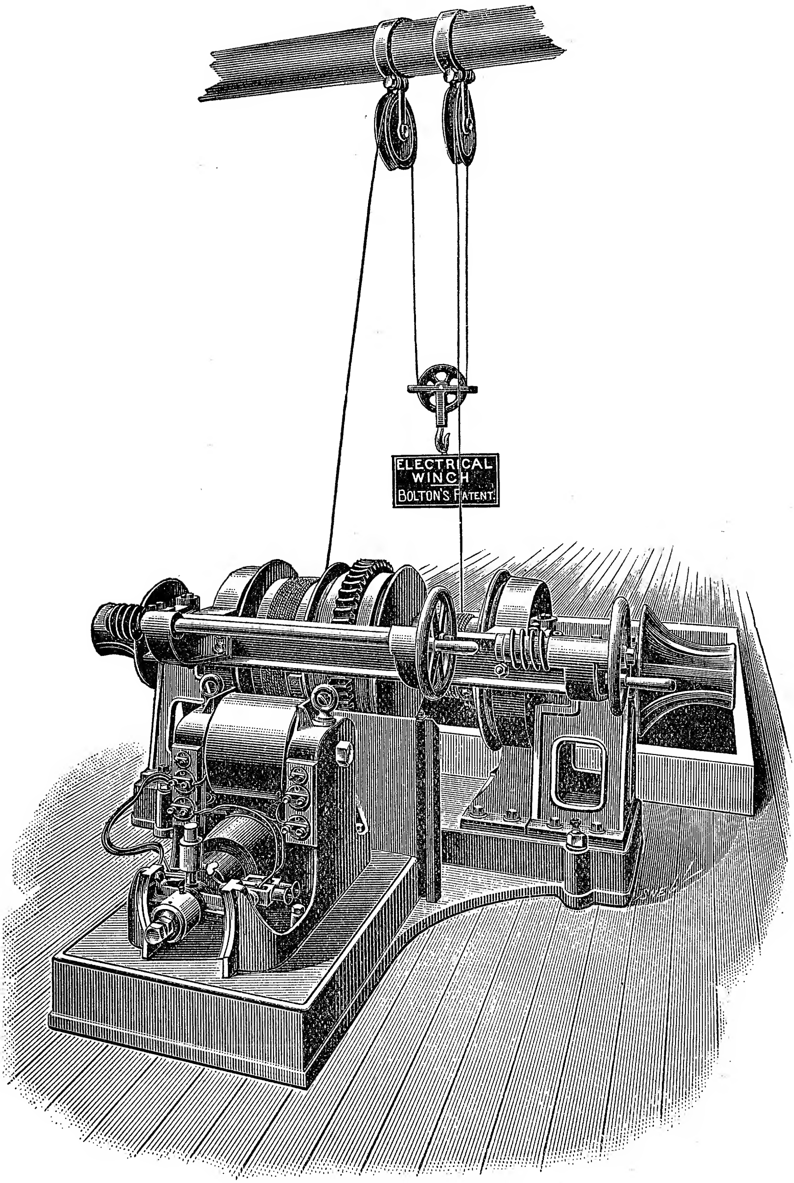
In cases where the power required is variable, a saving of water may be effected by the use of Messrs. Hastie's gear, which is an ingenious contrivance for varying the stroke of the engine in proportion to its requirements. In some large vessels, however, *Hydraulic Jib Cranes* are used, and these act silently and efficiently.

As the application of *Electricity* to the working of machinery becomes more clearly understood, new arrangements of the system are frequently being made, including those for lifting gear, an example of which, for ship and other purposes, by Messrs. R. Bolton & Co., is shown in the adjacent Plate.

This arrangement possesses all the qualifications of a steam winch, with great economy and ease in working under variable loads and speeds. The driving gear consists of a worm wheel and worm, the latter being carefully protected in a bath of oil placed underneath the wheel. The lifting is performed by means of two barrels of unequal diameter, to which are attached the ends of a rope leading to the derrick in the usual way. Hence it follows, that by revolving both barrels at once the rope is wound in at their *mean* circumferential speed, but by working only one of them at a time two slower velocities are obtained, thus producing, in the most direct and silent manner, the effects of single, double, and treble spur gear. Formerly, the anchor was weighed by means of the very slow and tedious rocking lever process, as it still is in sailing ships; now, however, steam power runs it in rapidly and most effectually.

The Plate of an *Improved Horizontal Steam Windlass* by Messrs. Clarke, Chapman & Co., on page 445, gives a good idea of the machinery, and although the capstan is placed on the upper deck, it can, if required, easily be made workable on the same level as the engines, whilst these again, as well as their connections, can be variously arranged. This windlass possesses several advantages, including :—

1. The application of a spring to each cable lifter, which entirely relieves the chain and also the windlass from the shocks and strains caused by heavy riding, or by any other cause.
2. The peculiar form of the cone wheels and winding drum, which are lined with hard wood, thus



ELECTRIC WINCH FOR SHIPS.

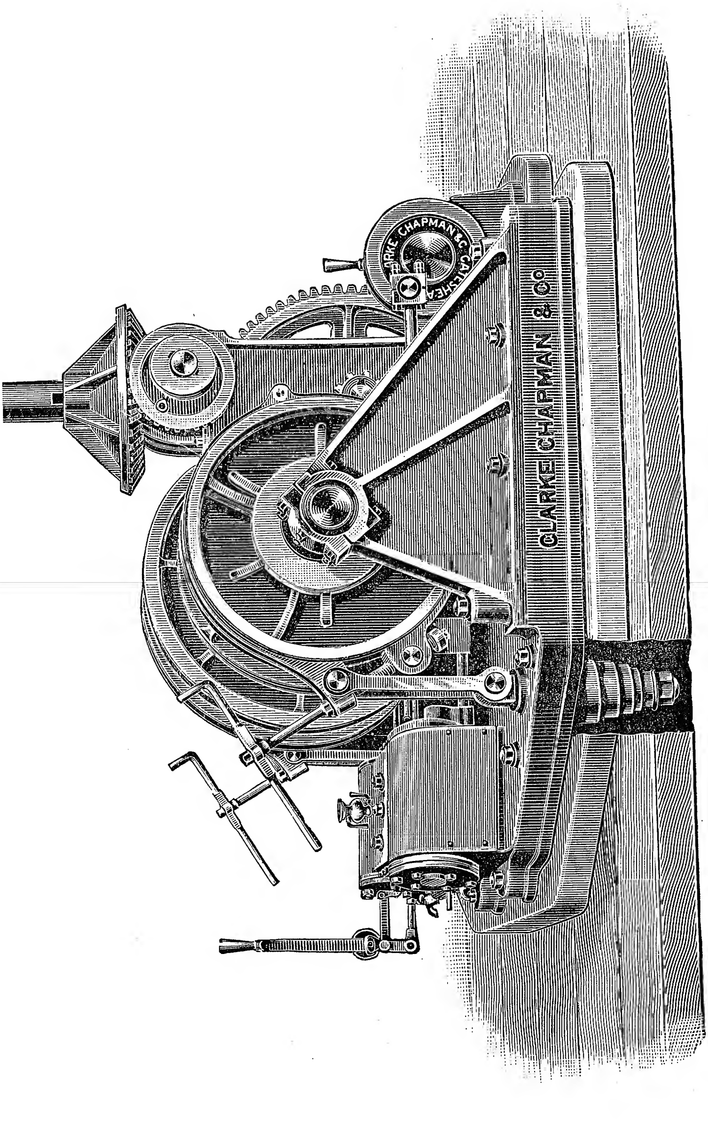
giving great holding power to the lifters while taking in the anchor.

3. As the latter are fitted with a special screw brake, one man has complete control of the paying out of the cable under the heaviest strain. Care has also been taken throughout to avoid complication, and to keep every part as strong and as simple as possible, and easily accessible for repairs.

No *Steering Gear* ever invented has been so extensively used as the Tiller, on account of its compactness, simplicity, and efficiency, so far at least as small vessels are concerned. The *rudder* may have been thought of by someone amongst the Phœnicians, who were the very earliest navigators, but in the Roman Galleys the oar alone was employed for steering purposes.

Those who have been on the Clyde in the season must have observed choice boats being paddled about to every point of the compass by crews of fair occupants and their friends. Sometimes, however, a skiff was selected which was only large enough for two, but, strange as it may appear, the same thing was done thousands of years ago amongst the Phœnicians, especially on one occasion when a gentleman of the period went out for a row in a rude bark of the Mediterranean. It is recorded in history that, after he had toilingly paddled his own canoe for a time, the lady who accompanied him stood up and held out the skirt of her dress to catch the breeze, which, to their surprise, slowly helped them onwards. Thus was originated in a very simple manner the idea of masts, yards, and sails, which have greatly benefited the navigators of all ages, and made a ship

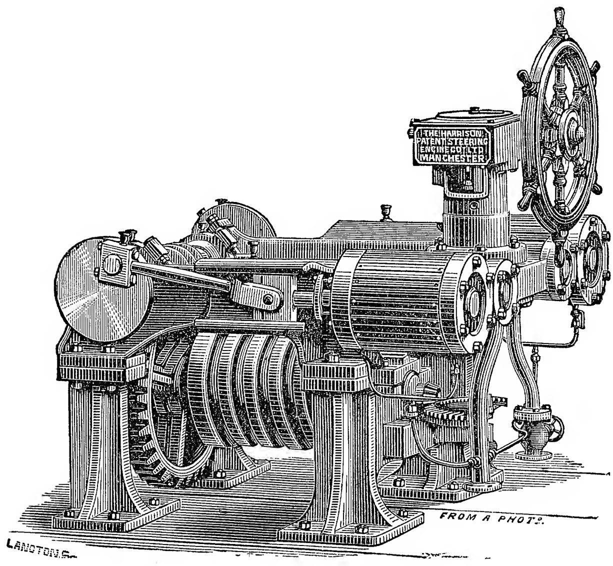
TO CAPSTAN, UPPER DECK.



HORIZONTAL STEAM WINDLASS.

under canvas one of the most beautiful objects of the ocean.

The invention of the *tiller* and its accompanying *rudder* were no doubt coincident, and their extreme importance has been universally recognised in small vessels to the present day. In larger ships the "wheel" became a necessity on account of its greater power in working, by



STEAM STEERING ENGINE.

means of screw or other gear, but as steamers increased in size even this proved insufficient, hence the *Steam Steering Engine* was introduced for the purpose of entirely relieving the steersmen of the enormous strain that would otherwise have been thrown upon them.

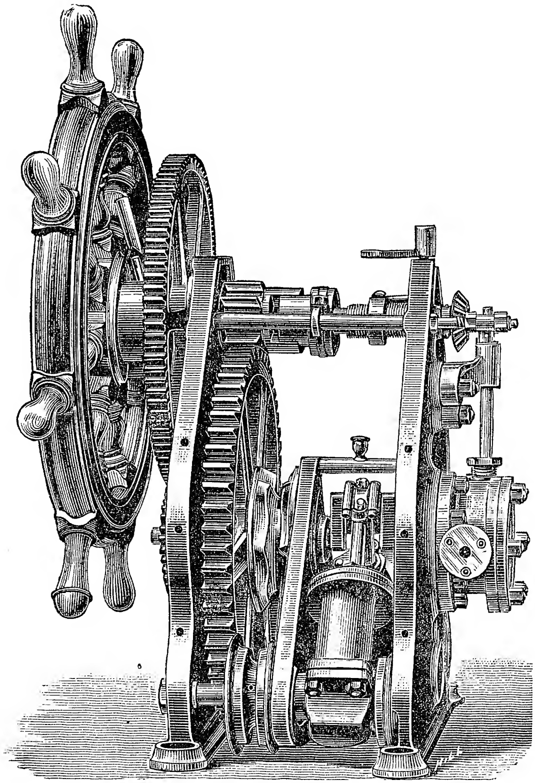
This will be apparent when it is considered that if an ocean racer, 460 feet long, had an ordinary tiller, it would require about twenty men to control it. With steam or hydraulic machinery, however, the largest ships can now be steered by only one man, who simply turns the wheel to starboard or port, whilst the engines automatically follow up the movement with all their energy. In the old Norse days, steering was performed with a large oar from a raised board or platform on the right hand side of a ship, hence the well-known term "star-board," from *steoran* to steer, and *bord* a plank. "Larboard" is of similar origin, *lar* meaning "lower," and on the left hand side, as it is still; owing, however, to the confusing similarity of the phrases, the Admiralty changed it to "port" in 1845.

The *Steering Engine* opened out a grand field for enterprising inventors, many of whom have patented devices which greatly increase the value of the machinery. Amongst the number is the Harrison Steering Engine Company, one of whose productions is adjacently shown. This gear has the great advantage of being noiseless, and is one of a series variously modified to suit different sizes of ships. In all forms, however, they have been extensively and most successfully employed in many lines of ocean mail, and other steamers.

The framing carries the chain winding drum, and also the worm wheel, which is driven by a worm on the crank shaft, while a valve box of peculiar construction is placed on the top of the steam chest, along with the steering wheel, whose slightest movement sensitively affects the engines and causes them at once to turn the rudder to suit the bridge officials. In some cases, when amidships, the wheel is placed on the deck above the engines, and connected with the actuating valve by means of a vertical shaft suitably geared. Either system, however, may be utilised, but both are sometimes employed.

A totally different arrangement, by Messrs. Higginson

& Co., is given in the annexed illustration of their *Steam Quarter-Master*, the engines of which are on the noiseless principle that forms a distinguishing feature of the productions of this firm. The actuating valves are at



STEAM QUARTERMASTER.

the back, and on the top of the adjacent frame there is a pointer to indicate the position of the tiller.

The most recent of all these appliances is the *Fawcett Hydraulic Steering Gear*, which can be placed amidships, with chain connections aft, or attached direct to the tiller if required. This gear is very simple and noiseless, as it has no rotary motion, and owing to the absence of all spur wheels, etc., it is less subject to wear and tear and to the possibility of a breakdown. The hydraulic cylinders that supply the power act also as springs, and automatically allow the rudder to relieve and readjust itself after being struck by a heavy sea.

One of the most serious accidents that can happen to a ship at a critical time is the sudden fracture of the steering chains, or the derangement of anything that causes the tiller to become unmanageable, while, at the same time, any attempt to connect the hand gear may result in another breakdown. The importance of rectifying these evils may be gathered from the fact that vessels have been severely damaged, or even lost, because the steering gear in this manner suddenly became useless. Hence the very popular *Safety Rudder Brake* of Messrs. John Hastie & Co. has supplied a long felt want, as it enables the tiller to be immediately secured until the repairs are effected. This apparatus consists of a brake quadrant firmly secured to the under side of the tiller quadrant, and so arranged that by the pressure of a grooved brake block, actuated by a powerful lever worked by hand gear, the desired end is accomplished.

At one time, so many ships were disabled by the breakage either of the rudder stock, the quadrant, or the steering gear, or their connecting chains or rods, that the Board of Trade directed close attention to the matter. As it was discovered that the extreme rigidity of some of the parts had been a fruitful source of accident, various kinds of springs were fixed to the steering chains to relieve the sudden shocks so frequently experienced in rough weather. These, however, possessed several disadvantages, which were eventually removed by the application of Messrs. Wilson & Pirrie's *Spring Steering Quadrant*, which has proved most acceptable in many ships. In this case the quadrant is placed above the tiller in such a way as to enable both to be directly connected by powerful spiral springs which receive the full force of the shocks upon the rudder, and thus prevent the possibility of fracture.

Messrs. McColl & Cumming's *Liquid Rudder Brake* is another excellent modern improvement, which comprises two cylinders filled with a non-freezing mixture of equal parts of glycerine and fresh water, the piston rods of which are directly attached to opposite ends of the tiller quadrant. The pistons are kept in motion by the movements of the rudder; should, however, a sudden strain come upon the latter, the fluid acts as a spring by more or less gradually passing from one end of the cylinders to the other. Or, if it is necessary to lock the rudder at any time, the closing of regulating valves will at once do so. By the application of one or other of the above inventions, it has now become practically impossible for a ship to be endangered by steering gear failures such as those which were at one time so frequent.

All the great innovations that have been recently introduced may be said to owe their origin to certain necessities, the meeting of which has often brought about such changes. It has been so in manufactures generally, as well as in steamships and their machinery, and especially so in reference to the now most important branch of engineering known as *Mechanical Refrigeration*. At one time it was the custom in Australia and New

Zealand to boil down the carcases of cattle and sheep for the sake of their hides, horns, and tallow, which found a profitable market in England, the meat being thrown away as refuse, because the system of preserving it for export was practically unknown.

Up to the year 1881, the inhabitants of these countries had a mine of wealth at their feet, and our own Beautiful Islanders a grand source of household economy within reach which none of them ever thought of until they were shown how one of the forces of nature could be advantageously utilised on their behalf, thus benefiting directly millions of beef and mutton producers and consumers, and opening out new avenues to prosperity in many other ways. During the above year, it became clearly evident that meat could be sent in a perfectly marketable state across the seas, and the New Zealanders, appreciating the invention, soon established works near the seaports from which the frozen carcases were transported to the refrigerating chambers of steamers, which form in themselves a very good and curious example of the application of the scientific fact to a practical purpose. The principle upon which these chambers are constructed is as follows:—

In all air there exists a quantity of sensible or insensible heat, which maintains it at a certain bulk, and can easily be taken from it. Hence it happens that when, for refrigerating purposes, the atmosphere is compressed into a cooler or receiver to about one-fiftieth of its original volume, a large quantity of heat is produced, which is subsequently abstracted by the circulation of sea water throughout the chamber. The air is now liberated from the cooler, but while attaining its former bulk in an expansion cylinder it produces the most intense cold. Thus it will be seen that when meat or any other perishable substances are enclosed in a refrigerating compartment they become frozen, and are maintained in this condition for any desired period whilst being kept in an atmosphere having a temperature of about 20° Fahrenheit.

The importance of utilising this system may be still further exemplified:—The air we breathe is charged more or less with life germs which have no affinity for metals, stone, or *ice*, etc. For meat, and other perishable commodities, however, they have a strong attraction, hence in a short time these germs settle down upon them and take root, thus creating putrefaction, which the application of the freezing process would have prevented.

Various methods are used to accomplish the desired end, particulars of which have been kindly given by the Linde British Refrigerating Company of London, Messrs. J. and E. Hall of Dartford, and the Haslam Engineering Company of Derby, all of whom are well known in this special department of science. The means employed by the first named may be described as the Dry Air Ammonia system, which, in the S.S. *Teutonic* and *Majestic*, is used for freezing the contents of their capacious meat-holds, and also the provision rooms.

Each of the former is provided with separate fittings, so as to allow its own refrigerator to work either hold, or one refrigerator both holds when required. On account of the limited available space, however, the machinery was placed between the screw tunnels, and thus it became necessary to employ two engines instead of those of the duplex type now so generally preferred.

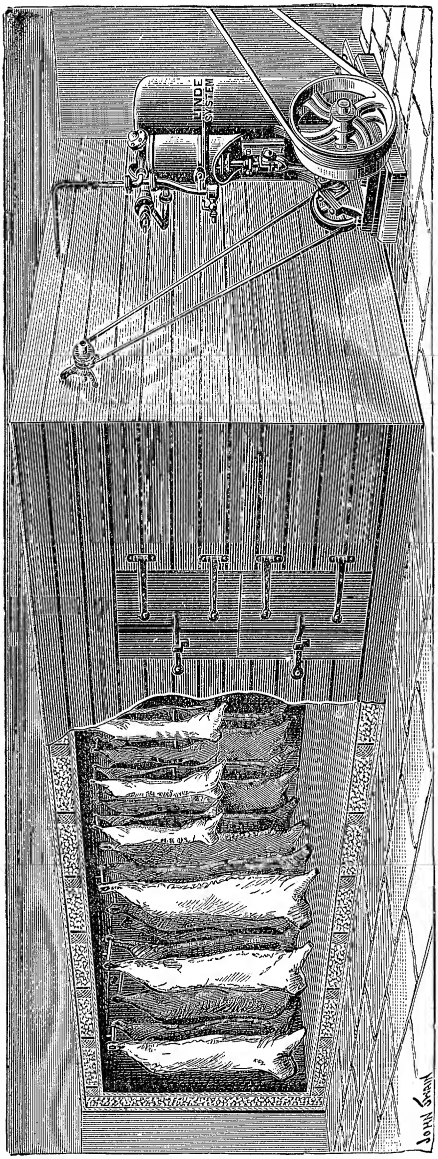
The system of cold-production on the above principle is based upon the evaporation of anhydrous ammonia, which boils under atmospheric pressure at about 30° below zero, Fahr. This low evaporating pressure is maintained by means of a small pump, which draws off the vapour as quickly as it is produced, and then compresses and discharges it into a vessel termed the condenser, in which the ammonia vapour is rendered fit for use again in the refrigerators.

These consist of a series of wrought iron tubes coiled in such a manner as to get the largest amount of surface into the smallest area. The coil spaces are below the meat-holds, the latter, as well as the provision rooms, being cooled by means of currents of cold air passed by Blackman propellers over the coils in which the ammonia is being evaporated, and then circulated through the holds by the usual wooden passages.

Many vessels are either partially or wholly fitted for the meat trade, but in all cases their holds are insulated. That is, a specially constructed timber lining, consisting of two layers of planks, with a non-conducting charcoal space of about 5″ between them, extends along the bottom, sides, and underneath the deck beams, thus making a perfectly air-tight compartment, which is only accessible to the freezing atmosphere, an example of which, on a small scale, is adjacently shown.

Another system is that of Messrs. J. & E. Hall, whose *Carbonic Anhydride Refrigerating* machinery is particularly adapted for the manufacture of ice for meat freezing establishments, for the importation and storage of chilled meat, and for preserving passengers' provisions on board ship, etc. These machines consist of three leading parts as follows:—

1. The *Compressor*, by means of which the gas drawn from the refrigerator is compressed;



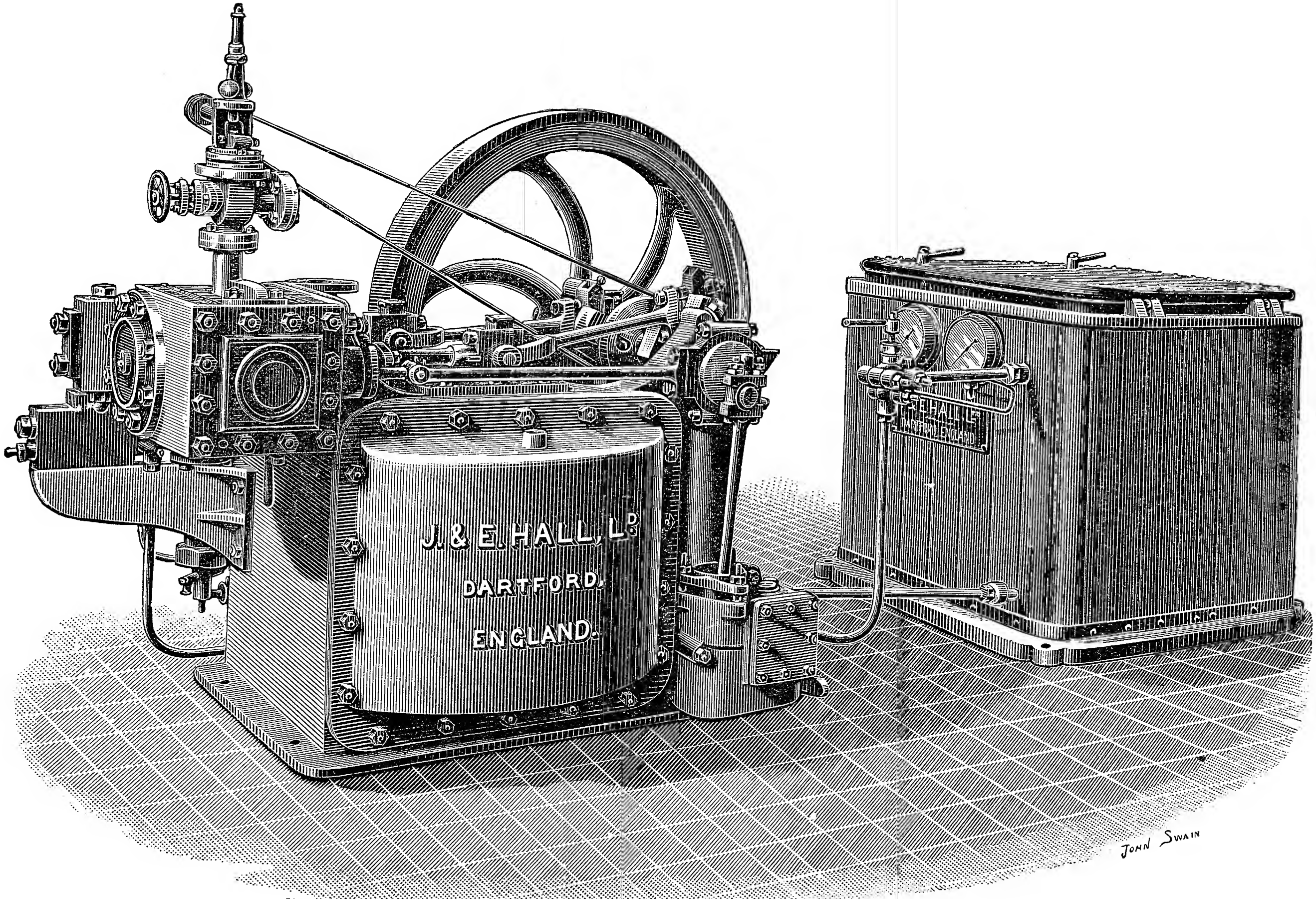
SECTION OF SMALL REFRIGERATING PLANT, SUITABLE FOR LAND OR FOR SHIP PURPOSES ON THE LINDE SYSTEM.

