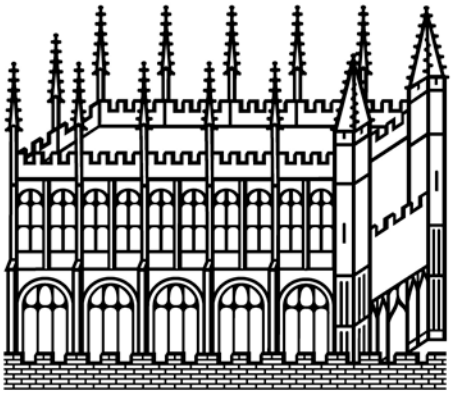

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THE SHIPOWNERS' AND ENGINEERS' GUIDE TO THE MARINE ENGINE

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FATHER OF SURFACE CONDENSATION

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GUIDE

TO THE

MARINE ENGINE

BY

WILLIAM ALLAN

AUTHOR OF "HEATHER BELLS," "ROSE AND THISTLE," &C.

ILLUSTRATED WITH DIAGRAMS

[ENTERED AT STATIONERS' HALL]

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PREFACE.

In the following pages it is our intention to present to Steamship Owners concise and reliable information concerning the Marine Engine, which will be found to embody the most modern experience and practice. As a proem to our remarks, we append a sketch of marine engine progress during the last forty years, which will no doubt be interesting to our readers, inasmuch as it will show the extent of engineering improvement in that time. We hope that our remarks will be found of value in not only enabling a steamship owner to prepare his specification for engines, but also in showing him what the arrangement of the engine should be so as to fulfil all the possible exigencies of sea-work.

Shipowners are not expected, nor as a rule do they profess, to know what a marine engine should be, their only guide to the value of what they are to receive being, in many instances, based upon the elaboration of the contents of the specification submitted. Hence, they may get a fully-written specification containing a great number of minor details, and explanations of purposes, while the engine as a whole may be utterly devoid of perfectness of arrangement, and made of such materials as to warrant rapid deterioration.

To remedy these deficiencies of knowledge is our object, and we shall endeavour to lay before steamship owners, in plain and understandable language, our ideas, based on a varied and wide knowledge of the subject, hoping thereby to assist them to a better understanding of the marine engine and the uses of its various parts.

From the Formulæ we give, a steamship owner will not only be enabled to fix upon the size of the engine necessary to drive a ship a certain speed, but he will also be capable of determining the dimensions of its principal details.

To further our purpose, we have annexed a lithograph of a marine engine. The lithograph is numbered in its details, and an explanatory key is attached, whereby the uses and functions of the various parts are made plain.

We treat exclusively of the Compound Engine, as being the type now in general use for steamships.

Should our ideas and suggestions enable any steamship owner to get a more complete and satisfactory engine, or give him a more extended knowledge of the subject, our self-imposed work in writing these pages will be amply remunerated.

Sunderland, March, 1880.

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A

SKETCH OF MARINE ENGINE PROGRESS

FROM

1840 TO 1880.

IN entering upon the subject of Marine Engine Progress, we can hardly review our present position without consulting the past. A cursory glance over the fields of bygone Marine Engineering will enable us to form a better idea of the value of our progress. It would be inconsistent with the spirit of this sketch to begin at the earliest attempts of ship propulsion by steam, and to trace these and all others up to the present date. To give each inventor or applier of a principle, or every improver of Marine Engine details, due justice, or to review the effects produced by the success of their schemes, would entail upon us an amount of labour and research incompatible with our present purpose.

As already observed, we shall descend a few brief stages of the past, and comment upon what was then prevalent in Marine Engineering, we shall then follow through the intervening years of improvement until we reach our present plateau of progress, where we shall endeavour to limn what we see around us as the modern results of our Engineering advancement. Our included period may be deemed modern, as many are living who witnessed the "*Comet*" of 1812, (the precursor of steam navigation,) and the "*Archimedes*" of 1840; still, the period we purpose embracing is really the historical reign of improvement.

Forty years ago! a very short time indeed. Let us fancy ourselves in the engine room of a first-class steamship of that day. What is the prospect before us in this centre of power? Our vessel is one with huge paddle wheels;

it has engines known as side lever; the framing for carrying the crank-shaft is of the Gothic window design, the cross-tails and connecting rods moving between the spaces; the crank-shaft is level with the deck; the boilers are placed before and abaft the engines; the pressure of steam is 10 lbs.; the space occupied in the hull by engines and boilers is somewhere about one-third of the ship's length. The boilers of these common condensing side lever engines are fed with salt water; the operation of scumming, or blowing-out from them, is continually going on at sea, in order to reduce the inevitable incrustation taking place in the interior of the boilers. The consumption of coal by this type of engine is something like 7 lbs. per indicated horse power per hour.

These boilers were known as Rectangular Flue, and being "all sides" were consequently stayed in every conceivable portion; in fact, their interiors were a maze of stay rods, gushet plates, and knee pieces. On the vessel reaching a port, the boilers had to be duly opened out, and the deposited scale removed from the sides, stays, flue plates, furnace tops, &c., an operation which was somewhat costly, as it entailed the labour of the greater portion of the firemen on board, and prevented their being employed in engine overhauling. Notwithstanding that this type of engine and boiler had many disadvantages, it was extensively adopted in the Mercantile Marine, and also in the Navy. In ships of war, it must have been apparent that they were liable when in action to be crippled by a single shot, though we are not aware of a side lever engined war-ship having been engaged in an actual conflict; however, these engines, with their low pressures and manifold imperfections, were the heralds of better designs.

During the reign of this arrangement of Marine Engine, active brains were at work endeavouring to discover a less cumbrous or simpler type, or one which would take up

smaller space in the ship. A step in this direction, although it never came into vogue generally for the merchant service, was known as *Maudslay's Direct-acting Double Cylinder Paddle Engine.*

Then came a truly grand design, making, in every sense of the term, a beautiful engine, and one which occupied less length space. This engine, known as the *Oscillating Paddle*, was first fitted into a steamer called the "*Aaron Manby*," in 1821. Maudslay, in 1829, fitted the "*Endeavour*" with an 8-horse oscillator, but it remained for John Penn to bring this type of engine into repute commercially.

Mr. Penn's first oscillating engines were made in 1837; from that date to the present, his firm have built the greater number of the paddle engines of the empire, in sizes ranging from 10 to 1000 H. P. The objections urged against this type of engine were successfully combatted by Mr. Penn: the result being, that side-lever and other types of paddle engines fell into disuse.

Amongst other forms of paddle engines we may mention Fairbairn's, although few of them were made, as the arrangement was objected to on account of its short connecting rod.

During these forward improvements in paddle engines, another master-mind was at work, whose aims were no mere detail improvements,—away into another region he soared! A new mode of propulsion was the day-dream of his being. The annihilation of paddle wheels and their engines, with all their short-comings, was ever present with that sturdy genius, Francis P. Smith, the practical inventor and introducer of the Screw Propeller.

Dealing as we are with those men whose inventions, improvements, and labours in the arena of Marine Engineering have tended to mould the commercial supremacy of Great Britain we stoop not to discuss priorities of invention,

or justice to inventors; it would be foreign to our purpose to mention other than those men who proved the commercial value and universal utility of their schemes, therefore we say of the famous first screw steamer, the "*Archimedes*" of 1840—

"A mighty leap was this, no transient stride,
A great conception of still greater brain;"

And true it was, for, from that day a change of ideas gradually filled the minds of Marine Engine builders. Men-of-war with clear broadsides were to be propelled by an unseen motor; vessels were to lie close alongside quay walls; engines of a different form were to be used, and were to run at a higher speed, and, above all, were to take up less space in the ship; these and many other advantages loomed before the minds of Engineers. The Government was not slow to avail itself of the advantages of the screw system; their Engineer advisers could no longer shut their eyes to the glorious dawn of a new era; 'twas no passing scheme this—there sped the well-named "*Archimedes*" over the waters, and without paddle wheels; who could gainsay the advantages she possessed? No one. Her appearance heralded the overthrow of existing systems of propulsion. Merchants began to be fully alive to the importance of the invention; Paddle-wheel steamers went out of fashion, Screw steamers began to be substituted; like every genuine discovery, propulsion by the screw slowly made its way, and engine-builders began to think more and more upon the most suitable form of engine required; hence the numerous arrangements of Screw Engines which at this period obtained, to wit:—Horizontal Direct-acting; Horizontal Geared; Diagonal Direct-acting; Oscillating Geared; Vertical Trunk Geared; Vertical Cylinder Overhead-Crank Geared; Steeple Geared, &c.; several forms of Rotary Engines were also brought forward,