2. The *Condenser*, in which the compressed and warm gas is cooled and liquified by the action of water; and—
3. The *Refrigerator*, in which the liquid carbonic anhydride is caused to evaporate, thus producing any degree of temperature that may be required, down to 50° below zero.

The charge of the anhydride originally put into the machine is repeatedly and progressively passed through the above processes, hence a small quantity only is occasionally required to replace any small losses. For the manufacture of ice, an adjacent tank containing brine is cooled by the evaporation of liquid anhydride within the coils of the refrigerator, and finally galvanised steel moulds containing water are immersed in the brine, thus producing transparent blocks of any required size.

For large cargoes, the carcases of meat are frozen on shore, and after being brought on board perfectly hard and rigid are stacked in bulk in the holds. The cold air is then passed through openings along a central trunk, and after percolating amongst the rows of carcases it is drawn back to the machine through trunks at the sides of the vessel. For ships' provision chambers the freshly killed meat, etc., is frozen by the machine, the cold air being also employed for making ice; for cooling the drinking water, wines, etc.; for preserving fruit, vegetables, and butter; and for cooling the atmosphere of the saloons and cabins in hot climates.

The Plate on the next page represents one of Messrs. Hall's most compact Refrigerating engines and freezing chambers for the last-named purposes, and fairly illustrates what is employed in a modified and greatly enlarged



REFRIGERATING MACHINERY FOR PASSENGER STEAMERS.

form in cargo ships, where immense holds take the place of the tank shown in the engraving.

In the year 1868, Mr.—now Sir—A. Seale Haslam commenced business for himself in the Union Foundry, of Derby. Soon afterwards he devoted himself to the practical application of a theory which had been talked about for 150 years, and with this in view, endeavoured to design an apparatus capable of producing the cold chambers necessary for the transhipment of fresh food from distant ports.

The fact upon which he based his numerous experiments was this:—Air which has been compressed, dried, and cooled, will, if suddenly allowed to expand, fall in temperature to a degree below the freezing point corresponding to the density of the compression. After many difficulties had been overcome, Mr. Haslam introduced, in 1881, his *Dry Air Refrigerating Machinery* to the S.S. *Orient*, which subsequently arrived in London with a cargo of meat, from Sydney, in perfect condition.

No sooner did this fact become known than numerous other leading steamship Companies adopted similar machinery, and while in the above year only about 20,000 frozen carcases were brought to England, the number was increased to upwards of 2,000,000 in 1891, through the increased application of the Haslam machines. Commerce is never more beneficently employed than when engaged in transferring the redundant food-products of one country to the shores of another where they are greatly needed. And mechanical science never appears in a better light than when it enables this to be accomplished with efficiency and economy, as it has now done in a very remarkable manner.

In some countries, vast herds of cattle and sheep are comparatively worthless as food for the inhabitants, owing to their scanty numbers. In the British Isles, on the other hand, the population is enormous, and the native food supply extremely limited. Hence the question naturally arose—How can these waste products be made to benefit exporters and importers, as well as vast communities, to whom they would be highly beneficial?

For a long time no solution of this problem could be found, until the successful adoption of *Mechanical Refrigeration* removed every difficulty, and opened out a highway of commerce hitherto unknown, for the importation of everything of a perishable nature that could be preserved in the frozen state during a long voyage.

Let us now return to the Sirius Works, where the Rising Sun liners are far advanced. The *Vencedora* is receiving her finishing touches previous to the launch, which is to take place to-morrow. The ship herself is a thing of beauty from stem to stern, and especially is this the case at the bow, which is adorned with a handsome figure-head in white and gold of the lady whose name she is to bear.

The engines have been taken down and temporarily black varnished at the polished parts to keep them from rusting, whilst the bedplate, condenser, columns, cylinders, and other heavy gear immediately required, including the boilers, are now lying at the sheer legs ready for lifting on board. The sea cocks, valves, etc., on the ship's side and bottom have been fixed in position, and all that has now to be done is to await the eventful day for which the ship-yard authorities are now making final preparations.

CHAPTER XXVIII.

LAUNCH OF THE S.S. *VENCEDORA.*—LATEST APPLICATIONS OF ELECTRICITY.

Final Preparations—Launch of the Steamer—General Ftting up of Ship and Machinery—Starting the Engines—Various Telegraphic Instruments—Official Trial Trip—The Indicator and its uses—Its Application — Indicator Card described — How to find the Horse Power—Official Record in full—Electricity as a Motive Power—Its Paradoxes—Electric Launches—Popular Explanation of leading terms and parts — Dynamos and their Engines— Electric Lighting—New Canadian Pacific Steamships—Last of the *Vencedora.*

THE great day has at last arrived when the *Vencedora* is to be launched upon the deep, hence the noble array of all kinds of flags with which the works and the ship are now adorned. By 11.30 the visitors have arrived, including the Mayor of Newcastle and his lady; Mr. Robinson, the Chairman of the Directors of the Rising Sun Company, his wife, and his daughter who is to be the Queen of the Launch. Some of the Directors are also present, unconsciously spreading themselves out, and looking as numerous as possible, whilst a choice assemblage of ladies and gentlemen have been brought from the Tyne and other districts in honour of the occasion; all of whom are gathering on and around the crimson cloth-covered *dais* at the bow of the ship.

Mr., Mrs., and Miss Baxendelle, and Mr., Mrs., and the Misses Farquharson are fully occupied in charmingly entertaining their visitors by chatting here and talking there, bowing and smiling to the right, smiling and bowing to the left, and making themselves generally useful and agreeable. Mr. B. is also delighted to meet many of his old friends of Great West Sou'-Western days, who are congratulating him most heartily.

Mr. F., for the same reason, is as felicitously serene as the responsibilities of launching his *first* ship will allow him to be. Captain Henderson, his lieutenant, and Mr. Williams, the shipyard foreman, however, are relieving him of much anxiety, as they are well-tried hands.

Mr. Robinson, of 333 Leadenhall Street, is a splendid specimen of a highly accomplished shipowner, but taking the company all round, it may be said that the flashes of wit and humour, and generally delightful conversation now in progress, are the distinguishing features, not only of this, but of all similar gatherings, where worth, talent, refinement, and high social qualities are combined.

The Queen of the Launch is gracefully moving about amongst her numerous admirers, and treating the whole business as lightly as if the performance was quite an everyday employment with her. Miss Robinson has very expressive features, an elegantly simple style, and pleasing manners, all of which in combination make her most attractive. Her dress is—but *here* we must stop. The whole of the staff from the various offices are sunning themselves in the open air—the foremen and apprentices are doing pretty much the same thing—and workmen in large numbers are occupying every point of advantage, while two steam-tugs, gaily dressed, are lying in the river, waiting to take the ship to the sheerlegs when afloat.

The beautiful lines of the *Vencedora* have now become clearly visible, as all the constructive supports have been removed. The elliptical stern is most tastefully finished off, and, like the bow, is adorned with the name of the vessel in polished brass block letters. The Works have been stopped in honour of the occasion, so that every one may witness the proceedings, and the united efforts of many hands, have by the wedging process, relieved the keel blocks of their enormous load and transferred it to the timber-built cradle which rests upon the launching ways. These ways have been well lubricated with grease and soap, and are set at an inclination towards the water that will enable the vessel to overcome by the force of gravity the very small amount of frictional resistance to which she will be exposed. So slight is this resistance that the ship might go off now and do much mischief, unless restrained by the dog-shores.

Captain Henderson, however, is vigilantly watching his chance on deck as the tide is now about full, and no sooner does it reach its highest point, and the Tynemouth steamer has passed on her outward voyage, than he gives the order to "LET GO."

In obedience to this command the dog-shores are released, and just as Miss Robinson dashes a ribbon-suspended bottle of wine against the bows of the now officially named *Vencedora*, she begins to move with very slow but *accelerando* motion, amidst the cheers and waving of hats and handkerchiefs of the assembled multitude, until her rudder touches the water. Then the stern sinks deeply into it followed by the body of the ship, and lastly, the fore end glides into the river whilst crashing through the dislocated timbers of the cradle. On account of the limited launching space, checking cables have to be employed for the purpose of restraining the speed of the ship as quickly as possible on entering the water, and thus keep her from running into the opposite bank. The latest and greatest example of this was the launch of the Cunard S.S. *Lucania*, whose weight of 9,000 tons was thus arrested within a distance of only 900 feet.

During the luncheon usual on such occasions, a few complimentary speeches are rolled off in the most felicitous style, in one of which Mr. Robinson refers to his "talented friends, the builders, in whom he places the greatest confidence, and whose efforts seem destined to be as successful in the future as they have been in the past." To this, Mr. Baxendelle and Mr. Farquharson reply in their own modest and most appreciative manner, and in a short time the visitors disperse quite delighted with the morning's performance.

When the ship has been brought to the sheer legs the bedplate of the engines is at once lowered from them into position on the previously prepared keelsons, to which it is very rigidly bolted. The necessity of exercising the utmost care in this respect will be apparent from the fact that a ship may sometimes roll so quickly and so violently as to take the mountain waves down her funnel, and thus become gradually wrecked above and below. Hence, if the engines and boilers are not able to stand this most severe treatment they may break loose at any time.

The condenser and main pumps and other gear are securely fixed, as also are the outer columns, while at the same time the crank shaft is let down carefully to its bearings, and similarly the cylinders and their connections upon their seats. After the main details have been bolted together, the engines begin to make a good show, and this rapidly increases as the handsome working gear is linked together. The ladders, platforms, and hand railings are now set up, so that easy get-at-ability to every part is insured throughout. To enable this to be satisfactorily accomplished, however, everything that relates to these accessories has to be carefully considered. For instance, good angles with the perpendicular for engines and boiler room ladders are from 18° to 20° for the latter, and 20° to 25° for the former, depending, of course, upon the available space. The inside width of a stokehole ladder should be 18″, but for engine rooms this may be increased more or less when possible, to suit as far as convenient their various surroundings.

Boiler room ladders may have their sides of $3'' \times \frac{3}{8}''$ iron, their steps of twin $\frac{5}{8}''$ rods being 9″ to 10″ pitch, and their handrails, as in the engine room, 1″ diameter, which is a standard size. In the latter, however, the steps are of elegantly designed cast iron, and all the platforms of round rods to allow free access of light, and good ventilation, while the handrail stanchions may be about 5′ 0″ apart, and the rails 3′ 0″ from centre to floor level. As the two latter are burnished in high class mail steamers, they effectively help to ornament an engine room, whilst at the same time proving indispensable for safety purposes, the well-finished cylinder top gear, polished copper pipes, overhead travelling crane, strong, lofty, and capacious skylight, and tasteful painting, producing a very attractive appearance.

The *Vencedora* will be finished as described. At present, however, the cylinder covers and adjacent spaces are occupied with hammers, chisels, files, bits of waste, pieces of wood, rope and chain tackle, strings of nuts, and so on lying all about, whilst the hands on the mezzanine floor and various platforms are adjusting everything and making the steam and water joints.

During this period, the tunnel shafts have been lowered into position, and all their gear attached. The boilers have been similarly but much more extensively treated owing to their numerous mountings, fittings, pipe connections with each other, and also with the ship and the main and auxiliary engines. The ladders, gratings, ventilators, etc., are now in position, and the whole of the machinery is in such a forward state that a preliminary trial of the engines may soon be expected. This consists in getting up steam in the boilers for the first time, setting the engines in motion and occasionally stopping them to rectify any leaky joint, ease a bearing, or adjust a stuffing box. Gradually, however, the initial stiffness in working is diminished as the reciprocating parts gradually drawfile themselves to a glassy surface, until at last the trial ends satisfactorily.

When the engineers, boilermakers, coppersmiths, carpenters, joiners, and ship hands generally have put things in order, painters, artists, decorators, upholsterers, and so on, have a busy time of it throughout the vessel. The riggers too—alas! *their* occupation is nearly gone, as in large steamers everything but naked pole masts is *rigger*-ously excluded; the poor sailmakers also have been similarly as*sail*ed at all points by modern innovations. Both of these useful classes, however, still find employment in those enormous and truly magnificent white winged descendants of an ancient race that ploughed the waters of the Mediterranean and the great oceans ages before steam navigation was ever thought of.

The flagmakers un*flagg*ingly direct their attention to the manufacture of the ensign that has braved the storms of adversity and the breezes of prosperity for a thousand years, and also the usual well-known colours for signalling and other purposes. When the united efforts of all these and others have thus been consolidated, the ship will be ready for the official trial trip, which will enable the owners and builders alike to satisfy themselves that the contract has been strictly fulfilled. Before this can be done, however, and while the rest of the work is being finished off, various appliances not yet referred to have to be installed.

The safe and rapid guidance of a ship is so entirely dependent upon the navigating officers, that apparatus for reducing to the utmost the risk of accident are now employed. The instruments in use include the following:—

A *Look-out Telegraph* whereby a forward "look out" can signal to the bridge the position of a "light" or "vessel" "ahead," or on the "port" or "starboard bow."

A *Docking Telegraph*, forming a communication between the bridge and stern for signalling special orders while warping ships in and out of dock, and an *Engine Direction Telltale*, the dial of which also indicates the speed of the engines ahead or astern; all commands transmitted through these instruments being upon the "reply" principle, so that the deck officers can know at once if their orders have been acted upon.

The wheel-house orders are:—"Course"—"steady"—"starboard," and "hard-a-starboard," &c.; whilst those to the engine room are:—"Stop"—"stand by"—"slow speed"—"half speed"—"full speed"—"ahead," or "astern," the ordinary gong being now superseded by a "Duplex," giving a deep sound for "starboard" or "ahead," and a shrill noise for "port" or "astern." The value of these and other modern innovations will be better understood if we imagine a collision between two great mail liners running east and west, each at 21 knots, or 24 miles an hour, simply because an order was misinterpreted, not to mention the minor dangers to which they are frequently exposed.

The navigating officers of ships for ages past have been enabled to find their position at sea by means of sextant observations. Mechanical science, however, has recently done much to aid them, especially at night or during a fog. The latest improvement of this nature is *Granville's Electric Log*, constructed by Messrs. Elliott, on an entirely new principle, which overcomes the great difficulties that have hitherto been experienced. It may be towed either astern or alongside, and provides an efficient means of accurately showing on the bridge, in the chart house, or in other positions where an indicator is fixed, the total distance run, and also, at any time, the rate per hour.

After an exhaustive series of trials at all speeds, this log may be considered thoroughly reliable. It also has advantages which place it far ahead of the old system, and these include :—(1) The speed of the ship is continuously under observation. (2) Owing to its great accuracy tables of corrections are not required. (3) Insulation from sea unnecessary. (4) Great simplicity and easy accessibility of working parts.

Another method of finding a ship's position is to make the main engines tell the distance by means of the *Engine Room Counter*, which is so fitted with gearing and dial-plates as to indicate the number of revolutions of the propeller from one to one million, at any rate of speed. Hence, when the number of revolutions of the screw per knot in smooth water is experimentally known, the distance run can easily be ascertained after making the necessary allowances for wind, currents, etc. For example: a knot is 6,080 feet, and if the screw has no slip, and the water is undisturbed, a propeller of 10 feet pitch would make 608 revolutions per mile, one of 20 feet 304, and so on for various other pitches.

To return to the *Vencedora*, whose engine starting performances have been satisfactorily accomplished as previously described. The vessel, now finished off, is taken to sea on her official trial trip, to which Mr. Robinson and some of his colleagues have been invited. The heads of the building firm with the required engineering staff are also there, and whilst the ship is running under easy steam, Mr. Ogden is diligently and most officiously examining everything from end to end of the engine and boiler room spaces. Mr. Baxendelle is *everywhere*, and this, to the initiated, means a great deal. A good long run under such careful supervision has clearly indicated the capabilities of the steamer. At this point, however, the officials and visitors retire for lunch, and after a few complimentary speeches have been delivered, preparations are made for "running the mile."

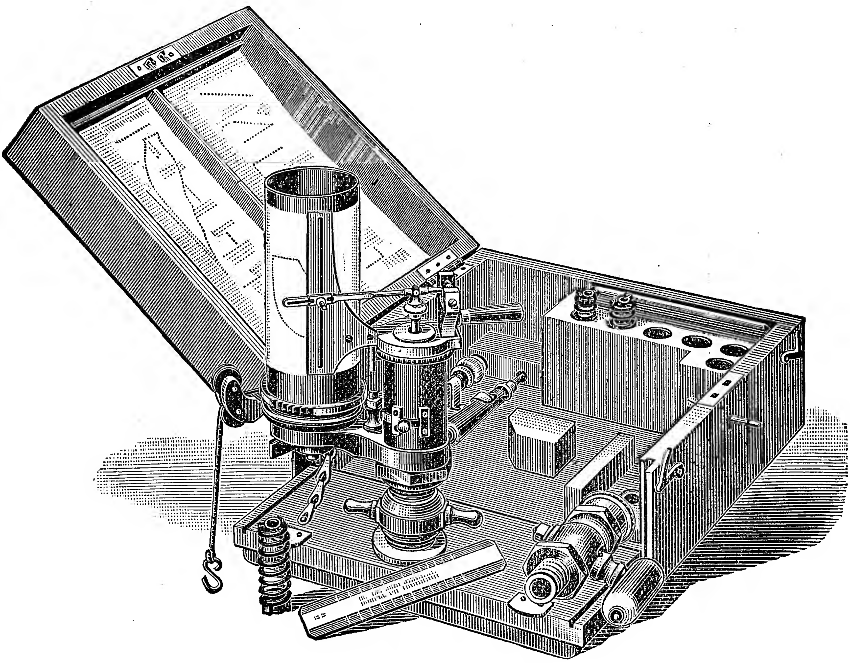
The ship is now driven at her utmost velocity several times each way between the landmarks, on account of the influences of wind and tide, during which the indicated power of the engines and the speed of the ship are carefully noted. Eventually, the trial ends with the satisfactory announcement that the mean power of the engines is exactly 537 horses above the contract, and the average speed of the vessel half a knot more than had been guaranteed.

As whole volumes have been written upon the *Indi-*

cator and its uses, which when exhaustively treated require careful study, we shall here give a few brief remarks upon the subject. This invaluable instrument has been employed in different forms ever since the time of Mr. Watt, to record on paper the various pressures in the cylinder of an engine when at work; and the shape of the diagrams it produces enables us to ascertain truths that cannot be reached in any other way. Each diagram shows the working of the engines under existing conditions, but the experience of the engineer must determine what produced, and what will improve, these conditions.

If properly used, the Indicator ought to show the pressure on the piston at all points of the stroke—where the pressure was greatest, and where least—where any change occurred in it—at what point the steam was admitted, and when exhausted from the cylinder. It will also show whether the piston and valve are steamtight, and whether the latter is set to give the best results; the point of cut-off or ratio of expansion; the economy of high speed and high pressure; the values of different kinds of valve gear, etc. The mechanical process by which all the above can be ascertained is very simple, and the instrument itself of easy application.

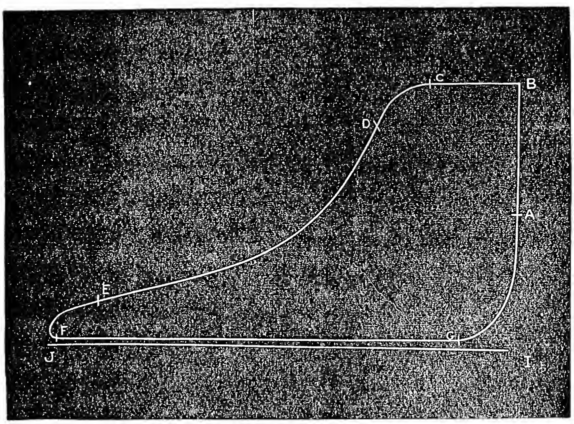
Amongst those at present in use, the latest improved *Richards' Indicator*, illustrated in the annexed view, is extremely popular, and as the details have been pictorially arranged they can be easily understood. The principal parts of the instrument are the steam cylinder and paper winding drum; spiral springs for three different pressures, to suit triple engines; a cock for attachment to a small pipe connecting the top and bottom of the main engine cylinders; and an ivory scale variously divided, for measuring off the steam or exhaust lines from the diagram, when drawn on the paper by the combined movements of the vertically reciprocating brass-pointed "pencil" and the revolving drum. Besides the above, the lid of the box contains several sheets of metallic paper, and a steel barred parallel ruler for instantaneously dividing a diagram into ten equal parts.



RICHARDS' INDICATOR, WITH ACCESSORIES.

When diagrams, or "cards," are to be taken, the cock on the cylinder connecting pipes is opened, thus exposing the indicator piston to the varying pressures of steam in that cylinder for either top or bottom stroke. Hence it follows that while the pencil vertically reciprocates as it lightly presses on the temporarily fixed paper, the drum has a rotary motion imparted to it, first, by a cord attached to a vibrating lever, and secondly, by a spring which produces the necessary return movement.

If an engine were perfect in every respect, and an indicator equally so, a correct diagram would be as shown in the adjacent view, which is a theoretical card for non-condensing engines :—J. I. is the atmospheric line from which the height of the card is measured by a suitable scale; A. B. is the admission line; B. C. the steam line; C. the point where the steam port begins to close;



THEORETICAL INDICATOR CARD.

D. where it *is* closed; D. E. the expansion curve; E. the point where the exhaust port begins to open. At F. the port *is* open, and the return stroke begins. At G. the exhaust port begins to close, thus forming the compression line which extends to A.

The steam line B. C. should be very near the boiler pressure when measured from the atmospheric line, and F. G. ought to be as close to J. I. as possible to avoid any back pressure. To obtain these results, however, the steam and exhaust pipes should be of ample area, and as straight and short as they can be made. The expansion line should correspond very closely with the true theoretical curve, but even an approximate perfection in this, as in the other cases, depends entirely upon the surrounding circumstances.

When steam cylinders, or pistons, or valves and their gear, or even the indicator itself, are out of order, the appearance of the diagrams differs more or less from the above, and it is this—sometimes most irregular—change of form that shows the true internal state of affairs, and points clearly to existing defects. After the diagrams are taken, they are divided into ten equal spaces by means of lines drawn across them perpendicularly to the atmospheric line. The average height of each space in pounds per square inch, is next measured by scale, either for steam alone, or additionally for vacuum, and when the sum of these is divided by 10 we obtain the *mean* pressure which alone is used for calculating the horse-power. This is obtained by the rule:—Mean pressure × area of cylinder × speed of piston in feet per minute, the product being divided by 33,000 to find the I. H. P. the engine is developing at that particular time.

For the convenience of engineers and shipowners, each card has a tabulated list of "Details of Diagrams" printed on the back, which are filled up by the chief engineer of the ship. These include such particulars as—Name of steamer—Date when taken—Voyage from—Scale of card—Boiler pressure—Vacuum—Revolutions per minute—Pressure in receiver—Grade of expansion, or distance travelled by piston before steam is cut off—Consumption of coal per day—Name of coal used—Quality of coal—State of wind and weather—Speed of ship—Draught forward and aft, etc. Collections of these cards thus form a valuable record of steamship performances for future reference and comparison.

One of the most prominent features of latter day engineering is the swiftly extending application of *electricity* for lighting and motive power purposes, good examples of which are now very numerously to be found. This power may be described as a subtle and invisible force that pervades the earth, and permeates the heavens. It may, however, for convenience, be termed "a fluid whose energy can be utilised when desired, but which disappears when done with—'like the snowfall on the river—a moment white, then gone for ever'"—as Mr. W. H. Preece touchingly puts it.

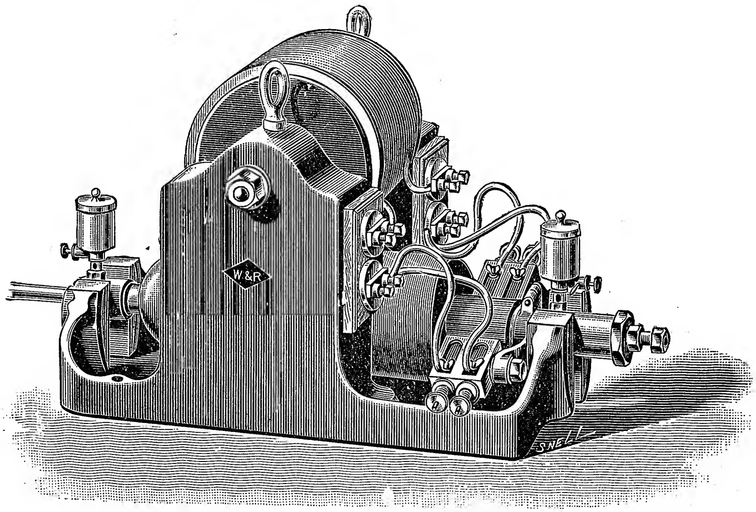
The *paradoxes* of electricity are more numerous than many would suppose. For instance, though invisible it can be made to produce the most powerful light known, and although noiseless it can create deafening peals of thunder, or operate the most delicate of all acoustic instruments—the telephone. Although existing in unlimited quantities of powerless form in and around the earth, it can be used to drive motors as powerful as a great steam engine, or as minute as a watch. Although we cannot touch or handle it, yet we can measure it with the greatest accuracy, and although it has apparently no velocity it can travel over many thousand miles with inconceivable rapidity. Although not a chemical it produces very powerful chemical action, and although it cannot be burnt it nevertheless produces the greatest known heat. Amongst other paradoxes, perhaps the greatest is that, although the laws of electricity are more definitely determined than those in many other branches of science, we cannot say what this wonderful agent really is, and so, as above, we call it a "fluid."