which, though apparently simple, were not economical, hence, a really practical design of this much patented Engine is still amongst the undiscovered combinations of mechanism. None of these types of Marine Engines seemed to find so much favour as the Two-Cylinder Inverted Direct-acting Common Condensing Engine, the condenser being formed by two of the columns to which the air-pumps were fitted. This arrangement seems to have been the out-growth of the various designs alluded to.

Notwithstanding the manifold advantages obtained by the introduction of the screw propeller, still something else was required. The *bête noire* of boiler incrustation existed ; the work done was still costly in fuel ; many had mooted the question,—cannot marine boilers be fed with fresh water ? James Watt perceived the benefits of surface condensation, but failed to apply it. In 1821, David Napier tried an experimental surface condenser in the steamer "*Post Boy*," but abandoned the plan.

In many minds, ideas existed for the attainment of this consummation, but it remained for Samuel Hall of Basford, to solve the problem by patenting in 1835, his arrangement of surface condenser, and applying it with success to the engines of the steamer "*Wilberforce*," in 1837. Here we may say that Hall was the father of surface condensation, he was a grand, but ill requited genius of engineering, who lit the way for others to follow. Where is the Marine Engine builder of the present day who has not profited by his invention ? Yet Samuel Hall died in absolute penury after spending a fortune over perfecting his arrangement of the Surface Condenser.

Many engineers dabbled away at Hall's invention, endeavouring to improve upon it, but the principle and *modus operandi* as planned by Hall remain unchanged, except in the mode of securing the tube ends.

Taking the year 1840 as the birth of Screw Propulsion, the long period of 20 years elapsed before surface condensation began to come into repute. Prejudice almost killed progress. Even in 1860 few vessels were fitted with surface condensers. In 1858 we find the "*Royal Bride*" built by Randolph & Elder, having a surface condenser (made by fitting tubes between the vessel's skin) below the stern-tube space, a very ingenious idea, but rather unpractical.

It would be difficult to synchronise the application of surface condensers to Marine Engines, but certain it is that in 1860—5 a sudden demand arose for Surface Condensing Marine Engines. Less fuel cost and clean boilers overcame the usual prejudices, and the Inverted Direct-acting Marine Engine, before alluded to became the favourite with shipowners and enginebuilders. This type presents many excellences over every other form of Marine Engine. Besides being peculiarly adapted for the application of Hall's Surface Condenser, it takes up a minimum of space, a long connecting rod can be obtained, and general get-at-ableness to every part secured,—advantages unobtainable in either the Horizontal, Diagonal, or Geared types of Engine; therefore, notwithstanding the various arrangements of Engine in vogue, the Inverted Direct-Acting found, and still finds, most favour. As is doubtless known to those interested in the subject, the cylinders are fitted to columns on both port and starboard sides. One set of these columns is generally cast with the condenser box attached; and on the interior face of said columns the guides are fitted. The air and the circulating, also the feed and bilge pumps, are wrought by levers attached to the connecting rod gudgeons. The link motion is generally between the columns, *i. e.* central, where every part can be seen, and got at readily. The whole arrangement being compact, handy, and easily overhauled, invaluable points in a Marine Engine.

We have now in 1865, this Surface-condensing type of Marine Engine coming rapidly into use. The consumption of fuel, which a few years before this date had been from 5 to 7 lbs. per H. P. per hour, now fell to 3½ lbs., and better work was performed, by reason of the boilers being run comparatively clean, and Engine repairs being easily done.

The desire for still less consumption began to be prevalent, higher pressures and greater expansion were demanded. Where 25 lbs. was used in 1860, 35 lbs. was required in 1865. Marine Engine builders were now convinced that Surface Condensation was not only a valuable necessity, but even an encouragement to higher pressures. Hence we find a general adoption of pressures from 25 lbs. to 35 lbs., and Engines fitted with

EXPANSION OR CUT-OFF VALVES.