Like water-power, it can be stored up, or accumulated for future use, and it possesses the great advantage of being extremely portable, and capable of having its direction and intensity changed with the greatest ease. It can be taken round corners into all sorts of crooks, crannies, and crevices, and up or down hill, much more easily than gas or water, and from one central station it can be made to sweep many miles around. According to Mr. B. H. Thwaite's "Scheme for England," this may be done most economically by placing the machinery for generating electricity near coal pits, thus saving the expense of carriage.

On the Continent and in America this power is rapidly surperseding the once highly popular rope gear, as the motor can be placed in almost any position, and at the same time requires the least amount of attention and the smallest area of space. Another of its peculiarities is the ease with which the waste power of rivers, such as the Niagara, etc., can be utilised for electric storage purposes so that energy may be distributed for a variety of purposes on a colossal scale. Even in shipyards, electro-magnetic tools have been favourably received, since much can now be easily performed by means of small machines capable of being placed in position on the plates, etc., by magnetic attraction, without the aid of bolts. With the object of saving much unnecessary labour, *Electric Portable Deck Plank Planing Machines* are now used, and these promise to become popular.

One of the most useful applications of this power has been adapted by the Immisch Electric Launch Co., to the propulsion of river boats as much as 65 feet in length and 10 feet in breadth, to the entire exclusion of the engines and boilers that usually occupy so much valuable space in steamers.

In the larger vessels the *midship saloon system* can be adopted with regal splendour if required, or at least in the Venetian gondola style, which is very suitable for the purpose. These little vessels are very popular on the Thames, and are also employed by various Governments, and by many private people.



ELECTRIC MOTOR FOR LAUNCHES.

The latest improved type of electric launch machinery is that by Messrs. Woodhouse & Rawson, illustrated above, which is not only simple in construction but capable of producing the greatest steadiness when running full speed. It also occupies extremely little space, and is under the immediate control of the lady or gentleman at the tiller by means of handles placed within easy reach. Launches thus fitted possess the great advantages of silent running and absence of the usual heat, smell, dirt, and smoke; whilst owing to the motor being placed under the floor, and the accumulators beneath the seats, the whole of the vessel is left free for passengers.

As the science of *Electrical Engineering* forms one of the most important themes of the day, we shall endeavour to explain in the simplest manner its leading features, and, firstly, the terms "volt," "ampère," "ohm," and "watt," now so extensively used.

The *Volt* is the unit of electro-motive force or pressure, usually written E. M. F., and when the electrician speaks of a machine giving an E. M. F. of so many volts he states its electrical pressure in terms which are analogous to the engineer's expression of so many pounds per square inch.

The *Ampère* is the unit of current, and is that amount of current which deposits 4·025 grammes of silver, or one 386·4 of a pound of copper per hour.

The *Ohm* is the unit of resistance, and is equal to the resistance of a column of pure mercury one square millimetre in section and 106 centimetres in height, at the temperature of melting ice. In order, however, to convey more clearly the meaning of these units, and to show how they are practically applied, a further unit named the "Watt" is used, which is equal to one "Volt-Ampère.'

A *Watt*, or *Volt-Ampère*, represents the work done by the dynamo or generator in a second, and, assuming that a dynamo is giving a current of 100 ampères at an E.M.F. of 100 volts, these multiplied together give 10,000 watts total output of the machine. And as 746 watts are equal to one horse power, this divisor gives the actual power, just as the 33,000 foot pounds per minute gives the same result to the engineer. In order, therefore, to ascertain the power required to drive a dynamo of any given capacity, the total proposed number of watts has to be divided by 746, and an allowance made, as in steam and other engines, to make up for loss. As good dynamos of sufficient size are capable of converting 96 per cent. of the actual power put into them into electrical energy, and as the total commercial efficiency of these machines ranges from 90 to a little above 93 per cent., it follows that the formula for working out the *actual* power required is, assuming the efficiency to be 90 per cent :—

$$\frac{10{,}000 \times 100}{746 \times 90} = 14{\cdot}89.$$

or say 15 horse power on the pulley of a dynamo generating 10,000 watts, or what is known as a ten-unit machine. This power is usually described as "brake horse power," and varies in different kinds of engines, but taking it for safety at 75 per cent. of the total I.H.P., the extra allowance to be given to driving engines may easily be determined.

The *Dynamo* itself consists of three principal parts—the field magnets, the armature, and the commutator—the design of the whole machine being based upon a fact discovered by Faraday in 1831, that a current of electricity is generated in conductors by moving them in a magnetic field.

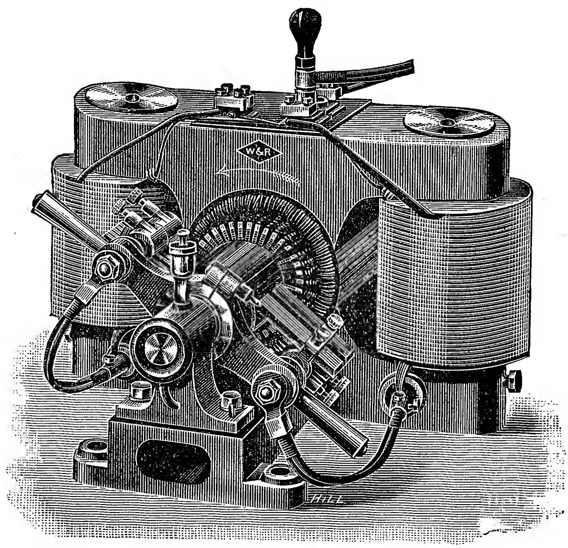
The *Magnets* are of soft iron shaped thus—U, the yoke being cast in the bedplate and forming a portion of a magnetic circuit. The magnetising coils are wound round the magnets in various ways, and the *Armature*, which revolves between their north and south poles, consists of a gun metal core upon which charcoal iron is coiled under severe tension until the requisite diameter is obtained, the resulting core thus becoming very solid, compact, and true. After this is done, copper conducting wires are wound upon it in sections at right angles to the direction of rotation, and subsequently joined so as to form a series of coils round the armature, the ends being attached to the commutator, thus forming a continuous coil.

The *Commutator* generally consists of a number of copper bars corresponding to the number of sections in the armature, and mounted on a gun metal sleeve placed upon the spindle of the machine. The commutator sections are insulated with mica, or in other ways, and when everything is finished off, which means much that is not here expressed, the machine is ready for use.

The annexed view of an improved 200-light "Manchester" *Dynamo* on the double magnetic circuit principle will show the parts referred to, and also their general construction. The armature, commutator, and brushes with their hand gear, are clearly seen in front, whilst the field magnet coils are visible on the right and left, the driving pulley being at the back.

Previous to testing a dynamo at the works, the magnets of the machine are initially magnetised in such a way as to make them of the required polarity. The armature, with its commutator, when mounted upon the spindle which runs in the bearings of the dynamo, is free to revolve between the north and south poles of the electro-magnets, and upon the machine being started a feeble E.M.F. is set up. In a very short time, the increased strength of the field magnets re-acts upon the armature, thus gradually bringing the machine up to the E.M.F. for which it was designed, the limit, of course, depending upon the driving speed, and upon the degree of magnetisation of the field magnets. For enabling electricity to be stored as a motive power in launches, etc., a certain number of *Accumulators* have to be used, and when these are fully charged their energy may be employed continuously or intermittently for various periods, as desired.

To Mr. W. C. Mountain, of the well-known firm of



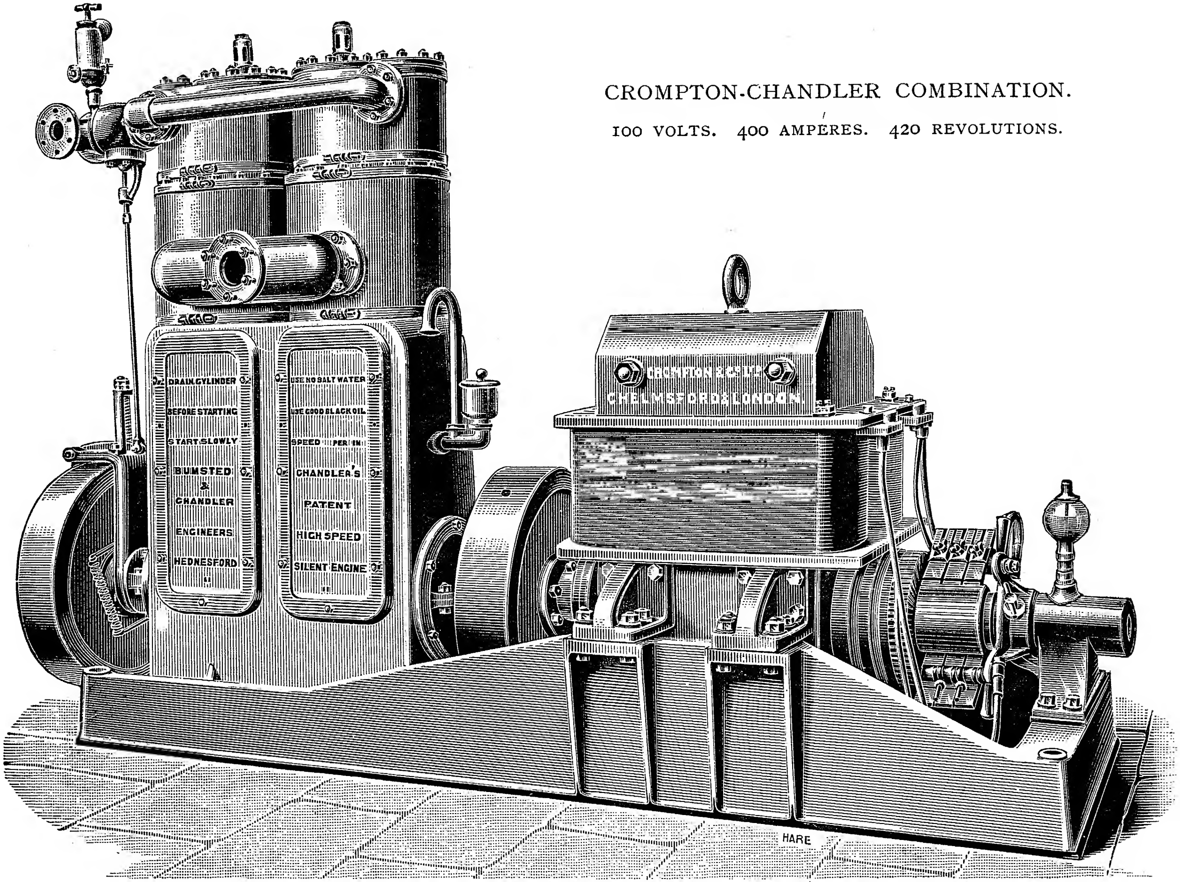
MANCHESTER DYNAMO.

Messrs. Ernest Scott & Mountain, we are indebted for much information of a very lucid and practical nature, which, even in the above very condensed and imperfect form, may indicate to some extent, at least, the elementary principles of electrical engineering.

In ship lighting, where the space at disposal for the engines and dynamo is very limited, it is necessary to

CROMPTON-CHANDLER COMBINATION.

100 VOLTS. 400 AMPÈRES. 420 REVOLUTIONS.



make them as compactly efficient as possible, an excellent example of which is shown in the opposite plate of the *Crompton Chandler Combination.* The engines, which have already been described in connection with the forced draught system, are by Messrs. Bumsted & Chandler, and while these develop 75 I.H.P. with 140 pound steam, their combined efficiency is fully 80 per cent. Complete sets of this type of machinery have been supplied to twenty-five of the British Indian ships, all those of Messrs. G. & J. Burns, and some of the Austrian Lloyd and other fleets, besides numerous land installations.

Those acquainted with launches or boats will know that their available space is often almost wholly occupied by passengers, hence it follows that when power of any kind is employed for propelling purposes it is absolutely necessary to make it as compact as possible. Various methods have been used to accomplish this, one of which is the *Petrol Motor* of Mr. Daimler, illustrated in the following views.

Fig. 1 is a Longitudinal Section of the machinery, and Fig. 2 a Transverse Section in a boat, showing a clear gangway fore and aft on each side; whilst Fig. 3 gives a good idea of the external appearance of a land motor, with the usual crank handle in front for starting purposes only, the whole engine being easily adaptable to marine propulsion. Fig. 4 illustrates a type of launch thus fitted with machinery, the position of which can be variously altered to suit the requirements of the owners.

The engines referred to differ materially from others, and, owing to their small weight, are specially suitable for light draught vessels. They also possess many advantages, including the *absence of a boiler*, economy in cost, space, and maintenance, ease in working, etc., all of which

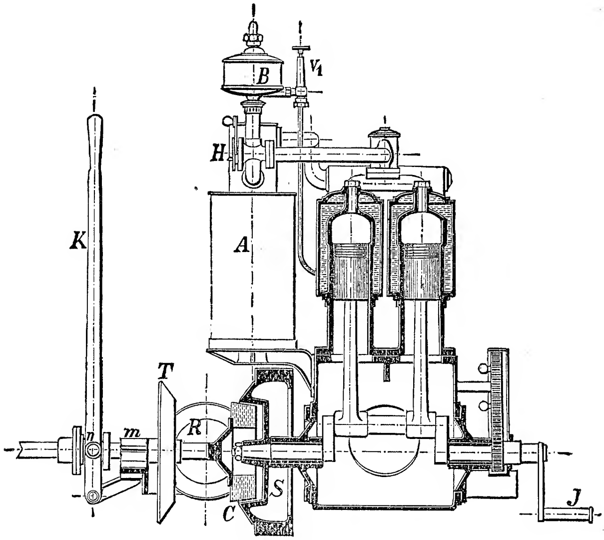


FIG. I.

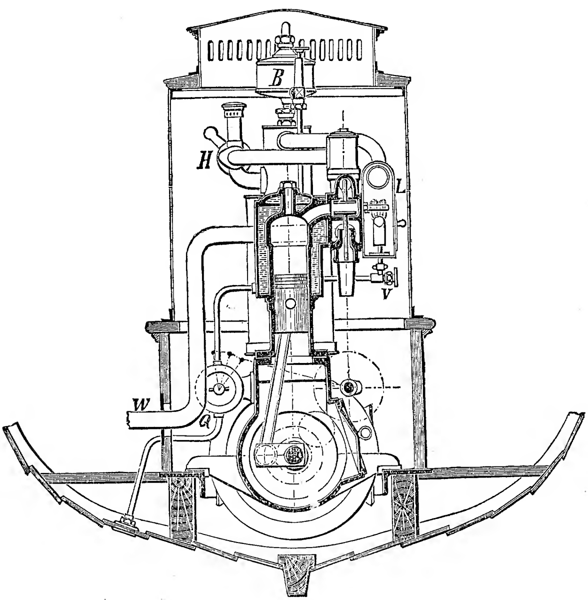


FIG 2.

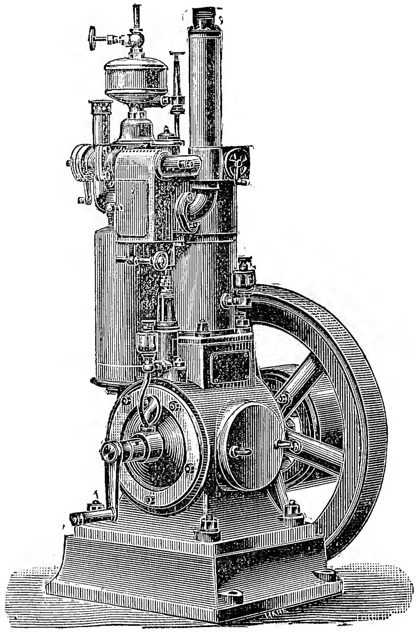


FIG. 3.

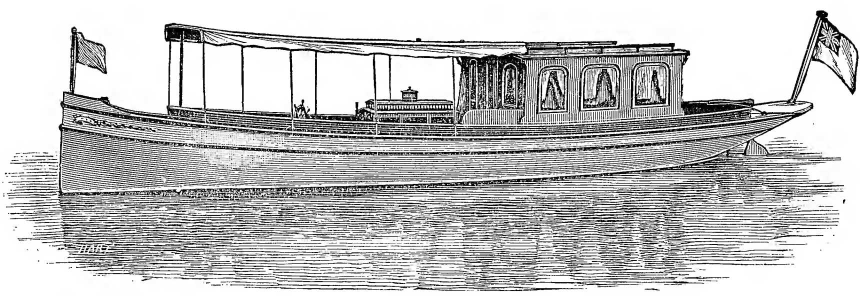


FIG. 4.

have made this system very popular on land and water. These boats have been extensively used for pleasure, fast travelling, ferry, towing, and other purposes, up to 100 passenger capacity, and are built of oak, pine, teak, mahogany, or steel.

The fuel employed is rectified petroleum, which, when burning, produces neither soot nor visible smoke nor smell; and as it acts upon the same principle as that of the ordinary gas engine, all danger is avoided, while its cost in working is about one penny per horse power per hour.

On reference to Figures 1 and 2, A is the gas-producing cylinder, B a vessel for supplying the lamp chamber L with petrol, H a valve for regulating the quantity of air to produce a suitable combustible gas for engine cylinders, and J the cranked starting handle. As the engines only run in *one* direction, the boat can be driven astern by means of the friction cone C, clutch S, reversing disc R, and cone T, by means of the lever K. A small pump, shown at the side in Fig. 2, is used for circulating cooling water through the cylinder water jackets, and W is the vapour exhaust pipe, the whole forming an engine which has produced excellent results.

One of the greatest improvements in Eastern travel, combining rapid transit on land and water, has recently been introduced by the Canadian Pacific Railway Company, whose new *Empress of India*, *of China* and *of Japan*, have proved so acceptable. These magnificent steamers were built by the Naval Construction and Armaments Co., of Barrow-in-Furness, for the mail service between Vancouver and Japan and China. Each vessel is of 6,000 tons, and is fitted as an armed cruiser, and, with its twin screw engines of 10,000, H. P., has attained a speed of 19 knots an hour. Our frontispiece shows the last named ship—from a photograph by Messrs. Adamson of Rothesay—and also represents the others, whose white painted sides are suited to the tropics, and whose extremely limited sail power results from the safety provided by having two sets of engines, the arrangement of which may be partially gathered from the half section of a twin screw steamer shown on page 398.

It may be asked why these vessels have figure-head stems, when those of the P. and O., Orient, Cunard, White Star, &c., have vertical ones? The reasons may be thus stated: —The ports on the Canadian Pacific Station have either open roadsteads or extensive wharf spaces, instead of crowded docks, hence the C. P. R. liners do not need to be rigidly shortened. Secondly, a figure-head stem gives an elegant finish to their bows. And thirdly, and perhaps most importantly, the Company probably wished to pay a graceful compliment to the Eastern nations with whom they traded, and who would no doubt be delighted to see handsome representations of their reigning monarchs adorning these ships in such an attractive manner.

At the conclusion of the trial trip of the *Vencedora*, the ship departed for London, with Chief-engineer Angus Macgregor in charge of her machinery. This gentleman had been in past days one of the most trusted responsibles of the Great West Sou'-Western Company, whose very famous ships *Pestonjee Bomanjee*, and *Belshazzar* were "guaranteed" by him at sea. That is, he was appointed by the builders, with the approval of the owners, to act for them for six months, to prevent the possibility of an accident at the outset.

Mr. Baxendelle and Mr. Farquharson accompany the ship with the object of taking notes of her performances for future use, and after a most successful run the vessel is berthed in the Royal Albert Dock. The loading at once begins, and is continued until Lloyd's Register mark on her side sinks to the required depth in the water. This well-known mark effectually checks overloading, and is graduated to suit fresh and salt water, for summer as well as for winter, in the Atlantic or in tropical seas.

The hour of departure has arrived, and the *Vencedora* steams away on her first voyage to Calcutta. To Mr. Baxendelle, Mr. Farquharson, and to the staff of the Sirius Works with whom we have been so happily associated, we must now bid farewell, at the same time wishing them all a long and very prosperous career.

CHAPTER XXIX.

A GIGANTIC MAIL LINER ON LONG VOYAGE STATION.

SS. *Centenarian* preparing for Sea—Record to be broken "in honour of *The Event*"—Owner's Advice to his Officers—White Star R.M.S. *Teutonic* and *Majestic*—Inspection Day before Sailing—Commercial Aspects of Steamship Splendour—Officers of *Centenarian*—Departure for Sydney—Life at Sea—Breasting the Record—Great Commotion—Passengers' Advice to Officers—Board of Trade Protection, and its Results—*Day Record Broken*—Wild Excitement—Engine Room Staff Interviewed—How the deed was done—Heading for an "Unknown Rock" at 22 knots an hour—Overwhelming Calamity Averted—What might have happened—Difficulties of Ocean Surveys—VOYAGE RECORD BROKEN.

WHEN a Royal Mail Liner of the highest order has been completed and sent to sea, her performances are closely watched by the owners and builders. The great object of their ambition is to *Break the Record* of all past voyages, and hence, when this is attained, everyone concerned is delighted, the vessel herself at once becoming an object of interest to the public generally, and especially to those who intend to become her passengers.

Although every modern invention is now utilised that can insure the safety of vessels, there is a peril to which some at least may be exposed in the course of a lifetime, and which has caused the sudden destruction of a few already, such, for instance, as the SS. *Cotopaxi*, *Quetta*, and others. In this chapter, therefore, we shall endeavour to explain, firstly, how the Record is broken, and, secondly, how a ship in full career may in a few minutes find a resting place beneath the wave, when to all appearance there is not the slightest prospect of danger.

To make these matters clearly intelligible, let us fancy ourselves in the beginning of the year 1912, that is, the centenary of Steam Navigation. Let us also imagine that some new discovery has been made in Australia, which provides remunerative employment for the vast multitudes who are crowding every ship bound for that region. So much, indeed, has this been the case, that a famous Royal Mail Company has added to its splendid fleet three new steamers of great size and speed to run on the station, the last of which has just come off her first voyage.

"*Centenarian's* cargo all out, Captain Vansittart?" said the Managing Director to the Marine Superintendent, as he called at 999 Leadenhall Street on his way to the ship.

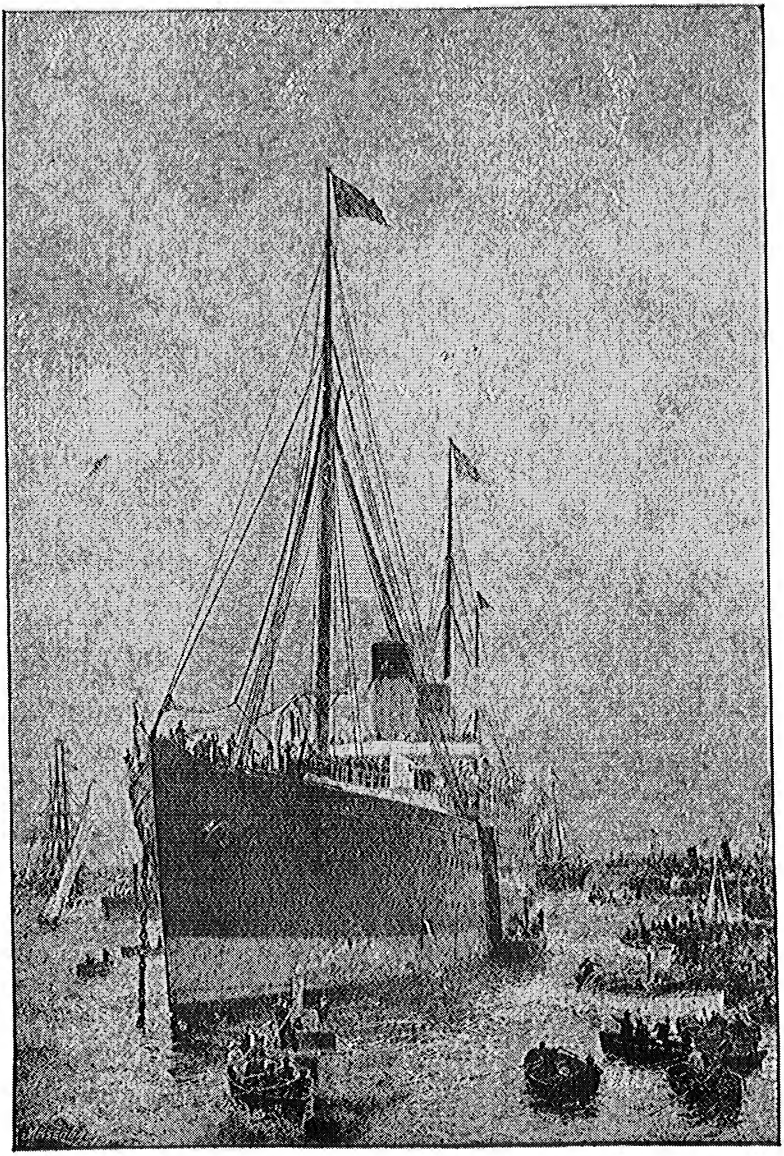
"Very nearly, sir, we are going into graving dock to-day."

"Well, then, give her bottom an extra scraping and cleaning, and see that the Hartmann-Rahtjen people make it as like enamel as possible. And, Mr. Hardcastle, just give the engines an extra careful overhaul, as we must *Break the Record* this time in honour of *The Event*."

"Can't do any more to them, sir, than we are doing, as the whole of the machinery is in splendid order, and we shall be finished in plenty of time."

"In that case let everything have a fresh coat of paint, and burnish up all the polished parts you possibly can, as we must give the new Governor and his friends a treat."

"All right, sir," replied the superintending engineer, and with these, and a few minor requests in memory, he



VISIT OF H.I.M. THE GERMAN EMPEROR AND H.R.H. THE PRINCE OF WALES
TO THE
WHITE STAR ROYAL MAIL STEAMER AND H.M. ARMED CRUISER "TEUTONIC."

and his colleague departed for the scene of operations at the Royal Albert Dock.

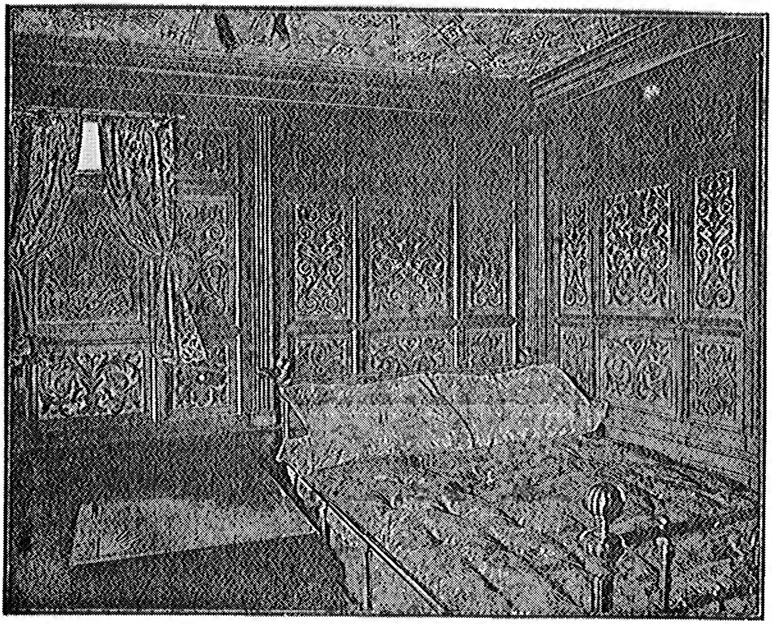
To enable what follows to be more easily understood, let us note some of the leading features of the White Star twin screw ships *Teutonic* and *Majestic* of 10,000 tons, 18,000 horse power, and 20½ knot speed, several views of which are distributed throughout this and the following chapters. These vessels were built by Messrs. Harland & Wolff in the "regardless of expense" style, or, at least, without any reference whatever to the binding obligations of the contract system.

Plate A shows the *Teutonic* receiving a visit from the Emperor of Germany and the Prince of Wales, her fine lines and general appearance being seen to great advantage.

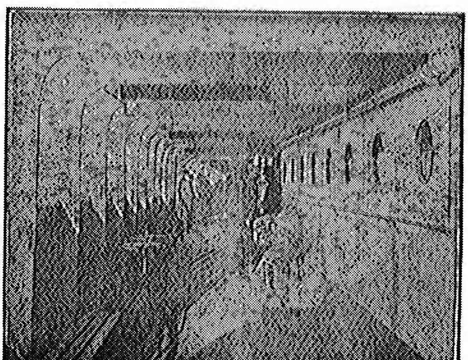
Plate B illustrates the *Grand Saloon* in all its splendour—a splendour too that combines everything that is beautiful with the greatest luxury, and presents a marvellous contrast to the ocean passenger steamers of early days. This banqueting hall occupies the full breadth of the waist of the ship, where the pitching motion and screw vibration are least felt.

An *Upper Deck State Room*, shown on the following page, is typical of many of the others; it may be said, however, that the sleeping apartments are greatly varied, some of them being spacious enough and magnificent enough for an empress, either in the political, theatrical, or musical world, or to suit the tastes of newly married millionaires on their wedding tours.

The exquisite beauty and rich embellishments of *A Corner in the Smoking Room* are clearly exhibited in Plate C. Here we have choice oil paintings representing the pictur-



VIEW OF AN UPPER DECK STATE ROOM.



VIEW OF COVERED WAY FOR STEERAGE.

esque Mediterranean shipping of the Middle Ages, with which the whole of the saloon is profusely adorned. Whilst, at the same time, the ceiling, high relief figure carvings, and stained glass windows, etc., are perfect studies in themselves.

The Library, shown in Plate D, needs no description, as it is so clearly delineated that the reader might easily enough fancy himself or herself looking through its handsome tomes, or inspecting the admirable books with which it is so liberally provided.

Lastly, we come to the sketch opposite illustrative of modern construction. Formerly, when the quarter deck was the seat of the aristocracy of a ship, the steerage people were located at the forward end, and greatly exposed to the weather, as indeed everyone else was. The introduction of the midship saloon system by Messrs. Ismay, Imrie & Co., was therefore a master-stroke of design, since in addition to enlarged accommodation, it provided a most capacious promenade overhead the full breadth of the vessel, and formed on the deck beneath an excellent covered way for steerage passengers and others. The bulwarks are plainly visible, so also are the upper-deck beams, and although the artist has hazily treated the side frames, they too can be noted.

To old hands a visit to the engineering departments of the *Teutonic* is quite a treat, as there is so much to remind one of the exquisite hand-finish of past days, which the best machined work of the present can never equal. Upon traversing these lower, or mezzanine regions, we find them in the most complete order, and electrically lighted throughout. The stone colour of the main and numerous auxiliary engines, and the white paint on the tunnel shafting, are kept in splendid condition. The polished parts are kept ever bright, and the most scrupulous cleanliness is everywhere discernible.

On the Inspection day before sailing, the whole of the ship's crew, in full uniform, is passed through its varied performances, in the presence of the captain and officers, the marine and engineering superintendents, and some of the representatives of the Company, who rigorously examine everything. The boats are manned, lowered, and replaced; the firemen are drilled; the pumps and water-tight doors tested; the rockets and signals examined; the stearing gear tried; the store rooms inspected, and every part of the vessel carefully looked into, until her safety is insured at all points. Besides this, the shore hands, as well as the sea-going staff, are so fully occupied up to the last, in rubbing, scrubbing, polishing, burnishing, trimming, and titivating in every direction, that by the time the passengers are admitted, a princess might adventure the soles of her feet all over the ship, and have a feeling of pride in sailing by her.

It may be asked, what is the use of such "extravagant" magnificence in an ocean mail liner? Well, the answer is simply this—"*It is profitable.*" The moral aspect of the question has been given on page 434, but its commercial features may be thus described:—

Between the Old and New Worlds there is a constant stream of wealthy people who travel for *pleasure*, as well as for business—people, too, of refined and luxurious tastes. Knowing this, Messrs. Ismay, Imrie & Co. have, in the most practical manner, made their ships extremely attractive in every respect, as we have endeavoured to show, and thus their passenger traffic has been greatly extended.

The history of the Clyde river steamers abundantly confirms these remarks, and the future records of the Thames will no doubt do the same, after a few more *Koh-I-Noors* have been put on the station, and thus created the overwhelming traffic which London and its visitors ought to be able to provide if a sufficient amount of speed and splendour combined is offered to them.

The S.S. *Centenarian*, previously referred to, is a 13,000 ton twin screw of 31,000 horse power, and 22 knot speed, built by Messrs. Harland & Wolff upon the most improved lines. As all the plates and notes however referring to the *Teutonic* can be made to represent similar portions of this Australian liner, hardly anything more need be said. Her exquisitely shaped hull is surmounted by two pole masts and three powerful-looking funnels symmetrically arranged, but in other respects, Plate A, will give a good idea of her external appearance.

Captain Westbrook is a great favourite with passengers on account of the kindhearted, genial, and impartial interest he takes in their welfare from first to last, and from every point of view. Mr. Greville, the first officer, is also very highly esteemed. Mr. Drummond, the chief engineer, is a remarkably fine specimen of his race, and all the other officers of the steam and navigating departments are everything that could be desired.

When the public came to know the private intentions of the Directors, such a rush was made upon the vessel that in a very short time 1800 passengers were accommodated, and as her working staff amounted to 415 in all, the ship had no less than 2215 individuals to transport to the colossal cities of the South.

The practical introduction of Steam Navigation was due to Henry Bell, whose steamer *Comet* began to run from

Glasgow to Greenock on January 12, 1812. It is, therefore, from that year that we date the permanent adoption of marine steam propulsion, the rapid advances of which we have endeavoured to illustrate in the preceding pages, and which have culminated in the ocean liner just about to depart on this the twelfth day of January, 1912.

The mails and passengers are all on board, including the Right Honourable the Earl of Balmain, K.G., the "New Governor" of New South Wales, and suite, also a heterogeneous assemblage of people with bright hopes for the future, and constituting in themselves the largest floating community that ever sailed over nearly 14,000 miles of water. Unhappily, for health restoration purposes, many are going to avail themselves of the long voyage round the Cape, which is preferable to the Red Sea *route* with its relaxing heat. In every seaport, and in every ship throughout the world, the eventful day is being observed by a marvellous display of flags, in which our own vessel is well to the fore.

The *Centenarian* is lying off Gravesend with her head pointing seawards—the anchor has just been weighed—the gangway has been taken in by the tender containing the "girls we've left behind us," and other friends—and at the exact time the *Comet* departed from Glasgow on her first voyage, the "*peter*" at the masthead disappears—the flag of the destination country flutters in its place, and as the propellers begin to revolve the ship moves off in *accelerando* style, amidst the enthusiastic cheers of multitudes. After some hours' steaming, Britannia's outline rapidly fades away as the steamer takes a sou'-westerly course at the rate of 22 knots an hour.

The English Channel plains are soon crossed, or at least the vast submerged plateau upon which the British

Isles are planted. This plateau has for ages been covered by water very gradually deepening towards the 100 fathom line, which extends from the west of Ireland to Bayonne, and forms not only the edge of the great Atlantic basin, but also the crest of a gigantic submarine mountain range that rises rapidly from the ocean bed to heights of 8,000 to 12,000 feet. When this line is cleared we at once enter upon the depths of the Bay of Biscay, whose 365 miles of stormy water are soon crossed.

Upon entering a warmer climate the passengers begin to organise all sorts of amusements, such as concerts, lectures, assizes, races, cricket, fancy balls, theatricals, and so on. The scientists study the motions of the ship and the engines, and also the peculiarities of sea and sky, and the secrets of ocean navigation, whilst the literary people contribute articles bearing upon daily events, which a talented editor and editress will kindly arrange in the columns of the weekly *Centenarian Times*. The steam and navigating officers, however, are fully occupied with their own special duties, but the idea uppermost in the minds of all is how to *Break the Record*, or, in other words, how to make the vessel perform what has never yet been accomplished in Southern seas.

The Equator has been crossed, a few passengers have been landed and embarked at Cape Town, and the "daily runs" are being scanned and commented upon more anxiously than ever, until at last the *Centenarian* actually breasts the Record for two days together, thus causing great excitement throughout the ship. There is not a single note book in a passenger's possession that has not these most important facts chronicled in distinguishing characters, and every one is in the highest expectation of still greater results. The captain is appealed to, and the chief engineer interviewed, by some of the enthusiasts, with the object of spurring them on to do something desperate, quite forgetting that these gentlemen, and also the whole official staff, are quite as anxious as themselves to win the coveted honour.

"W'y don't ye *screw down* the safety walves, and do as *I* tell yer?" was a question put to Mr. Drummond by a conceited individual, whose ideas of steam navigation were of the early Mississippi steamboat order.

Mr. D., however, knew too exactly what the consequences of this little movement would be if he acted upon the suggestion. Firstly, it was useless to do so, as each boiler had *two* safety valves, one being the "government," or lock-up valve, of which he held the key, and which he must on no account tamper with. Secondly, if the other valve were screwed down it could do no good, as its Admiralty associate would at once act with full power, and thus save the boiler perhaps from explosion. And last, but not least, because any engine room official who meddled with these valves after the Board of Trade surveyors had specified the exact load to be put upon them, would expose himself to a fine of £100, besides other evils of a supplementary nature. Hence, it will be seen, that the ruling powers watch most vigilantly in every respect over the safety of the travelling public, and wisely anticipate every movement of those in charge of machinery that may possibly become a source of danger.

Were it not for the rigid supervision from first to last of metallic structures generally, and of steamships and railways in particular, by constructors and surveyors alike, the highly beneficial science of engineering would soon become a devastating scourge, involving throughout the world the loss of millions of lives, and countless millions of pounds in valuable property, both of which are now almost exempt from danger of any kind.

When, as we said, for two consecutive days the highest record of the past had been equalled, the excitement of all became intense, and the progress of the vessel was closely watched, while the most strenuous efforts of those in the steam department were unceasingly put forth. Mr. Drummond's whole attention was bestowed upon the boiler room staff, and rather than allow the steam pressure to fall off in the slightest degree, he actually did a little firing on his own account to encourage the others. The result of these combined movements soon became apparent, as the ship attained her very highest speed, with the manganese bronze propellers slipping through the water with extreme smoothness, and her enameled bottom doing exactly the same thing, until next day at noon the following notice was posted up:—

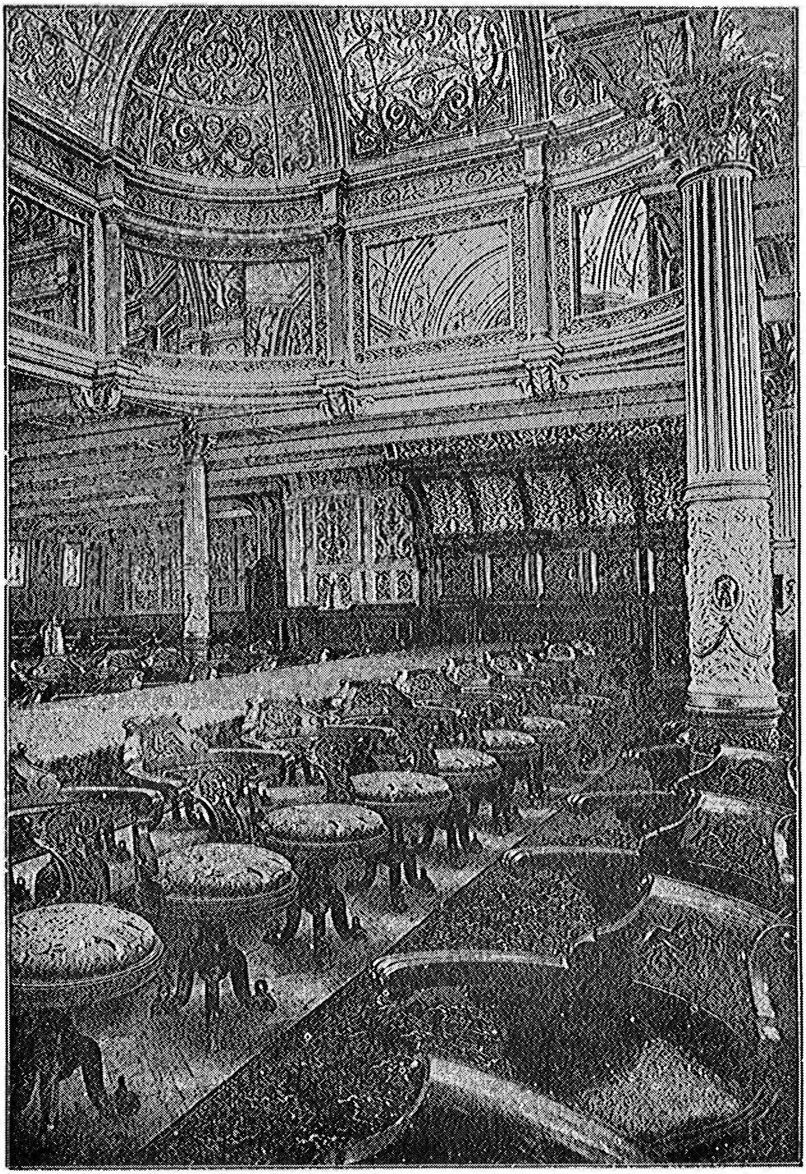
"THE RECORD BROKEN! latitude 40° 10′ S, longitude 50° 1′ E. Total distance run since yesterday at noon, 531 knots, which exceeds by ten knots all previous records!"

Everyone who knows how little it takes to cause a flutter amongst passengers who gaze day after day at sea and sky, when thus cut off from the world, will understand the nature of the commotion created by this incident. The first thing the inquisitive ones did was to make a rush upon the only available copy in the library of Haldane's *Engineering Popularly and Socially Considered*, tenth edition, and here they learnt exactly how the grand performance had been accomplished. Inasmuch, however, as only a limited number could study this volume at one time, some of the others minutely examined the interesting and amusing *P. and O. Pencillings* that handsomely adorned the library table, and also the Company's instructive *Orient*

Guides, whose excellent chapters upon "Seamanship and Navigation" could not, however, supply what was needed.

The rest of them—ladies and gentlemen—headed by the Viceroy, made a grand dash upon the engine room. Down the main entrance ladders they all went into the depths in Indian file, firmly clinging to the burnished handrails, until the mezzanine floor was reached, and here they had a full view of the mighty engines on both sides of them, running with the utmost smoothness, and giving out the power of upwards of 30,000 horses! From this point the scene was truly magnificent, as the massive and highly finished crank shafts and their connections, and all the adjacent working gear glistened like burnished steel or brass, effectively relieving the painted parts, and producing a most profound impression upon the minds of the visitors, especially the "New Governor," who in early years had ardently devoted much of his time to steam yacht building in his own works, until he acquired great fame in the nautical world.

Not content with the animated prospect before them, the invaders actually penetrated into the recesses of the tunnel, and were on the point of entering the boiler room when they were met by Mr. Drummond, who made them heartily welcome, and who at once requested his colleagues to spread themselves out so as to look as many as possible, and give all the information in their power. This they accordingly did, to the satisfaction of every one, the only difficulty being to convince some of their inquirers that they had *not* been "doing something to the screw propellers," or that the steam had *not* "run up ten degrees on the dial plate," or that the engines had *not* "been making a few extra turns per minute without their knowing it," and so on.



S.S. "TEUTONIC"—UNDER THE DOME IN THE SALOON.

Mr. D. ran exactly upon the same lines of argument, and added that in his own opinion the "Breaking of the Record" was due: firstly, to the excellence of the machinery; and, secondly, and most importantly, to the skill of the engine room staff over which he presided.

The unusual excitement that had pervaded everyone, manifested itself even at dinner, for no sooner did Captain Westbrook enter the saloon—shown in Plate B—than the whole company rose and cheered enthusiastically, while he himself received the ovation with charming simplicity and good humour. As every one chatted and talked, and smiled and laughed in the most felicitous style about the events of the day, it was felt that henceforth this grand performance of the *Centenarian* would form quite a sea-mark in history. Her speed had been reduced to 22 knots, as it was now very clear that the breaking of the *voyage* record would be easily accomplished, and with this in view the passengers and those off duty eventually retired to rest, perfectly satisfied with the day's proceedings.

Is there *no one* amongst the navigating staff of that crowded steamer who can give the commander the slightest hint that he is unconsciously running them all to swift and overwhelming destruction? Can no one tell him that right in his course lies an "unknown" rock, on which there is too little water to take the vessel over in safety, and too much to arrest her progress and give every one a chance for life? Cannot a passenger, startled from sleep by a vividly awful dream of impending danger, intreat the Captain to change his course for five minutes? Alas! not even one of them can do this. Captain Westbrook knows from the charts that he has to cross an elevated tract of ocean bed with 150 fathoms water over it, but is totally unaware of a most dangerous pinnacle towards which he is fast heading.

If it were possible, one of the main shafts might break, or a connecting rod snap, or, indeed, a whole engine fall to pieces on the floor, and thus enable the ocean current to drift the crippled ship clear of danger. Here, however, we are again baffled, as Messrs. Harland & Wolff have made everything too strong. The *Centenarian* is practically a lost ship, although apparently "unsinkable." The Shadow of Death is over her, and before half an hour has rolled away a disaster unparalleled in the history of Steam Navigation will have occurred, and this, too, on its great and glorious Centenary!

To some it may appear strange that so many should thus be allowed to drift to their end, as in numerous past cases they have done, but it must be remembered that if we had the gift of prescience it would sap and destroy the very foundations of social and business life in all their phases. Therefore, it is better *not* to know the future, than to be kept in misery by knowing too much.

As a striking example of this unconsciousness in people, just note how cheerily these poor firemen are raking, cleaning, and re-charging the furnaces, and closing their doors for the *last* time. There, too, is starboard fifth engineer Dalrymple, gazing admiringly at the thrust bearings of the shaft just about to stop for ever. Mr. Drummond is asleep, so also is the Captain, and indeed everyone else throughout the ship, except those on duty. High above them is first officer Greville, pacing the bridge in the "all's well" sort of style, trying to discover some ship's light, and thinking of his "intended," whom he little imagines he will never see again.

Such was the awful state of affairs up to 1.50, whilst the ship, carefully guarded at all points, was cleaving at 22 knot speed the waters of the Southern seas, many of the sleepers no doubt dreaming sweetly of past scenes, but not of the *Event* just at hand in all its hideous deformity—an event that will cause anguish to multitudes at home and abroad, and perhaps impaired reason to some who have anxiously watched and waited for loved ones who will never return unless, indeed, something unexpected occurs.

The two forward lookouts are gazing into the darkness, as usual, but without seeing anything until, at 1.51, they excitedly signal "SHIP AHEAD" to the officer on the bridge, who at once telegraphs "hard-a-port" to the wheelhouse, and with two tremendous bangs on each engine room gong requests those below to "stop" the engines, both movements being executed with amazing rapidity. The discovery was made not a moment too soon, and as the great liner rapidly swung off her course she almost grazed the stern of a dismasted and abandoned ship, into which she would otherwise have crashed to her own very serious damage. No sooner was this ocean peril cleared than "full speed ahead" and "course," were telegraphed below and aft, and everything went on as usual. Bravo! Mr. Greville, you have made the master-stroke of a century, and *doubly* saved your ship and all on board—without knowing it.

As previously stated, the *Centenarian* was running swiftly to destruction, totally unsuspected by anyone. The above most unlooked for event, however, caused the ship to swerve sufficiently out of her path to enable her just to clear the point of danger at two o'clock, by sweeping in safety through a very narrow but deep channel that might have been cut for the purpose. Had it not been for this "derelict" incident, her bottom would have been torn out, and the sea, rushing in like a deluge, would have extinguished the boiler fires, and caused immense volumes of steam to add to the terror and confusion of those only awakened out of sleep to jam every passage and block every exit to the deck, and even to disconcert the movements of a highly trained crew. Indeed, so overwhelming would have been the calamity, that in less than three minutes the vessel would have sunk in fifty fathom water, without leaving anything or anybody to show what had become of her.

After the ship had been long enough "missing" the usual Board of Trade inquiry would be held, in which the builders, engineers, owners, surveyors, nautical assessors and others, would take part. The plans would be closely examined for the purpose of finding a clue, however slight; her general structure minutely overhauled, and her stability in relation to loading considered. The opinions of officers who had previously sailed by her—but here lay the difficulty, as it was only the ship's second voyage, and all who were competent to give any information regarding her past performances were lost. After every feature of the case, including the discovery of one of the lifeboats, had been fully discussed by the experts, the Judgment of the Court would be given in such a manner as to throw not a single ray of light upon the cause of this mysterious event, which would in future be conspicuously recorded in the pages of maritime history.

Circumstances alter cases immensely, and although the *Cotopaxi* did not lose a single life after striking a Magellan rock during the day, the *Quetta* lost about 133, the *Utopia* 562 by fouling the ram of an ironclad, and the *Princess Alice* nearly 700, in a very few minutes, by collision on the Thames. We may therefore conclude that while disasters, such as described, may at one time be harmless to life, they may at another time be sweepingly fatal, especially during the earliest hours of the morning, when passengers are least able to save themselves.

It may, perhaps, be asked why such accidents happen at all when the oceans have been so carefully surveyed, and the dangerous spots so clearly marked on the charts. Perhaps the best answer would be that it is surprising that "unknown rocks" are not more frequently run upon, owing to the occult submarine forces constantly at work in some localities. The valuable records of H. M. S. *Challenger* expedition, and others upon Hydrography, give a very good general idea of ocean soundings, but the most complete information is to be derived from the Admiralty charts, especially in the vicinity of coast lines. And yet, with all this carefulness, it seems impossible for the surveyors to find out *every* submerged and dangerous pinnacle, unless perhaps in the "John Taylor" style.

This individual was the old man-of-war pilot of Mr. Charles MacIver's steam yacht, and one in whom the Cunard leader greatly trusted. "Are you *sure* you know this place well?" said the latter one day to Mr. Taylor, while passing through the "Narrows" of the Kyles of Bute.