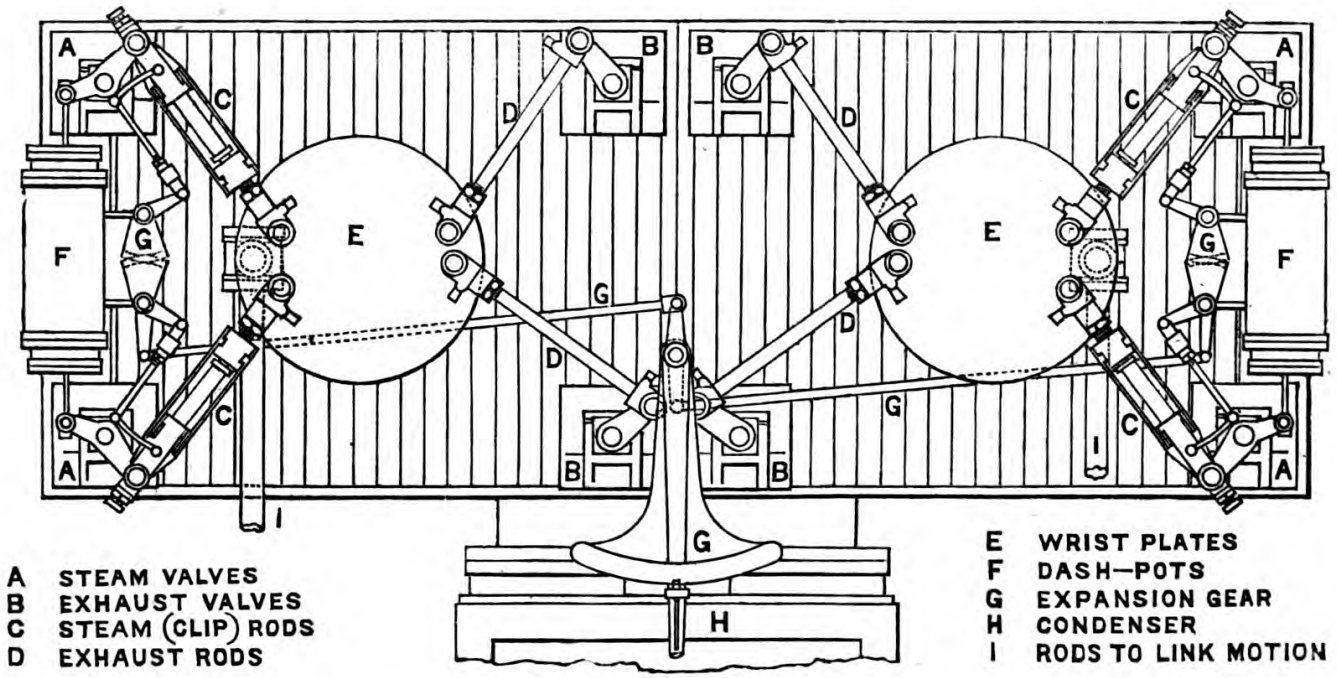
Various were the patented plans tried about this period to get a sudden yet variable cut-off of the steam, in order to produce an approximately theoretical diagram. The most prominent of these improvements in expansion gear was the application of the Corliss Valves to Marine Engines, by John F. Spencer. As no words can convey an accurate or understandable description of this gear, with its multifarious parts and strange nomenclature, its action and arrangement will be best understood by reference to the drawing annexed. This is similar to those fitted to 120 H. P. Marine Engines, and represents the front of the cylinders. It will be observed that the two steam and two exhaust valves on each cylinder receive their motion from the central disc, to which they are attached by rods. This disc is called the "Wristplate." The steam valves, after being moved the amount of opening given by the expansion gear, were released by a trigger (fitted into their rods,) which actuated the rod springs, and then brought suddenly back to their normal position by the

reaction of a spring acting on each valve, which was enclosed in a small cylinder called the "Dashpot." The rods actuating the steam valves were called "Cliprods." The "Wristplate" received its rocking motion from a lever on the end of which the link motion block was fitted. The rod between this lever end and the wristplate pin was made with socket bushes as the pins were of the ball form.