"*Know it?*" said John, "I ken every rock on this coast from Cape Wrath to the Mull o' Galloway. *There's one o' them*," he immediately added, as the ship bumped against a submarine obstacle he ought to have avoided.

Similarly, many a fine ship has found out an unsuspected rock or reef, only to leave her name to mark it for future reference.

The difficulties attendant upon exhaustive surveys are greatly due to the secret and active agency of coral insects on the one hand, and to volcanic action on the other, and occasionally both together, in a very remarkable way. The *Centenarian* incident was, therefore, purposely located where the sea is at least 1500 fathoms deep, and where an unknown rock would be an impossibility. Indeed, it may be said, that as the Atlantic is free from those seismatic disturbances that cause trouble in some localities, the charts indicate pretty closely all dangerous spots. In other places, especially in that hotbed of volcanoes and coral reefs—the main body of the Pacific—the most extraordinarily irregular conformation of the ocean bed is to be found, and also abundant means of producing the most unsuspected perils.

This, however, is not of so much consequence after all, since by far the greatest portion of the commerce of the world is carried across the safe waters of the Atlantic, Indian, and *South* Pacific oceans. Were it otherwise, many ships might even now be lost in the supposed *Centenarian* style, as no doubt some have been in past years from a similar cause.

On the day after the breaking of the Record, the miscellaneous employments of the passengers went on as merrily as usual. The known events referred to forming in themselves an all-absorbing topic of conversation, and giving the newspaper editors very much to record thrillingly and effectively in a special double number of *The Times*. Subsequently the *Voyage Record* to Melbourne was broken by 15 hours 59 minutes net steaming time, and as the *Centenarian* approached the harbour she received a perfect ovation from the assembled multitudes afloat and ashore who had come to meet her, as she called at their port before proceeding to her destination.

CHAPTER XXX.

GENERAL REMARKS.

Arrival of S.S. *Centenarian* in Sydney—Great Excitement—Record Broken for the third time—History of Ocean Steam Navigation—Origin of Cunard Company—History of White Star Company—Oceanic Literature of Steam Ship firms—Ocean Mail Liners of to-day—Personal Reminiscences of Engineering life—Engineering as a Practical Science—Infinities of its Principles—Finance of Engineering—Sketches of Light and Darkness—Final Remarks.

A FLASH of thought raises to view the beautiful and now immense city of Sydney. It is a day of sunshine and splendour in the beginning of February, 1912, and as the vast crowds coming in from all points seem to be animated with the "gr-r-eat excitement" spirit, we feel that something is going to happen, and all the more so as Victoria and Queensland seem to have poured in their flag treasures for the occasion, in addition to those locally available. Balmain, Wooloomooloo, the North Shore—George Street, Pitt Street, Kent Street, and other thoroughfares—the Circular Quay, Government House, the Botanic Gardens, etc., are all decked with a profusion of colours hitherto unequalled. A high tension state of feeling pervades all classes. Can it be owing to the expected arrival of the Viceroy? Well, not quite. The people have had many Lord Lieutenants since Governor Macquarie's time, and would not now be so enthusiastic, although the Earl of Balmain, K.G., promises to be very popular.

What is the cause of that large fleet of crowded steamers, yachts, and sailing boats, just inside the Heads, intently waiting for something that has not yet arrived? Early telegrams had announced that the *Centenarian* would be off the South Head at noon, and now here she comes with every sail set to catch the south-east gale! Captain Westbrook and Mr. Drummond have been on duty all night, the latter almost slave-driving the firemen, although in kind hearted sympathy he himself helps to use up the black diamonds in the regardless-of-expense style. The engine-room staff is fully occupied, and everything is pressed to the very highest limit, the prow of the ship is cleaving the water like a knife; and never in the history of steam navigation has a vessel been seen under such magnificently striking circumstances.

Exactly at the time specified she squarely passes the South Head lighthouse, "half speed" is therefore at once telegraphed to those below, and immediately afterwards the announcement is made that the R.M.S. *Centenarian* has *again* broken the Record! That is, she has travelled the distance from Melbourne in 15 minutes 29 seconds less time than any other vessel. The excitement that followed was simply unbounded, and even the Viceroy could not restrain his hearty approbation. Amidst a series of most enthusiastic demonstrations from those in the attendant fleet, the great liner makes her way up the harbour in a sufficiently *diminuendo* style to enable the escorting steamers to gain on her by degrees.

Hark! to the acclamations of countless thousands, and the firing of guns. Note the waving of hats and handkerchiefs and the dipping of ensigns, while amidst the

S.S. "TEUTONIC"—A CORNER IN THE SMOKE-ROOM.

greatest enthusiasm on all sides, the *Centenarian* drops her anchor opposite the Botanic Gardens, and—the voyage is over.

The incidents just referred to merely convey a faint idea of what happened in the United States, and especially in New York, when the *Sirius* and *Great Western* had successfully inaugurated Atlantic Steam Navigation. And, further, when Mr. Cunard reached Boston by the first Cunarder *Britannia*, this famous Canadian was so lionised that he received about 1,800 invitations to dinner within twenty-four hours after his arrival, as a small mark of appreciation from the joyous citizens.

The history of Ocean Steam Navigation is remarkable in many ways, but, compressed into nutshell space, its salient features may be thus described. In the year 1832, Junius Smith, an American Doctor of Laws, had a fifty-four days' passage by sailing ship from London to New York, thirty-two days being occupied in the return trip to Plymouth. These protracted voyages over little more than 3,000 miles, caused him to carefully consider the possibility of reducing the time to fifteen days by means of *steam* power. He next organised a Company in London with a capital of £100,000, that enabled him eventually to build the P.S. *British Queen*, of 2,400 tons, which in July, 1839, made her first run from London to New York in 14½ days. A great delay, however, in her building caused Dr. Smith to charter the *Sirius*, of 700 tons; whilst another Company specially built the *Great Western* for the same service. The former started from Cork, on April 4, and the latter from Bristol, on April 8, 1839, their respective runs being 18 and 15 days.

For some years previous to this, Mr.—afterwards Sir Samuel—Cunard had been pensively contemplating the possibility of a successful Atlantic steam passage, and now came to England to see what could be done. He visited that prince of Glasgow engineers in early days, Mr.—afterwards Sir—Robert Napier, who introduced him to Messrs. Burns and MacIver, the proprietors of a very prosperous line of coasting steamers. The result being that these gentlemen unitedly initiated, in 1840, what is known to this day as the "Cunard Line." Under the government of Mr. Charles MacIver and his colleagues, these vessels traversed the ocean at all times for the long period of forty years, wondrously unharmed by rock, or fire, or tempest, and have now reached the size of the S.S. *Campania* and *Lucania*, previously referred to, which have attained a speed of 23¼ knots an hour.

The history of the White Star Line is also most instructive, on account of the generalship displayed from first to last by its founders, Messrs. Ismay, Imrie & Co. Previous to 1870, they employed magnificent sailing ships, but in the above year a new departure was made by placing on the Atlantic station the S.S. *Oceanic*, whose midship saloon and other improvements inaugurated a new method of construction, of which Sir Edward Harland and Mr. Ismay were the originators. In view of the great depreciation of sailing vessels through the completion of the Suez canal, and also owing to the accumulation of facts bearing upon the financial and engineering aspects of Steam navigation as it now appeared, Mr. Ismay decided to introduce steamships of the highest attainable class, firstly with compound, and latterly with twin screw triple engines, of which the *Teutonic* and *Majestic* form the most advanced examples.

It may be added that Transatlantic passengers would do well to procure a copy of that most interesting and admirably illustrated book, by Mr. Thomas Rhodes, *To the Other Side*, which, for the sum of one shilling, gives much information concerning life in these ships, and also travel, etc., from ocean to ocean, across the great Continent. The very popular volume, too, by Mr. A. J. Maginnis, on the *Atlantic Ferry*, and those who have worked it, should also be read by everyone who desires such information.

We have only given two sketches from the great picture gallery of ocean Steam Navigation. The history of the Peninsular and Oriental Company, however, and other celebrated lines sailing from London, Glasgow, and Liverpool, bristles with most interesting features, but these cannot even be touched upon for want of space.

The popular literature of the Ocean, its ships, and its surroundings, has now become of a most attractive nature, the best part of it, however, has been originated by steamship Companies who wish to familiarise their present and prospective passengers with many things useful for them to know. Amongst books of this class may be mentioned the *Orient Guide*, which is a good sized volume containing many internal and external views of Orient liners, and also numerous maps, charts, and picturesque illustrations of foreign places. To these are added a variety of chapters upon social and professional life at sea, and subjects bearing upon navigation, seamanship, astronomy, general science, geography, etc.,—all of which are simply and pleasantly written.

Pleasure Cruises to the Land of the Midnight Sun, by the same Company, will have a special interest for those bound for the North Cape, as well as for others.

The Canadian Pacific Company possess a varied selection of similar literature, in which they most successfully endeavour to instruct people in the beautiful scenery, geography, climate, etc., of the country they hope they will feel inclined to visit, quite apart, however, from the pleasure they may have whilst voyaging by their splendid ships. *The New Highway to the Orient across the Mountains, Prairies, and Rivers of Canada*, in the thin quarto size that has now become so popular, will therefore be found a charming publication.

The handsomest and most original of our maritime treatises, however, is *P. & O. Pencillings*, by Mr. W. W. Lloyd. This book is published under the auspices of the Peninsular and Oriental Company, in the regardless-of-expense style, and contains many excellent lithographed plates, and numerous sketches, etc., illustrative of all the principal incidents on a voyage from London to the East. As this volume is bound in half morocco, with gilt edges, or otherwise, and contains much humorous instruction, we fancy that passengers, officers, adherents, and other friends of that magnificent old Company throughout the world will be delighted to possess copies for themselves. It may be further stated that, quite apart from the special advantages intending travellers derive from the perusal of all the volumes referred to, they form at the same time most attractive studies to those who are interested in oceanic matters, in a way, too, that differs materially from the ordinary books of travel.

The *Centenarian* narrative, though imaginarily located in the year 1912, nevertheless represents the best practice in the swiftest mail liners of to-day, whose very high speed on the Atlantic station will no doubt be adopted by the Australian racers of the future. It is also more or less a sketch of things that have already happened, or may even yet occur under similar circumstances. A few reminiscences of one's own experience will perhaps illustrate the manner in which the ordinary difficulties of every-day life may be unexpectedly overcome, much in the same way as the loss of the above ship was averted.

Some years ago, circumstances over which I had no control drifted me into an undertaking for which I had to acquire considerable experience on new lines. I had sufficient engineering knowledge for the purpose, but otherwise was almost a novice, and was thus compelled to feel my way cautiously. In spite of this, however, injudicious movements were entered upon only to be arrested by people and things, obstacles and disappointments, that seemed to have been unconsciously planted in my path just in time to avert mischief.

On one occasion I forgot to post a letter, but when calling subsequently on the friend to whom it had been addressed, I came in unexpectedly for important hints which would not otherwise have been obtained. When the work appeared sufficiently matured I requested the co-operation of a firm in London, their disappointing reply, however, enabled me to run upon better lines, and enter into a much more favourable arrangement with others. In short, these and similar incidents happened at the exact time and place, and in the simplest and most unexpected manner, just as the derelict of the ocean did for the *Centenarian*. Hence, the enterprise, which had originally been honeycombed with the germs of failure proved eventually successful.

To the earnest student, engineering is certainly one of the most fascinating of the practical sciences, and, at the same time, the most beneficially revolutionary of them all. For proof of this we have only to consider what has been accomplished during the past century towards developing the manufacturing and travelling resources of the world.

So closely do these affect the well-being, comfort, luxury, and prosperity of nations that there is hardly anything connected with transport or manufacture that does not indicate in some way or other the skill and enterprise of the engineer, which many have no means of knowing about, although the results are ever before them, to which reference has been made in previous pages.

The *Principles of Engineering Science* not only enter into every nook and cranny of the mechanical world, but they also wondrously permeate the whole of the animal and vegetable creation—the realms of subterrania—the mechanism of the planets and stars—the machinery of the heavens, and the dynamics of the spheres, either as solitary bodies or as vast independent systems that stud the infinities of space. In all these we have machinery on a boundless scale in perpetual motion, and without bearings or supports, which is inconceivably beyond our highest flights of inventive skill, or even of comprehension. Hence, it may truly be said that Engineering is the grandest and most extensively applicable of the practical sciences.

The only thing to be regretted is that the *Finance of Engineering* should have become so greatly deteriorated in these latter days. Formerly, large fortunes were acquired by industrious practitioners. Then came the era of at least liberal incomes, when even ordinary engineers could —metaphorically speaking—sit contentedly under their own vines and fig trees, with all contingencies provided for. Now, however, in too many cases, "success," as it is termed, is so infinitesimally out of proportion to the well directed and persistent efforts of those who try to obtain it, as not to deserve the name. The severe competition of recent times has chiefly been the cause of this, but additional reasons are to be found in commercial and other complications of universal significance over which we have little control, nor indeed are we ever likely to have so long as things remain as they are.

In all fairness we have shown the bright as well as the dark side of the profession, and now with great pleasure turn to experiences not yet referred to. Personally speaking, Engineering has enriched me beyond what I ever could have expected. She has given me magnificent health and a joyous spring through life. She has most lovingly and handsomely unfolded her secret treasures, and shown what may be found in her delightful bypaths as well as on the ordinary tracks. She has marvellously helped me out of every difficulty, and given me the true rest for the weary under cover of many disappointments. She has endowed me with the clearest attainable view of things ahead with the light of the future around them, and taught me much to which I attach more value than even to the greatest professional success.

Under these circumstances, it would be most ungrateful if I did not here try to encourage some forlorn and shipwrecked brothers or sisters who have been stranded on the sands of time, and thus help them to see light even in darkness. And when we regretfully note how much in this respect some of the leading scientists differ from Sir Isaac Newton and Sir Humphry Davy, I feel constrained to show how the study of *Engineering* science can educate one in solidly ringing, sledge-hammer-on-anvil tones, on lines of thought in which we have every reason to place the fullest confidence.

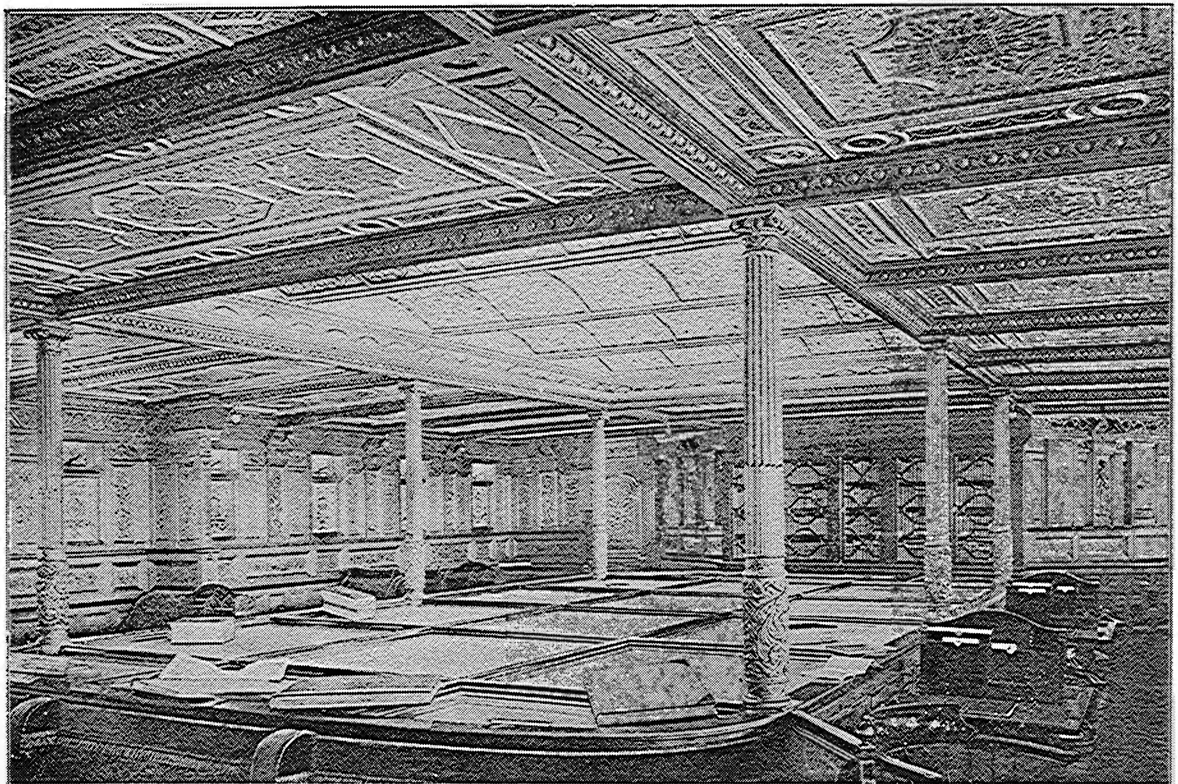
Hitherto, engineering subjects have not been made attractive to ladies, although in some cases this might have rendered them more instructive to those for whom they were primarily intended. Here, however, we have had the honour of making a new departure, for the following reasons:—

Our fair and highly valued friends are in the medical and other learned professions. They make splendid senior wranglers and missionaries to the heathen who bow down to wood and stone. They heartily join us in *Art*, and *General Science*, and *Literature*. They are now in our *drawing offices*, and above all, they have paid the author the supreme compliment of reading his *Civil and Mechanical Engineering* with as much appreciation as some of the highest professionals. It is therefore probable that this theme may soon hold an exalted position amongst their modern accomplishments.

The very generous reception of the above volume by readers of all classes has constrained me to adopt a similar style in this one, and to express myself with the unconventional simplicity and frankness of the sailor, otherwise it would have only been to court failure. And, as I am honoured with the highly gratifying encouragements of many prospective readers at home and throughout the world—chiefly in the United States, Canada, and the various Continental countries—there has existed an additional incentive to make this work as *readably* useful as possible. It has been a labour of love from beginning to end, although necessarily incomplete, as it would be impossible to treat Steamships and their Machinery in every department exhaustively in one volume, even of large size.

At the end of the first mentioned treatise I wished every good thing to shipowners, shipbuilders, and engineers, in every branch of the service. In a more accentuated form I must do so again, as many of them have so liberally given me every facility for obtaining the latest and best

PLATE D.



S S. "TEUTONIC"—IN THE LIBRARY.

information to utilise with a free hand. Particularly am I indebted to those firms who allowed me to visit their works and describe them in special chapters, or have kindly given permission to use plates and other illustrations of their productions, the origin of which is given in the text. And amongst shipowners, I have cordially to thank Messrs. Ismay, Imrie & Co., for four Plates and two smaller views of their R.M.S. *Teutonic*, which give an excellent general idea of their largest mail steamers, and also Mr. Archer Baker, of the Canadian Pacific Company, for the Plate of their R.M.S. *Empress of Japan*. In other respects the preface refers to what is here omitted.

The only favour still further requested from engineers and others is, that I may be kindly supplied with particulars concerning their latest improvements, which I shall at all times be most happy to receive.

INDEX.

A MUCH IMPROVED EDITION.

With 12 full page Plates, 510 pp., demy 8vo., cloth, 12*s.* 6*d.*,

Civil and Mechanical Engineering,

POPULARLY AND SOCIALLY CONSIDERED.

By J. W. C. HALDANE, Consulting Engineer.

ABSTRACTS OF REVIEWS.

"Mr. Haldane's intention has been to try to interest everyone in the science in which he is a practical proficient, and he has, on the whole, admirably carried out his conception."—*Saturday Review.*

"The author has given a bright and lively tone to a work of great value."—*Morning Post.*

"The volume is exceedingly interesting, and forms excellent reading for the popular, as well as the scientific world."—*Scientific American.*

"This production of Mr. Haldane's is a welcome novelty in the field of engineering literature, and contains much useful information and sound advice pleasantly conveyed."—*American Engineering News.*

"This volume is of a kind which has not been written before, and is full of interesting and really useful bits of engineering experience that are not as a rule recorded."—*The Engineer.*

"In an open and unrestrained style, Mr. Haldane gives the reminiscences of thirty-seven years' experience of engineering, and although light is thrown on the works of Messrs. Denny, Tod & Macgregor, Napier, &c., the reminiscences are mostly those of a long connection with Messrs. Laird. His experiences of private practice should be studied by such as desire to follow his steps."—*Engineering.*

"Mr. Haldane so deals with *Engineering*, that readers of all kinds will not lay down his book until they have read it through."—*Graphic.*

"As a work replete with interesting and serviceable information, clearly and pleasantly conveyed, it is, so far as engineering goes, practically unrivalled."—*British Journal of Commerce.*

"A volume which teems with valuable—one might even say indispensable—information."—*Machinery and Iron and Steel Trades' Review.*

"One of the most instructive books we have ever read."—*Engineer's Gazette.*

"The volume is unique, and Mr. Haldane is to be congratulated on the admirable manner in which he has handled his subject."—*The Steamship.*

"The aim of the writer has been to make this valuable work intelligible to the average reader, and in this Mr. Haldane has succeeded admirably."—*The Shipping Telegraph.*

"The book is written in a robust, breezy sort of manner, that enables

one to read chapter after chapter with pleasure, but at the same time with profit. The volume has, we think, been a labour of love."—*The Shipping World.*

"We are much obliged to Mr. Haldane for this book, which should have been noticed earlier, but we had not expected it to be so entertaining as it really is."—*Illustrated London News.*

"What gives Mr. Haldane's book its specially readable quality, is its unconventional style, and its author's familiar acquaintance with all sorts of engineering men, thus giving a peculiar insight into one of the most interesting departments of modern industry."—*The Scotsman.*

"Eminently practical and authoritative. Where the author acquired his scientific knowledge one may perceive, but where he gained his capital literary style is not so easy to determine."—*Glasgow Weekly Citizen.*

"Mr. Haldane's volume will convince the reader that no one could be more fitted to present in an attractive manner the different phases of engineering. His reminiscences of Messrs. Laird Brothers' Works are delightful reading."—*Journal of Commerce.*

"There is hardly a department of mechanical engineering Mr. Haldane is not practically acquainted with, and hardly a member of any of those departments but will find in this work something to interest, to amuse, and to edify,"—*Western Mail.*

"This book has a purpose which it is more likely to accomplish in its unconventional style than if it had been written as a formal treatise."—*Industries.*

"The book is one to be read at home, and should be in the library of every engineer and machinery user."—*Machinery Market.*

"We have much pleasure in recommending Mr. Haldane's most attractive book, especially when the details are set forth with such clearness and in so pleasing a style."—*Irish Times.*

"The whole work deserves the highest praise, and reflects much credit upon the author."—*Liverpool Mercury.*

"Mr. Haldane's book is one which only a veteran expert could have written."—*Newcastle Daily Leader.*

"The object of the author has been accomplished, with a success which is only possible where a fluent style and graphic pen are combined with a thorough knowledge of details, and a wide personal experience."—*Leeds Mercury.*

"The work affords the general reader all he wishes to know of engineering."—*Glasgow Herald.*

LONDON: E. & F. N. SPON, 125 STRAND.
NEW YORK: SPON & CHAMBERLAIN, 12 CORTLANDT STREET.

LIVERPOOL:
D. MARPLES AND CO.,
LORD STREET.

BOOKS RELATING TO APPLIED SCIENCE

PUBLISHED BY

E. & F. N. SPON.

LONDON: 125 STRAND.

NEW YORK: 12 CORTLANDT STREET.

The Engineers' Sketch-Book of Mechanical Movements, Devices, Appliances, Contrivances, Details employed in the Design and Construction of Machinery for every purpose. Collected from numerous Sources and from Actual Work. Classified and Arranged for Reference. *Nearly* 2000 *Illustrations.* By T. B. BARBER, Engineer. Second Edition, 8vo, cloth, 7*s.* 6*d.*

A Pocket-Book for Chemists, Chemical Manufacturers, Metallurgists, Dyers, Distillers, Brewers, Sugar Refiners, Photographers, Students, etc., etc. By THOMAS BAYLEY, Assoc. R.C. Sc. Ireland, Analytical and Consulting Chemist and Assayer. Fifth edition, 481 pp., royal 32mo, roan, gilt edges, 5*s.*

SYNOPSIS OF CONTENTS:

Atomic Weights and Factors—Useful Data—Chemical Calculations—Rules for Indirect Analysis—Weights and Measures—Thermometers and Barometers—Chemical Physics—Boiling Points, etc.—Solubility of Substances—Methods of Obtaining Specific Gravity—Conversion of Hydrometers—Strength of Solutions by Specific Gravity—Analysis—Gas Analysis—Water Analysis—Qualitative Analysis and Reactions—Volumetric Analysis—Manipulation—Mineralogy—Assaying—Alcohol—Beer—Sugar—Miscellaneous Technological matter relating to Potash, Soda, Sulphuric Acid, Chlorine, Tar Products, Petroleum, Milk, Tallow, Photography, Prices, Wages, Appendix, etc., etc.

Electricity, its Theory, Sources, and Applications. By JOHN T. SPRAGUE, M. Inst. E.E. Third edition, thoroughly revised and extended, *with numerous illustrations and tables*, crown 8vo, cloth, 15*s.*

Electric Toys. Electric Toy-Making, Dynamo Building and Electric Motor Construction for Amateurs. By T. O'CONOR SLOANE, Ph.D. *With cuts*, square 16mo, cloth, 4*s.* 6*d.*

The Phonograph, and How to Construct it. With a Chapter on Sound. By W. GILLETT. *With engravings and full working drawings*, crown 8vo, cloth, 5*s.*

Just Published, in Demy 8vo, cloth, containing 975 pages and 250 Illustrations, price 7s. 6d.