Great things were expected from this Expansion Gear; some eight steamers were fitted with it, but they were all failures. The pressure of steam employed was 35 lbs. and 40 lbs.; but the system, with its labyrinth of rods, springs, wristplates, dashpots, ball-joints, and turn-corner motions was relegated to the oblivion which inevitably awaits all uncommercial engineering. Withal, there was in reality no practical gain or superiority in their application, over a fairly made expansion valve, working from an eccentric. The diagrams taken off the Corliss Cut-off Valve fitted Engines, are no better than those off Engines fitted with the common expansion valve. Those appended are correct copies of the originals. It will be seen that in conformation they are very similar, while the fuel value was decidedly in favour of the ordinary expansively-wrought Engine; this advantage arising no doubt from the difficulty experienced in keeping a "rocking" or Corliss valve steam tight on its face. Another and vital drawback to the system, was its liability to derangement, and the cost of keeping it in repair, two factors which should always enter largely into any attempts at engineering improvements, but which are too often overlooked.

Ten years before this period (1865) the master-mind of John Elder was busy with the application of the Woolf, or Compound System of expansion, to Marine Engines. This system is the action of the steam from the boiler in one cylinder first, then continued in another, which is in

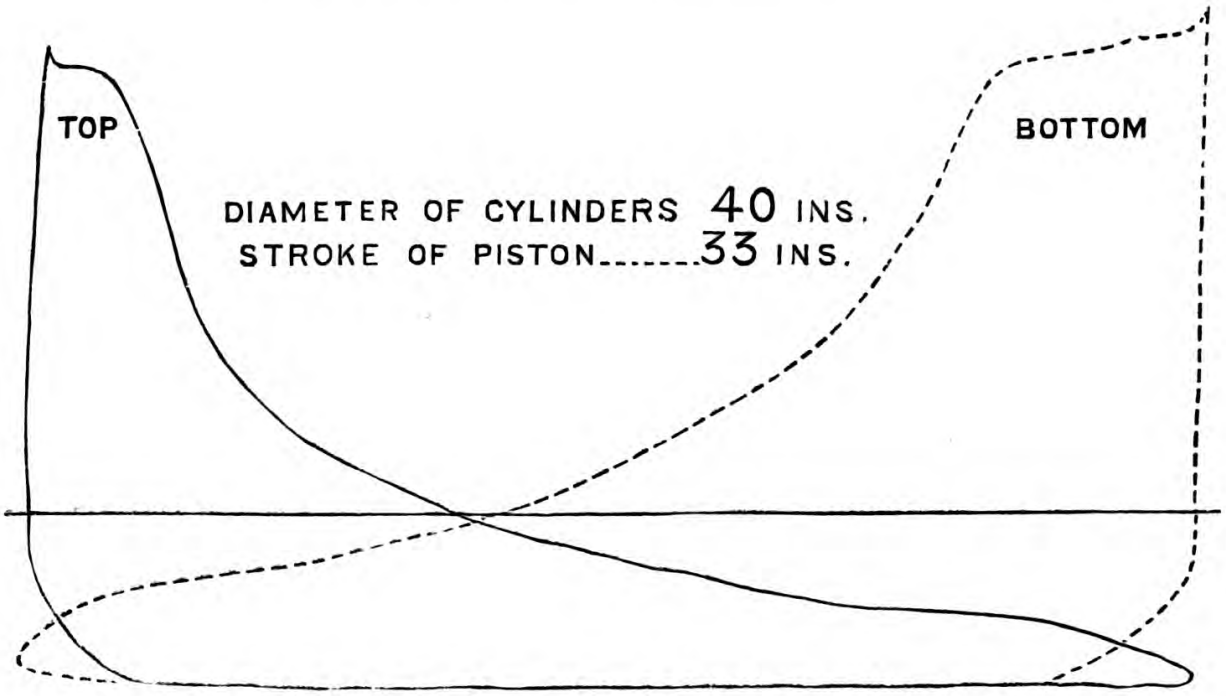
MARINE ENGINE.—CORLISS VALVE GEAR.