SPONS' HOUSEHOLD MANUAL:

A Treasury of Domestic Receipts and Guide for Home Management.

PRINCIPAL CONTENTS.

Hints for selecting a good House, pointing out the essential requirements for a good house as to the Site, Soil, Trees, Aspect, Construction, and General Arrangement; with instructions for Reducing Echoes, Waterproofing Damp Walls, Curing Damp Cellars.

Sanitation.—What should constitute a good Sanitary Arrangement; Examples (with Illustrations) of Well- and Ill-drained Houses; How to Test Drains; Ventilating Pipes, etc.

Water Supply.—Care of Cisterns; Sources of Supply; Pipes; Pumps; Purification and Filtration of Water.

Ventilation and Warming.—Methods of Ventilating without causing cold draughts, by various means; Principles of Warming; Health Questions; Combustion; Open Grates; Open Stoves; Fuel Economisers; Varieties of Grates; Close-Fire Stoves; Hot-air Furnaces; Gas Heating; Oil Stoves; Steam Heating; Chemical Heaters; Management of Flues; and Cure of Smoky Chimneys.

Lighting.—The best methods of Lighting; Candles, Oil Lamps, Gas, Incandescent Gas, Electric Light; How to test Gas Pipes; Management of Gas.

Furniture and Decoration.—Hints on the Selection of Furniture; on the most approved methods of Modern Decoration; on the best methods of arranging Bells and Calls; How to Construct an Electric Bell.

Thieves and Fire.—Precautions against Thieves and Fire; Methods of Detection; Domestic Fire Escapes; Fireproofing Clothes, etc.

The Larder.—Keeping Food fresh for a limited time; Storing Food without change, such as Fruits, Vegetables, Eggs, Honey, etc.

Curing Foods for lengthened Preservation, as Smoking, Salting, Canning, Potting, Pickling, Bottling Fruits, etc.; Jams, Jellies, Marmalade, etc.

The Dairy.—The Building and Fitting of Dairies in the most approved modern style; Butter-making; Cheesemaking and Curing.

The Cellar.—Building and Fitting; Cleaning Casks and Bottles; Corks and Corking; Aërated Drinks; Syrups for Drinks; Beers; Bitters; Cordials and Liqueurs; Wines; Miscellaneous Drinks.

The Pantry.—Bread-making; Ovens and Pyrometers; Yeast; German Yeast; Biscuits; Cakes; Fancy Breads; Buns.

The Kitchen.—On Fitting Kitchens; a description of the best Cooking Ranges, close and open; the Management and Care of Hot Plates, Baking Ovens, Dampers, Flues, and Chimneys; Cooking by Gas; Cooking by Oil; the Arts of Roasting, Grilling, Boiling, Stewing, Braising, Frying.

Receipts for Dishes—Soups, Fish, Meat, Game, Poultry, Vegetables, Salads, Puddings, Pastry, Confectionery, Ices, etc., etc.; Foreign Dishes.

The Housewife's Room.—Testing Air, Water, and Foods; Cleaning and Renovating; Destroying Vermin.

Housekeeping, Marketing.

The Dining-Room.—Dietetics; Laying and Waiting at Table: Carving; Dinners, Breakfasts, Luncheons, Teas, Suppers, etc.

The Drawing-Room.—Etiquette; Dancing; Amateur Theatricals; Tricks and Illusions; Games (indoor).

The Bedroom and Dressing-Room; Sleep; the Toilet; Dress; Buying Clothes; Outfits; Fancy Dress.

The Nursery.—The Room; Clothing; Washing; Exercise; Sleep; Feeding; Teething; Illness; Home Training.

The Sick-Room.—The Room; the Nurse; the Bed; Sick Room Accessories; Feeding Patients; Invalid Dishes and Drinks; Administering Physic; Domestic Remedies; Accidents and Emergencies; Bandaging; Burns; Carrying Injured Persons; Wounds; Drowning; Fits; Frost-bites; Poisons and Antidotes; Sunstroke; Common Complaints; Disinfection, etc.

The Bath-Room.—Bathing in General; Management of Hot-Water System.

The Laundry.—Small Domestic Washing Machines, and methods of getting up linen. Fitting up and Working a Steam Laundry.

The School-Room.—The Room and its Fittings; Teaching, etc.

The Playground.—Air and Exercise; Training; Outdoor Games and Sports.

The Workroom.—Darning, Patching, and Mending Garments.

The Library.—Care of Books.

The Garden.—Calendar of Operations for Lawn, Flower Garden, and Kitchen Garden.

The Farmyard.—Management of the Horse, Cow, Pig, Poultry, Bees, etc., etc.

Small Motors.—A description of the various small Engines useful for domestic purposes, from 1 man to 1 horse power, worked by various methods, such as Electric Engines, Gas Engines, Petroleum Engines, Steam Engines, Condensing Engines, Water Power, Wind Power, and the various methods of working and managing them.

Household Law.—The Law relating to Landlords and Tenants, Lodgers, Servants, Parochial Authorities, Juries, Insurance, Nuisance, etc.

On Designing Belt Gearing. By E. J. COWLING WELCH, Mem. Inst. Mech. Engineers, Author of 'Designing Valve Gearing.' Fcap. 8vo, sewed, 6*d.*

A Handbook of Formulæ, Tables, and Memoranda, for Architectural Surveyors and others engaged in Building. By J. T. HURST, C.E. Fourteenth edition, royal 32mo, roan, 5*s.*

"It is no disparagement to the many excellent publications we refer to, to say that in our opinion this little pocket-book of Hurst's is the very best of them all, without any exception. It would be useless to attempt a recapitulation of the contents, for it appears to contain almost *everything* that anyone connected with building could require, and, best of all, made up in a compact form for carrying in the pocket, measuring only 5 in. by 3 in., and about ¾ in. thick, in a limp cover. We congratulate the author on the success of his laborious and practically compiled little book, which has received unqualified and deserved praise from every professional person to whom we have shown it."—*The Dublin Builder.*

Tabulated Weights of Angle, Tee, Bulb, Round, Square, and Flat Iron and Steel, and other information for the use of Naval Architects and Shipbuilders. By C. H. JORDAN, M.I.N.A. Fourth edition, 32mo, cloth, 2*s.* 6*d.*

A Complete Set of Contract Documents for a Country Lodge, comprising Drawings, Specifications, Dimensions (for quantities), Abstracts, Bill of Quantities, Form of Tender and Contract, with Notes by J. LEANING, printed in facsimile of the original documents, on single sheets fcap., in paper case, 10*s.*

A Practical Treatise on Heat, as applied to the Useful Arts; for the Use of Engineers, Architects, &c. By THOMAS BOX. *With* 14 *plates.* Sixth edition, crown 8vo, cloth, 12*s.* 6*d.*

A Descriptive Treatise on Mathematical Drawing Instruments: their construction, uses, qualities, selection, preservation, and suggestions for improvements, with hints upon Drawing and Colouring. By W. F. STANLEY, M.R.I. Sixth edition, *with numerous illustrations,* crown 8vo, cloth, 5*s.*

Quantity Surveying. By J. LEANING. With 42 illustrations. Second edition, revised, crown 8vo, cloth, 9*s.*

CONTENTS:

A complete Explanation of the London Practice.
General Instructions.
Order of Taking Off.
Modes of Measurement of the various Trades.
Use and Waste.
Ventilation and Warming.
Credits, with various Examples of Treatment.
Abbreviations.
Squaring the Dimensions.
Abstracting, with Examples in illustration of each Trade.
Billing.
Examples of Preambles to each Trade.
Form for a Bill of Quantities.
Do. Bill of Credits.
Do. Bill for Alternative Estimate.
Restorations and Repairs, and Form of Bill.
Variations before Acceptance of Tender.
Errors in a Builder's Estimate.
Schedule of Prices.
Form of Schedule of Prices.
Analysis of Schedule of Prices.
Adjustment of Accounts.
Form of a Bill of Variations.
Remarks on Specifications.
Prices and Valuation of Work, with Examples and Remarks upon each Trade.
The Law as it affects Quantity Surveyors, with Law Reports.
Taking Off after the Old Method.
Northern Practice.
The General Statement of the Methods recommended by the Manchester Society of Architects for taking Quantities.
Examples of Collections.
Examples of "Taking Off" in each Trade.
Remarks on the Past and Present Methods of Estimating.

Spons' Architects' and Builders' Price Book, with useful Memoranda. Edited by W. YOUNG, Architect. Crown 8vo, cloth, red edges, 3*s.* 6*d.* *Published annually.* Nineteenth edition. *Now ready.*

Long-Span Railway Bridges, comprising Investigations of the Comparative Theoretical and Practical Advantages of the various adopted or proposed Type Systems of Construction, with numerous Formulæ and Tables giving the weight of Iron or Steel required in Bridges from 300 feet to the limiting Spans; to which are added similar Investigations and Tables relating to Short-span Railway Bridges. Second and revised edition. By B. BAKER, Assoc. Inst. C.E. *Plates*, crown 8vo, cloth, 5*s.*

Elementary Theory and Calculation of Iron Bridges and Roofs. By AUGUST RITTER, Ph.D., Professor at the Polytechnic School at Aix-la-Chapelle. Translated from the third German edition, by H. R. SANKEY, Capt. R.E. With 500 *illustrations*, 8vo, cloth, 15*s.*

The Elementary Principles of Carpentry. By THOMAS TREDGOLD. Revised from the original edition, and partly re-written, by JOHN THOMAS HURST. Contained in 517 pages of letterpress, and *illustrated with* 48 *plates and* 150 *wood engravings.* Sixth edition, reprinted from the third, crown 8vo, cloth, 12*s.* 6*d.*

Section I. On the Equality and Distribution of Forces — Section II. Resistance of Timber — Section III. Construction of Floors — Section IV. Construction of Roofs — Section V. Construction of Domes and Cupolas — Section VI. Construction of Partitions — Section VII. Scaffolds, Staging, and Gantries — Section VIII. Construction of Centres for Bridges — Section IX. Coffer-dams, Shoring, and Strutting — Section X. Wooden Bridges and Viaducts — Section XI. Joints, Straps, and other Fastenings — Section XII. Timber.

The Builder's Clerk: a Guide to the Management of a Builder's Business. By THOMAS BALES. Fcap. 8vo, cloth, 1*s.* 6*d.*

Practical Gold-Mining: a Comprehensive Treatise on the Origin and Occurrence of Gold-bearing Gravels, Rocks and Ores, and the methods by which the Gold is extracted. By C. G. WARNFORD LOCK, co-Author of 'Gold: its Occurrence and Extraction.' *With* 8 *plates and* 275 *engravings in the text*, royal 8vo, cloth, 2*l.* 2*s.*

Hot Water Supply: A Practical Treatise upon the Fitting of Circulating Apparatus in connection with Kitchen Range and other Boilers, to supply Hot Water for Domestic and General Purposes. With a Chapter upon Estimating. *Fully illustrated*, crown 8vo, cloth, 3*s.*

Hot Water Apparatus: An Elementary Guide for the Fitting and Fixing of Boilers and Apparatus for the Circulation of Hot Water for Heating and for Domestic Supply, and containing a Chapter upon Boilers and Fittings for Steam Cooking. 32 *illustrations*, fcap. 8vo, cloth, 1*s.* 6*d.*

The Use and Misuse, and the Proper and Improper Fixing of a Cooking Range. Illustrated, fcap. 8vo, sewed, 6*d.*

Iron Roofs: Examples of Design, Description. *Illustrated with* 64 *Working Drawings of Executed Roofs.* By ARTHUR T. WALMISLEY, Assoc. Mem. Inst. C.E. Second edition, revised, imp. 4to, half-morocco, 3*l.* 3*s.*

A History of Electric Telegraphy, to the Year 1837. Chiefly compiled from Original Sources, and hitherto Unpublished Documents, by J. J. FAHIE, Mem. Soc. of Tel. Engineers, and of the International Society of Electricians, Paris. Crown 8vo, cloth, 9*s.*

Spons' Information for Colonial Engineers. Edited by J. T. HURST. Demy 8vo, sewed.

No. 1, Ceylon. By ABRAHAM DEANE, C.E. 2*s.* 6*d.*

CONTENTS:

Introductory Remarks—Natural Productions—Architecture and Engineering—Topography, Trade, and Natural History—Principal Stations—Weights and Measures, etc., etc.

No. 2. Southern Africa, including the Cape Colony, Natal, and the Dutch Republics. By HENRY HALL, F.R.G.S., F.R.C.I. With Map. 3*s.* 6*d.*

CONTENTS:

General Description of South Africa—Physical Geography with reference to Engineering Operations—Notes on Labour and Material in Cape Colony—Geological Notes on Rock Formation in South Africa—Engineering Instruments for Use in South Africa—Principal Public Works in Cape Colony: Railways, Mountain Roads and Passes, Harbour Works, Bridges, Gas Works, Irrigation and Water Supply, Lighthouses, Drainage and Sanitary Engineering, Public Buildings, Mines—Table of Woods in South Africa—Animals used for Draught Purposes—Statistical Notes—Table of Distances—Rates of Carriage, etc.

No. 3. India. By F. C. DANVERS, Assoc. Inst. C.E. With Map. 4*s.* 6*d.*

CONTENTS:

Physical Geography of India—Building Materials—Roads—Railways—Bridges—Irrigation—River Works—Harbours—Lighthouse Buildings—Native Labour—The Principal Trees of India—Money—Weights and Measures—Glossary of Indian Terms, etc.

Our Factories, Workshops, and Warehouses: their Sanitary and Fire-Resisting Arrangements. By B. H. THWAITE, Assoc. Mem. Inst. C.E. *With* 183 *wood engravings*, crown 8vo, cloth, 9*s*.

A Practical Treatise on Coal Mining. By GEORGE G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Member of the Society of Engineers. *With* 82 *lithographic plates*. 2 vols., royal 4to, cloth, 3*l*. 12*s*.

A Practical Treatise on Casting and Founding, including descriptions of the modern machinery employed in the art. By N. E. SPRETSON, Engineer. Fifth edition, with 82 *plates* drawn to scale, 412 pp., demy 8vo, cloth, 18*s*.

A Handbook of Electrical Testing. By H. R. KEMPE, M.S.T.E. Fourth edition, revised and enlarged, crown 8vo, cloth, 16*s*.

The Clerk of Works: a Vade-Mecum for all engaged in the Superintendence of Building Operations. By G. G. HOSKINS, F.R.I.B.A. Third edition, fcap. 8vo, cloth, 1*s*. 6*d*.

American Foundry Practice: Treating of Loam, Dry Sand, and Green Sand Moulding, and containing a Practical Treatise upon the Management of Cupolas, and the Melting of Iron. By T. D. WEST, Practical Iron Moulder and Foundry Foreman. Second edition, *with numerous illustrations*, crown 8vo, cloth, 10*s*. 6*d*.

The Maintenance of Macadamised Roads. By T. CODRINGTON, M.I.C.E, F.G.S., General Superintendent of County Roads for South Wales. Second edition, 8vo, cloth, 7*s*. 6*d*.

Hydraulic Steam and Hand Power Lifting and Pressing Machinery. By FREDERICK COLYER, M. Inst. C.E., M. Inst. M.E. *With* 73 *plates*, 8vo, cloth, 18*s*.

Pumps and Pumping Machinery. By F. COLYER, M.I.C.E., M.I.M.E. *With* 23 *folding plates*, 8vo, cloth, 12*s*. 6*d*.

Pumps and Pumping Machinery. By F. COLYER. Second Part. *With* 11 *large plates*, 8vo, cloth, 12*s*. 6*d*.

A Treatise on the Origin, Progress, Prevention, and Cure of Dry Rot in Timber; with Remarks on the Means of Preserving Wood from Destruction by Sea-Worms, Beetles, Ants, etc. By THOMAS ALLEN BRITTON, late Surveyor to the Metropolitan Board of Works, etc., etc. *With* 10 *plates*, crown 8vo, cloth, 7*s*. 6*d*.

The Artillery of the Future and the New Powders. By J. A. LONGRIDGE, Mem. Inst. C.E. 8vo, cloth, 5*s*.

Gas Works: their Arrangement, Construction, Plant, and Machinery. By F. COLYER, M. Inst. C.E. *With* 31 *folding plates*, 8vo, cloth, 12*s*. 6*d*.

The Municipal and Sanitary Engineer's Handbook. By H. PERCY BOULNOIS, Mem. Inst. C.E., Borough Engineer, Portsmouth. *With numerous illustrations.* Second edition, demy 8vo, cloth, 15*s*.

CONTENTS:

The Appointment and Duties of the Town Surveyor—Traffic—Macadamised Roadways—Steam Rolling—Road Metal and Breaking—Pitched Pavements—Asphalte—Wood Pavements—Footpaths—Kerbs and Gutters—Street Naming and Numbering—Street Lighting—Sewerage—Ventilation of Sewers—Disposal of Sewage—House Drainage—Disinfection—Gas and Water Companies, etc., Breaking up Streets—Improvement of Private Streets—Borrowing Powers—Artizans' and Labourers' Dwellings—Public Conveniences—Scavenging, including Street Cleansing—Watering and the Removing of Snow—Planting Street Trees—Deposit of Plans—Dangerous Buildings—Hoardings—Obstructions—Improving Street Lines—Cellar Openings—Public Pleasure Grounds—Cemeteries—Mortuaries—Cattle and Ordinary Markets—Public Slaughter-houses, etc.—Giving numerous Forms of Notices, Specifications, and General Information upon these and other subjects of great importance to Municipal Engineers and others engaged in Sanitary Work.

Metrical Tables. By Sir G. L. MOLESWORTH, M.I.C.E. 32mo, cloth, 1*s*. 6*d*.

CONTENTS.

General—Linear Measures—Square Measures—Cubic Measures—Measures of Capacity—Weights—Combinations—Thermometers.

Elements of Construction for Electro-Magnets. By Count TH. DU MONCEL, Mem. de l'Institut de France. Translated from the French by C. J. WHARTON. Crown 8vo, cloth, 4*s*. 6*d*.

A Treatise on the Use of Belting for the Transmission of Power. By J. H. COOPER. Second edition, *illustrated*, 8vo, cloth, 15*s*.

A Pocket-Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers. By Sir GUILFORD L. MOLESWORTH, Mem. Inst. C.E. *With numerous illustrations*, 744 pp. Twenty-second edition, 32mo, roan, 6*s*.

SYNOPSIS OF CONTENTS:

Surveying, Levelling, etc.—Strength and Weight of Materials—Earthwork, Brickwork, Masonry, Arches, etc.—Struts, Columns, Beams, and Trusses—Flooring, Roofing, and Roof Trusses—Girders, Bridges, etc.—Railways and Roads—Hydraulic Formulæ—Canals, Sewers, Waterworks, Docks—Irrigation and Breakwaters—Gas, Ventilation, and Warming—Heat, Light, Colour, and Sound—Gravity: Centres, Forces, and Powers—Millwork, Teeth of Wheels, Shafting, etc.—Workshop Recipes—Sundry Machinery—Animal Power—Steam and the Steam Engine—Water-power, Water-wheels, Turbines, etc.—Wind and Windmills—Steam Navigation, Ship Building, Tonnage, etc.—Gunnery, Projectiles, etc.—Weights, Measures, and Money—Trigonometry, Conic Sections, and Curves—Telegraphy—Mensuration—Tables of Areas and Circumference, and Arcs of Circles—Logarithms, Square and Cube Roots, Powers—Reciprocals, etc.—Useful Numbers—Differential and Integral Calculus—Algebraic Signs—Telegraphic Construction and Formulæ.

Hints on Architectural Draughtsmanship. By G. W. TUXFORD HALLATT. Fcap. 8vo, cloth, 1*s.* 6*d.*

Spons' Tables and Memoranda for Engineers; selected and arranged by J. T. HURST, C.E., Author of 'Architectural Surveyors' Handbook,' 'Hurst's Tredgold's Carpentry,' etc. Eleventh edition, 64mo, roan, gilt edges, 1*s.*; or in cloth case, 1*s.* 6*d.*

This work is printed in a pearl type, and is so small, measuring only $2\frac{1}{2}$ in. by $1\frac{3}{4}$ in. by $\frac{1}{4}$ in. thick, that it may be easily carried in the waistcoat pocket.

"It is certainly an extremely rare thing for a reviewer to be called upon to notice a volume measuring but $2\frac{1}{2}$ in. by $1\frac{3}{4}$ in., yet these dimensions faithfully represent the size of the handy little book before us. The volume—which contains 118 printed pages, besides a few blank pages for memoranda—is, in fact, a true pocket-book, adapted for being carried in the waistcoat pocket, and containing a far greater amount and variety of information than most people would imagine could be compressed into so small a space. . . . . The little volume has been compiled with considerable care and judgment, and we can cordially recommend it to our readers as a useful little pocket companion."—*Engineering.*

A Practical Treatise on Natural and Artificial Concrete, its Varieties and Constructive Adaptations. By HENRY REID, Author of the 'Science and Art of the Manufacture of Portland Cement.' New Edition, *with* 59 *woodcuts and* 5 *plates*, 8vo, cloth, 15*s.*

Notes on Concrete and Works in Concrete; especially written to assist those engaged upon Public Works. By JOHN NEWMAN, Assoc. Mem. Inst. C.E., crown 8vo, cloth, 4*s.* 6*d.*

Electricity as a Motive Power. By Count TH. DU MONCEL, Membre de l'Institut de France, and FRANK GERALDY, Ingénieur des Ponts et Chaussées. Translated and Edited, with Additions, by C. J. WHARTON, Assoc. Soc. Tel. Eng. and Elec. *With* 113 *engravings and diagrams*, crown 8vo, cloth, 7*s.* 6*d.*

Treatise on Valve-Gears, with special consideration of the Link-Motions of Locomotive Engines. By Dr. GUSTAV ZEUNER, Professor of Applied Mechanics at the Confederated Polytechnikum of Zurich. Translated from the Fourth German Edition, by Professor J. F. KLEIN, Lehigh University, Bethlehem, Pa. *Illustrated*, 8vo, cloth, 12*s.* 6*d.*

The French-Polisher's Manual. By a French-Polisher; containing Timber Staining, Washing, Matching, Improving, Painting, Imitations, Directions for Staining, Sizing, Embodying, Smoothing, Spirit Varnishing, French-Polishing, Directions for Re-polishing. Third edition, royal 32mo, sewed, 6*d.*

Hops, their Cultivation, Commerce, and Uses in various Countries. By P. L. SIMMONDS. Crown 8vo, cloth, 4*s.* 6*d.*

The Principles of Graphic Statics. By GEORGE SYDENHAM CLARKE, Major Royal Engineers. *With* 112 *illustrations.* Second edition, 4to, cloth, 12*s.* 6*d.*

Dynamo Tenders' Hand-Book. By F. B. BADT, late 1st Lieut. Royal Prussian Artillery. *With* 70 *illustrations.* Third edition, 18mo, cloth, 4*s*. 6*d*.

Practical Geometry, Perspective, and Engineering Drawing; a Course of Descriptive Geometry adapted to the Requirements of the Engineering Draughtsman, including the determination of cast shadows and Isometric Projection, each chapter being followed by numerous examples; to which are added rules for Shading, Shade-lining, etc., together with practical instructions as to the Lining, Colouring, Printing, and general treatment of Engineering Drawings, with a chapter on drawing Instruments. By GEORGE S. CLARKE, Capt. R.E. Second edition, *with* 21 *plates.* 2 vols., cloth, 10*s*. 6*d*.

The Elements of Graphic Statics. By Professor KARL VON OTT, translated from the German by G. S. CLARKE, Capt. R.E., Instructor in Mechanical Drawing, Royal Indian Engineering College. *With* 93 *illustrations*, crown 8vo, cloth, 5*s*.

A Practical Treatise on the Manufacture and Distribution of Coal Gas. By WILLIAM RICHARDS. Demy 4to, with *numerous wood engravings and* 29 *plates*, cloth, 28*s*.

SYNOPSIS OF CONTENTS:

Introduction—History of Gas Lighting—Chemistry of Gas Manufacture, by Lewis Thompson, Esq., M.R.C.S.—Coal, with Analyses, by J. Paterson, Lewis Thompson, and G. R. Hislop, Esqrs.—Retorts, Iron and Clay—Retort Setting—Hydraulic Main—Condensers—Exhausters—Washers and Scrubbers—Purifiers—Purification—History of Gas Holder—Tanks, Brick and Stone, Composite, Concrete, Cast-iron, Compound Annular Wrought-iron—Specifications—Gas Holders—Station Meter—Governor—Distribution—Mains—Gas Mathematics, or Formulæ for the Distribution of Gas, by Lewis Thompson, Esq.—Services—Consumers' Meters—Regulators—Burners—Fittings—Photometer—Carburization of Gas—Air Gas and Water Gas—Composition of Coal Gas, by Lewis Thompson, Esq.—Analyses of Gas—Influence of Atmospheric Pressure and Temperature on Gas—Residual Products—Appendix—Description of Retort Settings, Buildings, etc., etc.

The New Formula for Mean Velocity of Discharge of Rivers and Canals. By W. R. KUTTER. Translated from articles in the 'Cultur-Ingénieur,' by LOWIS D'A. JACKSON, Assoc. Inst. C.E. 8vo, cloth, 12*s*. 6*d*.