A STEAM VALVES
B EXHAUST VALVES
C STEAM (CLIP) RODS
D EXHAUST RODS

E WRIST PLATES
F DASH—POTS
G EXPANSION GEAR
H CONDENSER
I RODS TO LINK MOTION

CORLISS VALVE DIAGRAM.



connection with the Condenser. The Cylinders are generally known as the High and Low Pressure. John Elder, in his designs for the s. s. "*Brandon,*" built and engined in 1854, adopted the four cylinder system. The Engines of this steamer were known as—Four Cylinder, Vertical Geared Common Condensing-the crank-shaft being above the cylinders. The Paddle Steamers, "*Valparaiso*" and "*Inca*" built in 1855–6 were Four Cylinder, Diagonal, Common Condensing. In 1858 his s. s. "*Royal Bride*" was fitted with Four Cylinder Inverted, Direct-Acting, Common Condensing Engines—as mentioned, this vessel had a surface-condensing contrivance in the after peak. It will thus be seen that to Mr. Elder belongs the credit of having pertinaciously clung to and adopted for marine purposes, the Compound System. Nor was he slow to perceive the necessity for higher pressures, which he forthwith began to adopt, with such success as to reduce the consumption of fuel in his Compound Surface Condensing Paddle Engines of 1864, to 2·5lbs. per H. P. per hour. This wonderful result was for a time doubted, but the fact being incontrovertible, there arose in 1866–7, a general demand for higher pressures and Compound Engines. The inverted type was now designed on the compound system, and many of those at work were compounded, either by the substitution of two new cylinders, one high and one low pressure; or by the addition of two high pressure cylinders fitted above and attached to, the original cylinders. New boilers were also supplied of a pressure ranging from 50 lbs. to 65 lbs. From using steam for marine purposes of 10 lbs. and 15 lbs. in the short space of ten years we find steamers at sea with 60 lbs. and 65 lbs. pressure, in some instances where a peculiar form of boiler was adopted, such as Rowan's—the pressures were even 120 lbs.

Confining ourselves strictly to the improvements on the Marine Engine which have proved commercial successes, we will not dwell on the many schemes for low consumption which were at one time abroad, during the dawn of compound engineering;—in boilers, slide-valves, pistons, pumps, furnaces, furnace-bars and doors, &c., designs intended to obtain results which were in the majority of cases purely ideal; we cannot condemn, but are rather proud of our men of failure, their plans and aims acting as beacons to the rising generation of British Engineers. We find there is good in every thing, even in a mechanical muddle.

The Improvements or Progress of Marine Engineering during the last forty years may now be classed as follows:—

1st.—The general supercession of Side-Lever Paddle Engines by Oscillating Engines, an improvement by John Penn, date 1837 and upwards.

2nd.—The application of the screw for propulsive purposes, and gradual overthrow of Paddle Engines, an improvement by Francis P. Smith, date 1840 and upwards.

3rd.—The application of Surface Condensation to Marine Engines, an improvement by Samuel Hall, of Basford, date 1835 and upwards.

4th.—The application of the Compound System, with higher pressures, to paddle-wheel vessels, an improvement by John Elder, date 1854 and upwards.

5th.—The application of the same system to screw-propelled vessels with inverted engines, an improvement by John Elder, date 1858 and upwards.

In general terms, the foregoing are the *real* improvements, and, as we are dealing exclusively with leaders, not followers; with principles, not details; we may be pardoned for not alluding to the work of the numerous army of detail-arrangers which Marine Engineering progress has furnished; men, in a certain sense clever enough to see and

adopt modes of detail-improvement possessing value-advantages in cost of manufacture, and simplicity in working, but whose laudable efforts have not altered a principle or revolutionised the designs of the above-named world-famous pioneers of Modern Marine Engineering.

We will now describe the modern types of Compound Engines which find favour with our shipowners. As mentioned before, in the compounding of the ordinary Inverted Direct-Acting Surface Condensing Engine, instead of fitting one high and one low pressure cylinder to the columns, it was often found to be more advantageous to fit two additional cylinders above the original ones, that is, one high pressure above each of the existing or low pressure cylinders; these four cylinder engines gave every satisfaction. A large number on the same arrangement have been constructed by Messrs. Maudslay, for the White Star Line of Steamships. One advantage they possess is, in the fact, that the cylinders being small in diameter are easier moulded and less liable to fracture in the port passages than large cylinders. Their disadvantages are—

1st.—Difficulty in overhauling, or renewing the low-pressure piston.

2nd.—Their centre of gravity is higher from the keel.

3rd.—Greater consumption of engine-room stores.