The Practical Millwright and Engineer's Ready Reckoner; or Tables for finding the diameter and power of cog-wheels, diameter, weight, and power of shafts, diameter and strength of bolts, etc. By THOMAS DIXON. Fourth edition, 12mo, cloth, 3*s*.

Tin: Describing the Chief Methods of Mining, Dressing and Smelting it abroad; with Notes upon Arsenic, Bismuth and Wolfram. By ARTHUR G. CHARLETON, Mem. American Inst. of Mining Engineers. *With plates*, 8vo, cloth, 12*s*. 6*d*.

Perspective, Explained and Illustrated. By G. S. CLARKE, Capt. R.E. *With illustrations*, 8vo, cloth, 3*s*. 6*d*.

Practical Hydraulics; a Series of Rules and Tables for the use of Engineers, etc., etc. By THOMAS BOX. Ninth edition, *numerous plates*, post 8vo, cloth, 5*s*.

The Essential Elements of Practical Mechanics; based on the Principle of Work, designed for Engineering Students. By OLIVER BYRNE, formerly Professor of Mathematics, College for Civil Engineers. Third edition, *with* 148 *wood engravings*, post 8vo, cloth, 7*s*. 6*d*.

CONTENTS:

Chap. 1. How Work is Measured by a Unit, both with and without reference to a Unit of Time—Chap. 2. The Work of Living Agents, the Influence of Friction, and introduces one of the most beautiful Laws of Motion—Chap. 3. The principles expounded in the first and second chapters are applied to the Motion of Bodies—Chap. 4. The Transmission of Work by simple Machines—Chap. 5. Useful Propositions and Rules.

Breweries and Maltings: their Arrangement, Construction, Machinery, and Plant. By G. SCAMELL, F.R.I.B.A. Second edition, revised, enlarged, and partly rewritten. By F. COLYER, M.I.C.E., M.I.M.E. *With* 20 *plates*, 8vo, cloth, 12*s*. 6*d*.

A Practical Treatise on the Construction of Horizontal and Vertical Waterwheels, specially designed for the use of operative mechanics. By WILLIAM CULLEN, Millwright and Engineer. *With* 11 *plates*. Second edition, revised and enlarged, small 4to, cloth, 12*s*. 6*d*.

A Practical Treatise on Mill-gearing, Wheels, Shafts, Riggers, etc.; for the use of Engineers. By THOMAS BOX. Third edition, *with* 11 *plates*. Crown 8vo, cloth, 7*s*. 6*d*.

Mining Machinery: a Descriptive Treatise on the Machinery, Tools, and other Appliances used in Mining. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Mem. of the Society of Engineers. Royal 4to, uniform with the Author's Treatise on Coal Mining, containing 182 *plates*, accurately drawn to scale, with descriptive text, in 2 vols., cloth, 3*l*. 12*s*.

CONTENTS:

Machinery for Prospecting, Excavating, Hauling, and Hoisting—Ventilation—Pumping—Treatment of Mineral Products, including Gold and Silver, Copper, Tin, and Lead, Iron, Coal, Sulphur, China Clay, Brick Earth, etc.

Tables for Setting out Curves for Railways, Canals, Roads, etc., varying from a radius of five chains to three miles. By A. KENNEDY and R. W. HACKWOOD. *Illustrated* 32mo, cloth, 2*s*. 6*d*.

Practical Electrical Notes and Definitions for the use of Engineering Students and Practical Men. By W. PERREN MAYCOCK, Assoc. M. Inst. E.E., Instructor in Electrical Engineering at the Pitlake Institute, Croydon, together with the Rules and Regulations to be observed in Electrical Installation Work. Second edition. Royal 32mo, roan, gilt edges, 4*s.* 6*d.*, or cloth, red edges, 3*s.*

The Draughtsman's Handbook of Plan and Map Drawing; including instructions for the preparation of Engineering, Architectural, and Mechanical Drawings. *With numerous illustrations in the text, and* 33 *plates* (15 *printed in colours*). By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. 4to, cloth, 9*s.*

CONTENTS:

The Drawing Office and its Furnishings—Geometrical Problems—Lines, Dots, and their Combinations—Colours, Shading, Lettering, Bordering, and North Points—Scales—Plotting—Civil Engineers' and Surveyors' Plans—Map Drawing—Mechanical and Architectural Drawing—Copying and Reducing Trigonometrical Formulæ, etc., etc.

The Boiler-maker's and Iron Ship-builder's Companion, comprising a series of original and carefully calculated tables, of the utmost utility to persons interested in the iron trades. By JAMES FODEN, author of 'Mechanical Tables,' etc. Second edition revised, *with illustrations*, crown 8vo, cloth, 5*s.*

Rock Blasting: a Practical Treatise on the means employed in Blasting Rocks for Industrial Purposes. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. *With* 56 *illustrations and* 12 *plates*, 8vo, cloth, 10*s.* 6*d.*

Experimental Science: Elementary, Practical, and Experimental Physics. By GEO. M. HOPKINS. *Illustrated by* 672 *engravings.* In one large vol., 8vo, cloth, 15*s.*

A Treatise on Ropemaking as practised in public and private Rope-yards, with a Description of the Manufacture, Rules, Tables of Weights, etc., adapted to the Trade, Shipping, Mining, Railways, Builders, etc. By R. CHAPMAN, formerly foreman to Messrs. Huddart and Co., Limehouse, and late Master Ropemaker to H.M. Dockyard, Deptford. Second edition, 12mo, cloth, 3*s.*

Laxton's Builders' and Contractors' Tables; for the use of Engineers, Architects, Surveyors, Builders, Land Agents, and others. Bricklayer, containing 22 tables, with nearly 30,000 calculations. 4to, cloth, 5*s.*

Laxton's Builders' and Contractors' Tables. Excavator, Earth, Land, Water, and Gas, containing 53 tables, with nearly 24,000 calculations. 4to, cloth, 5*s.*

Egyptian Irrigation. By W. WILLCOCKS, M.I.C.E., Indian Public Works Department, Inspector of Irrigation, Egypt. With Introduction by Lieut.-Col. J. C. ROSS, R.E., Inspector-General of Irrigation. *With numerous lithographs and wood engravings*, royal 8vo, cloth, 1*l.* 16*s.*

Screw Cutting Tables for Engineers and Machinists, giving the values of the different trains of Wheels required to produce Screws of any pitch, calculated by Lord Lindsay, M.P., F.R.S., F.R.A.S., etc. Cloth, oblong, 2*s.*

Screw Cutting Tables, for the use of Mechanical Engineers, showing the proper arrangement of Wheels for cutting the Threads of Screws of any required pitch, with a Table for making the Universal Gas-pipe Threads and Taps. By W. A. MARTIN, Engineer. Second edition, oblong, cloth, 1*s.*, or sewed, 6*d.*

A Treatise on a Practical Method of Designing Slide-Valve Gears by Simple Geometrical Construction, based upon the principles enunciated in Euclid's Elements, and comprising the various forms of Plain Slide-Valve and Expansion Gearing; together with Stephenson's, Gooch's, and Allan's Link-Motions, as applied either to reversing or to variable expansion combinations. By EDWARD J. COWLING WELCH, Memb. Inst. Mechanical Engineers. Crown 8vo, cloth, 6*s.*

Cleaning and Scouring: a Manual for Dyers, Laundresses, and for Domestic Use. By S. CHRISTOPHER. 18mo, sewed, 6*d.*

A Glossary of Terms used in Coal Mining. By WILLIAM STUKELEY GRESLEY, Assoc. Mem. Inst. C.E., F.G.S., Member of the North of England Institute of Mining Engineers. *Illustrated with numerous woodcuts and diagrams*, crown 8vo, cloth, 5*s.*

A Pocket-Book for Boiler Makers and Steam Users, comprising a variety of useful information for Employer and Workman, Government Inspectors, Board of Trade Surveyors, Engineers in charge of Works and Slips, Foremen of Manufactories, and the general Steam-using Public. By MAURICE JOHN SEXTON. Second edition, royal 32mo, roan, gilt edges, 5*s.*

Electrolysis: a Practical Treatise on Nickeling, Coppering, Gilding, Silvering, the Refining of Metals, and the treatment of Ores by means of Electricity. By HIPPOLYTE FONTAINE, translated from the French by J. A. BERLY, C.E., Assoc. S.T.E. *With engravings.* 8vo, cloth, 9*s.*

Barlow's Tables of Squares, Cubes, Square Roots, Cube Roots, Reciprocals of all Integer Numbers up to 10,000. Post 8vo, cloth, 6*s*.

A Practical Treatise on the Steam Engine, containing Plans and Arrangements of Details for Fixed Steam Engines, with Essays on the Principles involved in Design and Construction. By ARTHUR RIGG, Engineer, Member of the Society of Engineers and of the Royal Institution of Great Britain. Demy 4to, *copiously illustrated with woodcuts and* 96 *plates*, in one Volume, half-bound morocco, 2*l*. 2*s*.; or cheaper edition, cloth, 25*s*.

This work is not, in any sense, an elementary treatise, or history of the steam engine, but is intended to describe examples of Fixed Steam Engines without entering into the wide domain of locomotive or marine practice. To this end illustrations will be given of the most recent arrangements of Horizontal, Vertical, Beam, Pumping, Winding, Portable, Semi-portable, Corliss, Allen, Compound, and other similar Engines, by the most eminent Firms in Great Britain and America. The laws relating to the action and precautions to be observed in the construction of the various details, such as Cylinders, Pistons, Piston-rods, Connecting-rods, Cross-heads, Motion-blocks, Eccentrics, Simple, Expansion, Balanced, and Equilibrium Slide-valves, and Valve-gearing will be minutely dealt with. In this connection will be found articles upon the Velocity of Reciprocating Parts and the Mode of Applying the Indicator, Heat and Expansion of Steam Governors, and the like. It is the writer's desire to draw illustrations from every possible source, and give only those rules that present practice deems correct.

A Practical Treatise on the Science of Land and Engineering Surveying, Levelling, Estimating Quantities, etc., with a general description of the several Instruments required for Surveying, Levelling, Plotting, etc. By H. S. MERRETT. Fourth edition, revised by G. W. USILL, Assoc. Mem. Inst. C.E. 41 *plates, with illustrations and tables*, royal 8vo, cloth, 12*s*. 6*d*.

PRINCIPAL CONTENTS:

Part 1. Introduction and the Principles of Geometry. Part 2. Land Surveying; comprising General Observations—The Chain—Offsets Surveying by the Chain only—Surveying Hilly Ground—To Survey an Estate or Parish by the Chain only—Surveying with the Theodolite—Mining and Town Surveying—Railroad Surveying—Mapping—Division and Laying out of Land—Observations on Enclosures—Plane Trigonometry. Part 3. Levelling—Simple and Compound Levelling—The Level Book—Parliamentary Plan and Section—Levelling with a Theodolite—Gradients—Wooden Curves—To Lay out a Railway Curve—Setting out Widths. Part 4. Calculating Quantities generally for Estimates—Cuttings and Embankments—Tunnels—Brickwork—Ironwork—Timber Measuring. Part 5. Description and Use of Instruments in Surveying and Plotting—The Improved Dumpy Level—Troughton's Level—The Prismatic Compass—Proportional Compass—Box Sextant—Vernier—Pantagraph—Merrett's Improved Quadrant—Improved Computation Scale—The Diagonal Scale—Straight Edge and Sector. Part 6. Logarithms of Numbers—Logarithmic Sines and Co-Sines, Tangents and Co-Tangents—Natural Sines and Co-Sines—Tables for Earthwork, for Setting out Curves, and for various Calculations, etc., etc., etc.

Mechanical Graphics. A Second Course of Mechanical Drawing. With Preface by Prof. PERRY, B.Sc., F.R.S. Arranged for use in Technical and Science and Art Institutes, Schools and Colleges, by GEORGE HALLIDAY, Whitworth Scholar. 8vo, cloth, 6*s*.

The Assayer's Manual: an Abridged Treatise on the Docimastic Examination of Ores and Furnace and other Artificial Products. By BRUNO KERL. Translated by W. T. BRANNT. *With* 65 *illustrations*, 8vo, cloth, 12*s*. 6*d*.

Dynamo-Electric Machinery: a Text-Book for Students of Electro-Technology. By SILVANUS P. THOMPSON, B.A., D.Sc., M.S.T.E. [*New edition in the press.*

The Practice of Hand Turning in Wood, Ivory, Shell, etc., with Instructions for Turning such Work in Metal as may be required in the Practice of Turning in Wood, Ivory, etc.; also an Appendix on Ornamental Turning. (A book for beginners.) By FRANCIS CAMPIN. Third edition, *with wood engravings*, crown 8vo, cloth, 6*s*.

CONTENTS:

On Lathes—Turning Tools—Turning Wood—Drilling—Screw Cutting—Miscellaneous Apparatus and Processes—Turning Particular Forms—Staining—Polishing—Spinning Metals—Materials—Ornamental Turning, etc.

Treatise on Watchwork, Past and Present. By the Rev. H. L. NELTHROPP, M.A., F.S.A. *With* 32 *illustrations*, crown 8vo, cloth, 6*s*. 6*d*.

CONTENTS:

Definitions of Words and Terms used in Watchwork—Tools—Time—Historical Summary—On Calculations of the Numbers for Wheels and Pinions; their Proportional Sizes, Trains, etc.—Of Dial Wheels, or Motion Work—Length of Time of Going without Winding up—The Verge—The Horizontal—The Duplex—The Lever—The Chronometer—Repeating Watches—Keyless Watches—The Pendulum, or Spiral Spring—Compensation—Jewelling of Pivot Holes—Clerkenwell—Fallacies of the Trade—Incapacity of Workmen—How to Choose and Use a Watch, etc.

Algebra Self-Taught. By W. P. HIGGS, M.A., D.Sc., LL.D., Assoc. Inst. C.E., Author of 'A Handbook of the Differential Calculus,' etc. Second edition, crown 8vo, cloth, 2*s*. 6*d*.

CONTENTS:

Symbols and the Signs of Operation—The Equation and the Unknown Quantity—Positive and Negative Quantities—Multiplication—Involution—Exponents—Negative Exponents—Roots, and the Use of Exponents as Logarithms—Logarithms—Tables of Logarithms and Proportionate Parts—Transformation of System of Logarithms—Common Uses of Common Logarithms—Compound Multiplication and the Binomial Theorem—Division, Fractions, and Ratio—Continued Proportion—The Series and the Summation of the Series—Limit of Series—Square and Cube Roots—Equations—List of Formulæ, etc.

Spons' Dictionary of Engineering, Civil, Mechanical, Military, and Naval; with technical terms in French, German, Italian, and Spanish, 3100 pp., and *nearly* 8000 *engravings*, in super-royal 8vo, in 8 divisions, 5*l*. 8*s*. Complete in 3 vols., cloth, 5*l*. 5*s*. Bound in a superior manner, half-morocco, top edge gilt, 3 vols., 6*l*. 12*s*.

Notes in Mechanical Engineering. Compiled principally for the use of the Students attending the Classes on this subject at the City of London College. By HENRY ADAMS, Mem. Inst. M.E., Mem. Inst. C.E., Mem. Soc. of Engineers. Crown 8vo, cloth, 2*s.* 6*d.*

Canoe and Boat Building: a complete Manual for Amateurs, containing plain and comprehensive directions for the construction of Canoes, Rowing and Sailing Boats, and Hunting Craft. By W. P. STEPHENS. *With numerous illustrations and 24 plates of Working Drawings.* Crown 8vo, cloth, 9*s.*

Proceedings of the National Conference of Electricians, Philadelphia, October 8th to 13th, 1884. 18mo, cloth, 3*s.*

Dynamo-Electricity, its Generation, Application, Transmission, Storage, and Measurement. By G. B. PRESCOTT. *With 545 illustrations.* 8vo, cloth, 1*l.* 1*s.*

Domestic Electricity for Amateurs. Translated from the French of E. HOSPITALIER, Editor of "L'Electricien," by C. J. WHARTON, Assoc. Soc. Tel. Eng. *Numerous illustrations.* Demy 8vo, cloth, 6*s.*

CONTENTS:

1. Production of the Electric Current—2. Electric Bells—3. Automatic Alarms—4. Domestic Telephones—5. Electric Clocks—6. Electric Lighters—7. Domestic Electric Lighting—8. Domestic Application of the Electric Light—9. Electric Motors—10. Electrical Locomotion—11. Electrotyping, Plating, and Gilding—12. Electric Recreations—13. Various applications—Workshop of the Electrician.

Wrinkles in Electric Lighting. By VINCENT STEPHEN. *With illustrations.* 18mo, cloth, 2*s.* 6*d.*

CONTENTS:

1. The Electric Current and its production by Chemical means—2. Production of Electric Currents by Mechanical means—3. Dynamo-Electric Machines—4. Electric Lamps—. Lead—6. Ship Lighting.

Foundations and Foundation Walls for all classes of Buildings, Pile Driving, Building Stones and Bricks, Pier and Wall construction, Mortars, Limes, Cements, Concretes, Stuccos, &c. 64 *illustrations.* By G. T. POWELL and F. BAUMAN. 8vo, cloth, 10*s.* 6*d.*

Manual for Gas Engineering Students. By D. LEE. 18mo, cloth, 1*s.*

Telephones, their Construction and Management. By F. C. ALLSOP. Crown 8vo, cloth, 5*s.*

Hydraulic Machinery, Past and Present. A Lecture delivered to the London and Suburban Railway Officials' Association. By H. ADAMS, Mem. Inst. C.E. *Folding plate.* 8vo, sewed, 1*s.*

Twenty Years with the Indicator. By THOMAS PRAY, Jun., C.E., M.E., Member of the American Society of Civil Engineers. 2 vols., royal 8vo, cloth, 12*s.* 6*d.*

Annual Statistical Report of the Secretary to the Members of the Iron and Steel Association on the Home and Foreign Iron and Steel Industries in 1889. Issued June 1890. 8vo, sewed, 5*s.*

Bad Drains, and How to Test them; with Notes on the Ventilation of Sewers, Drains, and Sanitary Fittings, and the Origin and Transmission of Zymotic Disease. By R. HARRIS REEVES. Crown 8vo, cloth, 3*s.* 6*d.*

Well Sinking. The modern practice of Sinking and Boring Wells, with geological considerations and examples of Wells. By ERNEST SPON, Assoc. Mem. Inst. C.E., Mem. Soc. Eng., and of the Franklin Inst., etc. Second edition, revised and enlarged. Crown 8vo, cloth, 10*s.* 6*d.*

The Voltaic Accumulator: an Elementary Treatise. By ÉMILE REYNIER. Translated by J. A. BERLY, Assoc. Inst. E.E. *With* 62 *illustrations*, 8vo, cloth, 9*s.*

Ten Years' Experience in Works of Intermittent Downward Filtration. By J. BAILEY DENTON, Mem. Inst. C.E. Second edition, with additions. Royal 8vo, cloth, 5*s.*

Land Surveying on the Meridian and Perpendicular System. By WILLIAM PENMAN, C.E. 8vo, cloth, 8*s.* 6*d.*

The Electromagnet and Electromagnetic Mechanism. By SILVANUS P. THOMPSON, D.Sc., F.R.S. Second edition, 8vo, cloth, 15*s.*

Incandescent Wiring Hand-Book. By F. B. BADT, late 1st Lieut. Royal Prussian Artillery. *With* 41 *illustrations and* 5 *tables.* 18mo, cloth, 4*s.* 6*d.*

A Pocket-book for Pharmacists, Medical Practitioners, Students, etc., etc. (*British, Colonial, and American*). By THOMAS BAYLEY, Assoc. R. Coll. of Science, Consulting Chemist, Analyst, and Assayer, Author of a 'Pocket-book for Chemists,' 'The Assay and Analysis of Iron and Steel, Iron Ores, and Fuel,' etc., etc. Royal 32mo, boards, gilt edges, 6*s.*

The Fireman's Guide; a Handbook on the Care of Boilers. By TEKNOLOG, föreningen T. I. Stockholm. Translated from the third edition, and revised by KARL P. DAHLSTROM, M.E. Second edition. Fcap. 8vo, cloth, 2*s.*

The Mechanician: A Treatise on the Construction and Manipulation of Tools, for the use and instruction of Young Engineers and Scientific Amateurs, comprising the Arts of Blacksmithing and Forging; the Construction and Manufacture of Hand Tools, and the various Methods of Using and Grinding them; description of Hand and Machine Processes; Turning and Screw Cutting. By CAMERON KNIGHT, Engineer. *Containing* 1147 *illustrations*, and 397 pages of letter-press. Fourth edition, 4to, cloth, 18*s.*

A Treatise on Modern Steam Engines and Boilers, including Land Locomotive, and Marine Engines and Boilers, for the use of Students. By FREDERICK COLYER, M. Inst. C.E., Mem. Inst. M.E. *With* 36 *plates.* 4to, cloth, 12*s.* 6*d.*

CONTENTS:

1. Introduction—2. Original Engines—3. Boilers—4. High-Pressure Beam Engines—5. Cornish Beam Engines—6. Horizontal Engines—7. Oscillating Engines—8. Vertical High-Pressure Engines—9. Special Engines—10. Portable Engines—11. Locomotive Engines—12. Marine Engines.

Steam Engine Management; a Treatise on the Working and Management of Steam Boilers. By F. COLYER, M. Inst. C.E., Mem. Inst. M.E. New edition, 18mo, cloth, 3*s.* 6*d.*

Aid Book to Engineering Enterprise. By EWING MATHESON, M. Inst. C.E. The Inception of Public Works, Parliamentary Procedure for Railways, Concessions for Foreign Works, and means of Providing Money, the Points which determine Success or Failure, Contract and Purchase, Commerce in Coal, Iron, and Steel, &c. Second edition, revised and enlarged, 8vo, cloth, 21*s.*

Pumps, Historically, Theoretically, and Practically Considered. By P. R. BJÖRLING. *With* 156 *illustrations.* Crown 8vo, cloth, 7*s.* 6*d.*

The Marine Transport of Petroleum. A Book for the use of Shipowners, Shipbuilders, Underwriters, Merchants, Captains and Officers of Petroleum-carrying Vessels. By G. H. LITTLE, Editor of the 'Liverpool Journal of Commerce.' Crown 8vo, cloth, 10*s.* 6*d.*

Liquid Fuel for Mechanical and Industrial Purposes. Compiled by E. A. BRAYLEY HODGETTS. *With wood engravings.* 8vo, cloth, 7*s.* 6*d.*

Tropical Agriculture: A Treatise on the Culture, Preparation, Commerce and Consumption of the principal Products of the Vegetable Kingdom. By P. L. SIMMONDS, F.L.S., F.R.C.I. New edition, revised and enlarged, 8vo, cloth, 21*s.*

Health and Comfort in House Building; or, Ventilation with Warm Air by Self-acting Suction Power. With Review of the Mode of Calculating the Draught in Hot-air Flues, and with some Actual Experiments by J. DRYSDALE, M.D., and J. W. HAYWARD, M.D. *With plates and woodcuts.* Third edition, with some New Sections, and the whole carefully Revised, 8vo, cloth, 7*s.* 6*d.*

Losses in Gold Amalgamation. With Notes on the Concentration of Gold and Silver Ores. *With six plates.* By W. MCDERMOTT and P. W. DUFFIELD. 8vo, cloth, 5*s.*

A Guide for the Electric Testing of Telegraph Cables. By Col. V. HOSKIŒR, Royal Danish Engineers. Third edition, crown 8vo, cloth, 4*s.* 6*d.*

The Hydraulic Gold Miners' Manual. By T. S. G. KIRKPATRICK, M.A. Oxon. *With* 6 *plates.* Crown 8vo, cloth, 6*s.*

"We venture to think that this work will become a text-book on the important subject of which it treats. Until comparatively recently hydraulic mines were neglected. This was scarcely to be surprised at, seeing that their working in California was brought to an abrupt termination by the action of the farmers on the *débris* question, whilst their working in other parts of the world had not been attended with the anticipated success."—*The Mining World and Engineering Record.*

A Text-Book of Tanning, embracing the Preparation of all kinds of Leather. By HARRY R. PROCTOR, F.C.S., of Low Lights Tanneries. *With illustrations.* Crown 8vo, cloth, 10*s.* 6*d.*

The Arithmetic of Electricity. By T. O'CONOR SLOANE. Crown 8vo, cloth, 4*s.* 6*d.*

The Turkish Bath: Its Design and Construction for Public and Commercial Purposes. By R. O. ALLSOP, Architect. *With plans and sections.* 8vo, cloth, 6*s.*

Earthwork Slips and Subsidences upon Public Works: Their Causes, Prevention and Reparation. Especially written to assist those engaged in the Construction or Maintenance of Railways, Docks, Canals, Waterworks, River Banks, Reclamation Embankments, Drainage Works, &c., &c. By JOHN NEWMAN, Assoc. Mem. Inst. C.E., Author of 'Notes on Concrete,' &c. Crown 8vo, cloth, 7*s.* 6*d.*

Gas and Petroleum Engines: A Practical Treatise on the Internal Combustion Engine. By WM. ROBINSON, M.E., Senior Demonstrator and Lecturer on Applied Mechanics, Physics, &c., City and Guilds of London College, Finsbury, Assoc. Mem. Inst. C.E., &c. *Numerous illustrations.* 8vo, cloth, 14*s.*

Waterways and Water Transport in Different Countries. With a description of the Panama, Suez, Manchester, Nicaraguan, and other Canals. By J. STEPHEN JEANS, Author of 'England's Supremacy,' 'Railway Problems,' &c. *Numerous illustrations.* 8vo, cloth, 14*s.*

A Treatise on the Richards Steam-Engine Indicator and the Development and Application of Force in the Steam-Engine. By CHARLES T. PORTER. Fourth Edition, revised and enlarged, 8vo, cloth, 9*s.*

CONTENTS.