Notwithstanding these drawbacks, their ocean work compares favourably with any other type; and the White Star voyages are performed with a regularity and speed which have as yet been unsurpassed.

The next design of Marine Engine we shall notice, is the type, having merely two cylinders, one above the other, and almost exclusively adopted by Mr. Holt. This engine occupies the least length space of any type. The high pressure cylinder is placed sometimes above and sometimes below the low pressure.

From all we can learn, the performance of this engine is highly favourable, the S. S. "*Myra*" having made a passage from Liverpool to Calcutta in 29 days 6 hours; but being in every sense of the term a single engine, it requires to have a ponderous fly-wheel on the shaft, ostensibly to prevent "sticking on the centre," and also the means of overcoming this difficulty when it occurs, viz. by having a horizontal steam cylinder bolted to the bulk-head, the piston-rod of which has a double pawl attached, this pawl falling into corresponding teeth cast on the periphery of the fly-wheel. In the hands of an expert engineer, the "sticking" can be generally avoided. Notwithstanding their occupying a minimum of length space in the ship, this type has not obtained with shipowners generally.

The next design of Marine Engine we shall consider, is the Three Cylinder Inverted, having one high and two low pressure cylinders.

For vessels where machinery space is subservient to speed, and for screw engines of large power, this is the best form of engine which can be adopted, and possesses many advantages over every other form.

1st.—The arrangement is simple.

2nd.—They can be easily overhauled in every part.

3rd.—The twisting moment on the crank-shaft is more even.

4th.—The upward and downward pressures on the crank-shaft at many positions of the stroke nearly balance each other, hence the friction is less than in any other type of engine.

5th.—And the incidental advantage of having to manipulate lighter cylinders, &c. in the factory.

The latest specimens of the Three Cylinder Inverted Compound Engine are those fitted by the firm of Elder & Co. from the designs of Mr. Jamieson, into the Guion Line s. s.

"*Arizona*," and the Anderson Australian Line s.s. "*Orient.*" Without doubt they are the most magnificent examples of Modern Marine Engineering that the world has yet seen, exhibiting a triumph of skill and art, which the engineers of 1840 never dreamt of, and maintaining the proud position which British Marine Engine Builders hold, as "Second to none."

The three foregoing types of Engine, viz., the Four Cylinder Two-Crank type, the Two Cylinder One-Crank or Holt's type, and the Three Cylinder Three-Crank type, are the exceptions in our Mercantile Marine; the Engine of the period being the Two Cylinder Two-Crank type; nine-tenths of the vessels afloat and being built are fitted with this form of Engine, some of them of the very largest size, such as the Inman Line "*City of Berlin*," "*City of Chester*," &c., vessels whose machinery is of colossal proportions and symmetry, and whose Atlantic voyages are among the fastest on record.

In thus describing the four principal types of Compound Engines adopted in the Mercantile Marine, we cannot but draw attention to the fact that from all the information we can gather, their consumption of coal per Indicated Horse Power per hour is pretty much alike, and, in any of the types, seldom exceeds 2 lbs. with the pressures at present in vogue, viz., 70 and 75 lbs. In some cases we find 1·8 lbs. in others 2·2 lbs.; but taken as a mean, we are safe in stating that there is not an ocean-going steamer doing its work on less than 2 lbs. of fuel per I.H.P. per hour.

Passing now from types of Engines to details, we find ourselves in a field of improvement deserving notice. Amongst the many details of improvement characterised as embodying additional safety to steamships may be mentioned the following:—

CRANK-SHAFTS are now invariably made in interchangeable

halves,—thus enabling the engineer in charge to bring his vessel into port should one engine break down.

CIRCULATING PUMPS are invariably arranged to draw from the bilges,—therefore should a heavy leak occur the engineer has at command the largest pumps in the vessel.

SURFACE CONDENSERS are so arranged that they may be used as common condensers, injecting either from the sea or bilge ; therefore, should the condenser tubes fail, or in the event of a leak, the engineer can always keep his engines going, condensing with the common jet either from the bilge or sea.

AN AIR PUMP and CIRCULATING PUMP are (in those engines designed to guard against possible exigencies,) invariably fitted to each cylinder ; therefore, should any accident affect one cylinder or engine, the engineer has a complete engine ready to perform every function necessary to propel the ship.