The Nature and Use of the Indicator:
The several lines on the Diagram.
Examination of Diagram No. 1.
Of Truth in the Diagram.
Description of the Richards Indicator.
Practical Directions for Applying and Taking Care of the Indicator.
Introductory Remarks.
Units.
Expansion.
Directions for ascertaining from the Diagram the Power exerted by the Engine.
To Measure from the Diagram the Quantity of Steam Consumed.
To Measure from the Diagram the Quantity of Heat Expended.
Of the Real Diagram, and how to Construct it.
Of the Conversion of Heat into Work in the Steam-engine.
Observations on the several Lines of the Diagram.
Of the Loss attending the Employment of Slow-piston Speed, and the Extent to which this is Shown by the Indicator.
Of other Applications of the Indicator.
Of the use of the Tables of the Properties of Steam in Calculating the Duty of Boilers.
Introductory.
Of the Pressure on the Crank when the Connecting-rod is conceived to be of Infinite Length.
The Modification of the Acceleration and Retardation that is occasioned by the Angular Vibration of the Connecting-rod.
Method of representing the actual pressure on the crank at every point of its revolution.
The Rotative Effect of the Pressure exerted on the Crank.
The Transmitting Parts of an Engine, considered as an Equaliser of Motion.
A Ride on a Buffer-beam (Appendix).

In demy 4to, handsomely bound in cloth, *illustrated with 220 full page plates*, Price 15*s.*

ARCHITECTURAL EXAMPLES

IN BRICK, STONE, WOOD, AND IRON.

A COMPLETE WORK ON THE DETAILS AND ARRANGEMENT OF BUILDING CONSTRUCTION AND DESIGN.

By WILLIAM FULLERTON, Architect.

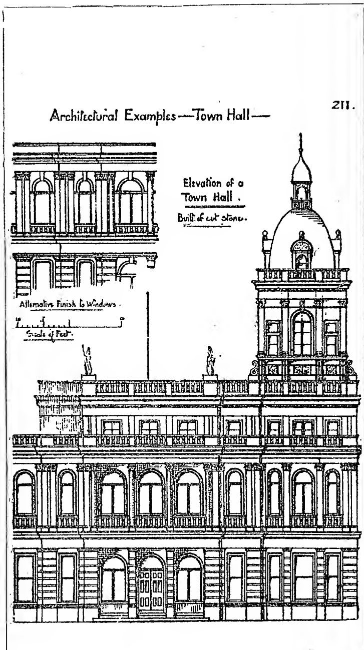
Containing 220 Plates, with numerous Drawings selected from the Architecture of Former and Present Times.

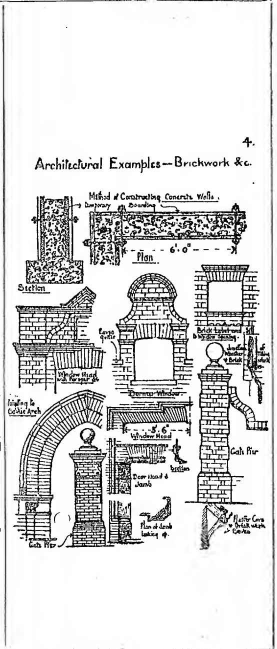
The Details and Designs are Drawn to Scale, $\frac{1}{8}''$, $\frac{1}{4}''$, $\frac{1}{2}''$, and Full size being chiefly used.

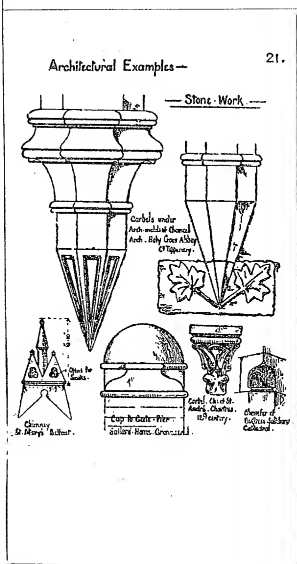
The Plates are arranged in Two Parts. The First Part contains Details of Work in the four principal Building materials, the following being a few of the subjects in this Part:—Various forms of Doors and Windows, Wood and Iron Roofs, Half Timber Work, Porches, Towers, Spires, Belfries, Flying Buttresses, Groining, Carving, Church Fittings, Constructive and Ornamental Iron Work, Classic and Gothic Molds and Ornament, Foliation Natural and Conventional, Stained Glass, Coloured Decoration, a Section to Scale of the Great Pyramid, Grecian and Roman Work, Continental and English Gothic, Pile Foundations, Chimney Shafts according to the regulations of the London County Council, Board Schools. The Second Part consists of Drawings of Plans and Elevations of Buildings, arranged under the following heads:—Workmen's Cottages and Dwellings, Cottage Residences and Dwelling Houses, Shops, Factories, Warehouses, Schools, Churches and Chapels, Public Buildings, Hotels and Taverns, and Buildings of a general character.

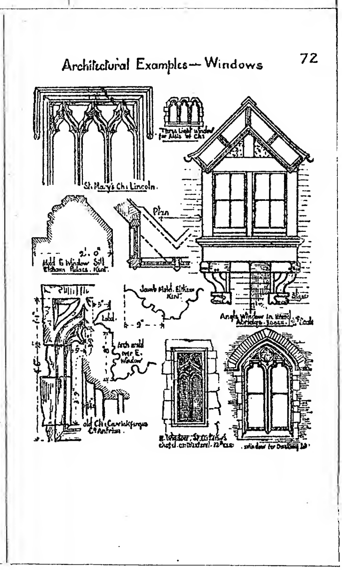
All the Plates are accompanied with particulars of the Work, with Explanatory Notes and Dimensions of the various parts.

Specimen Pages, reduced from the originals.









Crown 8vo, cloth, with illustrations, 5*s*.

WORKSHOP RECEIPTS,

FIRST SERIES.

By ERNEST SPON.

Synopsis of Contents.

Bookbinding.
Bronzes and Bronzing.
Candles.
Cement.
Cleaning.
Colourwashing.
Concretes.
Dipping Acids.
Drawing Office Details.
Drying Oils.
Dynamite.
Electro - Metallurgy — (Cleaning, Dipping, Scratch-brushing, Batteries, Baths, and Deposits of every description).
Enamels.
Engraving on Wood, Copper, Gold, Silver, Steel, and Stone.
Etching and Aqua Tint.
Firework Making — (Rockets, Stars, Rains, Gerbes, Jets, Tourbillons, Candles, Fires, Lances, Lights, Wheels, Fire-balloons, and minor Fireworks).
Fluxes.
Foundry Mixtures.
Freezing.
Fulminates.
Furniture Creams, Oils, Polishes, Lacquers, and Pastes.
Gilding.
Glass Cutting, Cleaning, Frosting, Drilling, Darkening, Bending, Staining, and Painting.
Glass Making.
Glues.
Gold.
Graining.
Gums.
Gun Cotton.
Gunpowder.
Horn Working.
Indiarubber.
Japans, Japanning, and kindred processes.
Lacquers.
Lathing.
Lubricants.
Marble Working.
Matches.
Mortars.
Nitro-Glycerine.
Oils.
Paper.
Paper Hanging.
Painting in Oils, in Water Colours, as well as Fresco, House, Transparency, Sign, and Carriage Painting.
Photography.
Plastering.
Polishes.
Pottery—(Clays, Bodies, Glazes, Colours, Oils, Stains, Fluxes, Enamels, and Lustres).
Scouring.
Silvering.
Soap.
Solders.
Tanning.
Taxidermy.
Tempering Metals.
Treating Horn, Mother-o'-Pearl, and like substances.
Varnishes, Manufacture and Use of.
Veneering.
Washing.
Waterproofing.
Welding.

Besides Receipts relating to the lesser Technological matters and processes, such as the manufacture and use of Stencil Plates, Blacking, Crayons, Paste, Putty, Wax, Size, Alloys, Catgut, Tunbridge Ware, Picture Frame and Architectural Mouldings, Compos, Cameos, and others too numerous to mention.

Crown 8vo, cloth, 485 pages, with illustrations, 5*s.*

WORKSHOP RECEIPTS,

SECOND SERIES.

BY ROBERT HALDANE.

SYNOPSIS OF CONTENTS.

Acidimetry and Alkalimetry.
Albumen.
Alcohol.
Alkaloids.
Baking-powders.
Bitters.
Bleaching.
Boiler Incrustations.
Cements and Lutes.
Cleansing.
Confectionery.
Copying.
Disinfectants.
Dyeing, Staining, and Colouring.
Essences.
Extracts.
Fireproofing.
Gelatine, Glue, and Size.
Glycerine.
Gut.
Hydrogen peroxide.
Ink.
Iodine.
Iodoform.
Isinglass.
Ivory substitutes.
Leather.
Luminous bodies.
Magnesia.
Matches.
Paper.
Parchment.
Perchloric acid.
Potassium oxalate.
Preserving.

Pigments, Paint, and Painting: embracing the preparation of *Pigments*, including alumina lakes, blacks (animal, bone, Frankfort, ivory, lamp, sight, soot), blues (antimony, Antwerp, cobalt, cæruleum, Egyptian, manganate, Paris, Péligot, Prussian, smalt, ultramarine), browns (bistre, hinau, sepia, sienna, umber, Vandyke), greens (baryta, Brighton, Brunswick, chrome, cobalt, Douglas, emerald, manganese, mitis, mountain, Prussian, sap, Scheele's, Schweinfurth, titanium, verdigris, zinc), reds (Brazilwood lake, carminated lake, carmine, Cassius purple, cobalt pink, cochineal lake, colcothar, Indian red, madder lake, red chalk, red lead, vermilion), whites (alum, baryta, Chinese, lead sulphate, white lead—by American, Dutch, French, German, Kremnitz, and Pattinson processes, precautions in making, and composition of commercial samples—whiting, Wilkinson's white, zinc white), yellows (chrome, gamboge, Naples, orpiment, realgar, yellow lakes); *Paint* (vehicles, testing oils, driers, grinding, storing, applying, priming, drying, filling, coats, brushes, surface, water-colours, removing smell, discoloration; miscellaneous paints—cement paint for carton-pierre, copper paint, gold paint, iron paint, lime paints, silicated paints, steatite paint, transparent paints, tungsten paints, window paint, zinc paints); *Painting* (general instructions, proportions of ingredients, measuring paint work; carriage painting—priming paint, best putty, finishing colour, cause of cracking, mixing the paints, oils, driers, and colours, varnishing, importance of washing vehicles, re-varnishing, how to dry paint; woodwork painting).

Crown 8vo, cloth, 480 pages, with 183 illustrations, 5*s*.

WORKSHOP RECEIPTS,

THIRD SERIES.

By C. G. WARNFORD LOCK.

Uniform with the First and Second Series.

Synopsis of Contents.

Alloys.
Aluminium.
Antimony.
Barium.
Beryllium.
Bismuth.
Cadmium.
Cæsium.
Calcium.
Cerium.
Chromium.
Cobalt.
Copper.
Didymium.
Electrics.
Enamels and Glazes.
Erbium.
Gallium.
Glass.
Gold.
Indium.
Iridium.
Iron and Steel.
Lacquers and Lacquering.
Lanthanum.
Lead.
Lithium.
Lubricants.
Magnesium.
Manganese.
Mercury.
Mica.
Molybdenum.
Nickel.
Niobium.
Osmium.
Palladium.
Platinum.
Potassium.
Rhodium.
Rubidium.
Ruthenium.
Selenium.
Silver.
Slag.
Sodium.
Strontium.
Tantalum.
Terbium.
Thallium.
Thorium.
Tin.
Titanium.
Tungsten.
Uranium.
Vanadium.
Yttrium.
Zinc.
Zirconium.

WORKSHOP RECEIPTS,

FOURTH SERIES,

DEVOTED MAINLY TO HANDICRAFTS & MECHANICAL SUBJECTS.

BY C. G. WARNFORD LOCK.

250 Illustrations, with Complete Index, and a General Index to the Four Series, 5s.

Waterproofing — rubber goods, cuprammonium processes, miscellaneous preparations.

Packing and Storing articles of delicate odour or colour, of a deliquescent character, liable to ignition, apt to suffer from insects or damp, or easily broken.

Embalming and Preserving anatomical specimens.

Leather Polishes.

Cooling Air and Water, producing low temperatures, making ice, cooling syrups and solutions, and separating salts from liquors by refrigeration.

Pumps and Siphons, embracing every useful contrivance for raising and supplying water on a moderate scale, and moving corrosive, tenacious, and other liquids.

Desiccating—air- and water-ovens, and other appliances for drying natural and artificial products.

Distilling—water, tinctures, extracts, pharmaceutical preparations, essences, perfumes, and alcoholic liquids.

Emulsifying as required by pharmacists and photographers.

Evaporating—saline and other solutions, and liquids demanding special precautions.

Filtering—water, and solutions of various kinds.

Percolating and Macerating.

Electrotyping.

Stereotyping by both plaster and paper processes.

Bookbinding in all its details.

Straw Plaiting and the fabrication of baskets, matting, etc.

Musical Instruments—the preservation, tuning, and repair of pianos, harmoniums, musical boxes, etc.

Clock and Watch Mending—adapted for intelligent amateurs.

Photography—recent development in rapid processes, handy apparatus, numerous recipes for sensitizing and developing solutions, and applications to modern illustrative purposes.

Crown 8vo, cloth, with 373 illustrations, price 5*s.*

WORKSHOP RECEIPTS,

FIFTH SERIES.

BY C. G. WARNFORD LOCK, F.L.S.

Containing many new Articles, as well as additions to Articles included in the previous Series, as follows, viz. :—

Anemometers.
Barometers, How to make.
Boat Building.
Camera Lucida, How to use.
Cements and Lutes.
Cooling.
Copying.
Corrosion and Protection of Metal Surfaces.
Dendrometer, How to use.
Desiccating.
Diamond Cutting and Polishing. Electrics. New Chemical Batteries, Bells, Commutators, Galvanometers, Cost of Electric Lighting, Microphones, Simple Motors, Phonogram and Graphophone, Registering Apparatus, Regulators, Electric Welding and Apparatus, Transformers.
Evaporating.
Explosives.
Filtering.
Fireproofing, Buildings, Textile Fabrics.
Fire-extinguishing Compounds and Apparatus.
Glass Manipulating. Drilling, Cutting, Breaking, Etching, Frosting, Powdering, &c.
Glass Manipulations for Laboratory Apparatus.
Labels. Lacquers.
Illuminating Agents.
Inks. Writing, Copying, Invisible, Marking, Stamping.
Magic Lanterns, their management and preparation of slides.
Metal Work. Casting Ornamental Metal Work, Copper Welding, Enamels for Iron and other Metals, Gold Beating, Smiths' Work.
Modelling and Plaster Casting.
Netting.
Packing and Storing. Acids, &c.
Percolation.
Preserving Books.
Preserving Food, Plants, &c.
Pumps and Syphons for various liquids.
Repairing Books.
Rope Tackle.
Stereotyping.
Taps, Various.
Tobacco Pipe Manufacture.
Tying and Splicing Ropes.
Velocipedes, Repairing.
Walking Sticks.
Waterproofing.

NOW COMPLETE.

With nearly 1500 *illustrations*, in super-royal 8vo, in 5 Divisions, cloth. Divisions 1 to 4, 13*s*. 6*d*. each ; Division 5, 17*s*. 6*d*. ; or 2 vols., cloth, £3 10*s*.

SPONS' ENCYCLOPÆDIA

OF THE

INDUSTRIAL ARTS, MANUFACTURES, AND COMMERCIAL PRODUCTS.

EDITED BY C. G. WARNFORD LOCK, F.L.S.

Among the more important of the subjects treated of, are the following :—

Acids, 207 pp. 220 figs.
Alcohol, 23 pp. 16 figs.
Alcoholic Liquors, 13 pp.
Alkalies, 89 pp. 78 figs.
Alloys. Alum.
Asphalt. Assaying.
Beverages, 89 pp. 29 figs.
Blacks.
Bleaching Powder, 15 pp.
Bleaching, 51 pp. 48 figs.
Candles, 18 pp. 9 figs.
Carbon Bisulphide.
Celluloid, 9 pp.
Cements. Clay.
Coal-tar Products, 44 pp. 14 figs.
Cocoa, 8 pp.
Coffee, 32 pp. 13 figs.
Cork, 8 pp. 17 figs.
Cotton Manufactures, 62 pp. 57 figs.
Drugs, 38 pp.
Dyeing and Calico Printing, 28 pp. 9 figs.
Dyestuffs, 16 pp.
Electro-Metallurgy, 13 pp.
Explosives, 22 pp. 33 figs.
Feathers.
Fibrous Substances, 92 pp. 79 figs.
Floor-cloth, 16 pp. 21 figs.
Food Preservation, 8 pp.
Fruit, 8 pp.
Fur, 5 pp.
Gas, Coal, 8 pp.
Gems.
Glass, 45 pp. 77 figs.
Graphite, 7 pp.
Hair, 7 pp.
Hair Manufactures.
Hats, 26 pp. 26 figs.
Honey. Hops.
Horn.
Ice, 10 pp. 14 figs.
Indiarubber Manufactures, 23 pp. 17 figs.
Ink, 17 pp.
Ivory.
Jute Manufactures, 11 pp., 11 figs.
Knitted Fabrics — Hosiery, 15 pp. 13 figs.
Lace, 13 pp. 9 figs.
Leather, 28 pp. 31 figs.
Linen Manufactures, 16 pp. 6 figs.
Manures, 21 pp. 30 figs.
Matches, 17 pp. 38 figs.
Mordants, 13 pp.
Narcotics, 47 pp.
Nuts, 10 pp.
Oils and Fatty Substances, 125 pp.
Paint.
Paper, 26 pp. 23 figs.
Paraffin, 8 pp. 6 figs.
Pearl and Coral, 8 pp.
Perfumes, 10 pp.
Photography, 13 pp. 20 figs.
Pigments, 9 pp. 6 figs.
Pottery, 46 pp. 57 figs.
Printing and Engraving, 20 pp. 8 figs.
Rags.
Resinous and Gummy Substances, 75 pp. 16 figs.
Rope, 16 pp. 17 figs.
Salt, 31 pp. 23 figs.
Silk, 8 pp.
Silk Manufactures, 9 pp. 11 figs.
Skins, 5 pp.
Small Wares, 4 pp.
Soap and Glycerine, 39 pp. 45 figs.
Spices, 16 pp.
Sponge, 5 pp.
Starch, 9 pp. 10 figs.
Sugar, 155 pp. 134 figs.
Sulphur.
Tannin, 18 pp.
Tea, 12 pp.
Timber, 13 pp.
Varnish, 15 pp.
Vinegar, 5 pp.
Wax, 5 pp.
Wool, 2 pp.
Woollen Manufactures, 58 pp. 39 figs.

MECHANICAL MANIPULATION.

THE MECHANICIAN:

A TREATISE ON THE CONSTRUCTION AND MANIPULATION OF TOOLS, FOR THE USE AND INSTRUCTION OF YOUNG ENGINEERS AND SCIENTIFIC AMATEURS;

Comprising the Arts of Blacksmithing and Forging the Construction and Manufacture of Hand Tools, and the various Methods of Using and Grinding them ; the Construction of Machine Tools, and how to work them; Turning and Screw-cutting; the various details of setting out work, &c., &c.

By CAMERON KNIGHT, Engineer.

96 4to plates, containing 1147 illustrations, and 397 pages of letterpress, second edition, reprinted from the first, **4to, cloth, 18s.**

Of the six chapters constituting the work, the first is devoted to forging; in which the fundamental principles to be observed in making forged articles of every class are stated, giving the proper relative positions for the constituent fibres of each article, the mode of selecting proper quantities of material, steam-hammer operations, shaping-moulds, and the manipulations resorted to for shaping the component masses to the intended forms.

Engineers' tools and their construction are next treated, because they must be used during all operations described in the remaining chapters, the author thinking that the student should first acquire knowledge of the apparatus which he is supposed to be using in the course of the processes given in Chapters 4, 5, and 6. In the fourth chapter planing and lining are treated, because these are the elements of machine-making in general. The processes described in this chapter are those on which all accuracy of fitting and finishing depend. The next chapter, which treats of shaping and slotting, the author endeavours to render comprehensive by giving the hand-shaping processes in addition to the machine-shaping.

In many cases hand-shaping is indispensable, such as sudden breakage, operations abroad, and on board ship, also for constructors having a limited number of machines. Turning and screw-cutting occupy the last chapter. In this, the operations for lining, centering, turning, and screw-forming are detailed and their principles elucidated.

The Mechanician is the result of the author's experience in engine making during twenty years; and he has concluded that, however retentive the memory of a machinist might be, it would be convenient for him to have a book of primary principles and processes to which he could refer with confidence.

JUST PUBLISHED.

In demy 8vo, cloth, 600 pages, and 1420 Illustrations, 6*s.*

SPONS'
MECHANICS' OWN BOOK;
A MANUAL FOR HANDICRAFTSMEN AND AMATEURS.

CONTENTS.

Mechanical Drawing—Casting and Founding in Iron, Brass, Bronze, and other Alloys—Forging and Finishing Iron—Sheetmetal Working—Soldering, Brazing, and Burning—Carpentry and Joinery, embracing descriptions of some 400 Woods, over 200 Illustrations of Tools and their uses, Explanations (with Diagrams) of 116 joints and hinges, and Details of Construction of Workshop appliances, rough furniture, Garden and Yard Erections, and House Building—Cabinet-Making and Veneering — Carving and Fretcutting — Upholstery — Painting, Graining, and Marbling — Staining Furniture, Woods, Floors, and Fittings—Gilding, dead and bright, on various grounds—Polishing Marble, Metals, and Wood—Varnishing—Mechanical movements, illustrating contrivances for transmitting motion—Turning in Wood and Metals—Masonry, embracing Stonework, Brickwork, Terracotta and Concrete—Roofing with Thatch, Tiles, Slates, Felt, Zinc, &c.—Glazing with and without putty, and lead glazing—Plastering and Whitewashing— Paper-hanging — Gas-fitting—Bell-hanging, ordinary and electric Systems — Lighting — Warming — Ventilating — Roads, Pavements, and Bridges — Hedges, Ditches, and Drains — Water Supply and Sanitation—Hints on House Construction suited to new countries.

E. & F. N. SPON, 125, Strand, London.
New York: 12, Cortlandt Street.

SPONS' DICTIONARY OF ENGINEERING,

CIVIL, MECHANICAL, MILITARY, & NAVAL,

WITH

Technical Terms in French, German, Italian, and Spanish.

In 97 numbers, Super-royal 8vo, containing 3132 *printed pages* and 7414 *engravings*. **Any number can be had separate**: Nos. 1 to 95 1*s*. each, post free; Nos. 96, 97, 2*s*., post free. *See also page* 112.

COMPLETE LIST OF ALL THE SUBJECTS:

In super-royal 8vo, 1168 pp., *with* 2400 *illustrations*, in 3 Divisions, cloth, price 13*s*. 6*d*. each; or 1 vol., cloth, 2*l*.; or half-morocco, 2*l*. 8*s*.

A SUPPLEMENT

TO

SPONS' DICTIONARY OF ENGINEERING.

EDITED BY ERNEST SPON, MEMB. SOC. ENGINEERS.

Abacus, Counters, Speed Indicators, and Slide Rule.
Agricultural Implements and Machinery.
Air Compressors.
Animal Charcoal Machinery.
Antimony.
Axles and Axle-boxes.
Barn Machinery.
Belts and Belting.
Blasting. Boilers.
Brakes.
Brick Machinery.
Bridges.
Cages for Mines.
Calculus, Differential and Integral.
Canals.
Carpentry.
Cast Iron.
Cement, Concrete, Limes, and Mortar.
Chimney Shafts.
Coal Cleansing and Washing.
Coal Mining.
Coal Cutting Machines.
Coke Ovens. Copper.
Docks. Drainage.
Dredging Machinery.
Dynamo - Electric and Magneto-Electric Machines.
Dynamometers.
Electrical Engineering, Telegraphy, Electric Lighting and its practicaldetails,Telephones
Engines, Varieties of.
Explosives. Fans.
Founding, Moulding and the practical work of the Foundry.
Gas, Manufacture of.
Hammers, Steam and other Power.
Heat. Horse Power.
Hydraulics.
Hydro-geology.
Indicators. Iron.
Lifts, Hoists, and Elevators.
Lighthouses, Buoys, and Beacons.
Machine Tools.
Materials of Construction.
Meters.
Ores, Machinery and Processes employed to Dress.
Piers.
Pile Driving.
Pneumatic Transmission.
Pumps.
Pyrometers.
Road Locomotives.
Rock Drills.
Rolling Stock.
Sanitary Engineering.
Shafting.
Steel.
Steam Navvy.
Stone Machinery.
Tramways.
Well Sinking.