PISTON RODS are carried through the cylinder-covers, thus forming a guide to the motion of the piston.

LINERS of steel or hard cast iron are fitted into the high pressure cylinders ; thus obviating their being bored out should they wear oval or irregularly, as a new liner can at any time be inserted, and will cost much less than the operation of boring.

ONE BILGE PUMP of the Main Engine is generally arranged to throw sea water on deck ; the captain has thus an additional pump ready in case of fire, and the deck can be washed at sea without having recourse to the "Donkey Pump ;" the wash deck service is (or should be) a galvanized iron pipe running under the bulwark rail for the whole length of the vessel, having couplings fitted at intervals ; thus obviating the use of the cumbrous and leaky leather hose-pipe system.

All bilge and compartment valves are now placed in the engine room immediately under the control of the engineer, who can thereby pump from any part of the ship without leaving his post. In fine, all detail arrangements are now so perfect and so well designed, that we believe little room is left for improvement in the type of Marine Engine in use at the present day.

As we have stated, the steam pressure used in 1840 was 10 lbs., that it increased to 60 lbs. and 65 lbs. in 1860; now in 1880 we have 80 lbs., and in some cases even 90 lbs. and 100 lbs. adopted. This increase of working pressure naturally necessitated another form of boiler. The old-fashioned stay-filled, rectangular-flue types were found to be unsuitable for high pressures, and were discarded for the Tubular System, which was introduced in 1844, and came into gradual use with the adoption of surface condensation. Hence, we find various forms of tubular boilers brought forward; the best known being the oval and circular. The advantages of using oval boilers for high pressures may be briefly stated as follows :—

1st,—They occupy small length or breadth space.

2nd,—The maximum of steam space can be obtained, if required, without the necessity of fitting domes.

We fail to see any practical disadvantages in this form of boiler, although it may be urged that cleaning is rendered more difficult by reason of the staying of the sides, the stays passing through the tube spaces. We do not think this a tangible objection; but from a builder's point of view there is one disadvantage of serious moment; *i. e.* cost in construction.

The Circular Boiler is the one which is most in repute for high pressures. This type is unquestionably the simplest and best which can be made for modern requirements. The only staying required, is for the ends, above the combustion

chambers, leaving thereby clear spaces above the tubes for efficient cleaning. The general practice in designing these boilers, is to give 5 cubic feet of total steam space, and 20 square feet of heating surface per Nominal H.P., allowing for the usual cleaning spaces between the tubes ($1\frac{1}{4}$"). One third of the boiler's diameter is generally above the combustion chamber top, while $\frac{2}{3}$rds go for tube depth and furnaces. Priming is apt to occur if the space above the combustion chamber is less than this, while the steam space of 5 cubic feet per Nominal H. P. is obtained by fitting a dome or receiver above the boiler. With this proportion of steam space in the boiler, including dome, we have never seen priming occur, even in the heaviest weather. In the construction of marine boilers great improvements have taken place, these partake more of a question of workmanship than design, and deserve notice. Only six years ago punching the holes was general, now this barbarism is almost extinct; *all holes are now drilled* through both plates at once, therefore fair and true holes are obtained. Rivets are not now put in to *draw* the plates together, but merely to *hold* them; the plates are in close contact prior to being rivetted. Plating is now a question of accurate and careful workmanship—filling in pieces, drifting, open space caulking, and other coarse practices, seldom exist. The engineering of marine boiler building is now of a high and scientific order, and not as it once was, when based on the doctrine of "anything will do for a boiler." Therefore we have in the Circular Boiler as now constructed, a type possessing all the elements of simplicity and safety, and a good generator of steam—in fact, a boiler that is indeed "bad to beat." Notwithstanding all the pseudo-improvements, which have of late been brought forward in the form of water-tube boilers, these generators will never be suitable for marine purposes, the element of danger is too

evident in them ; should a single tube give out the boiler is virtually useless, and in the act of giving out serious consequences must inevitably ensue to those around. All the attempts that have been hitherto made (and they are not a few) have been utter failures. The most notable examples of discomfiture in modern marine boiler annals, were those of the water-tube boilers for the Guion Line, s. s. "*Dacotah*" and "*Montana,*" the minor examples were the Howard boilers fitted into the s. s. "*Mark Antony,*" "*Fairy Dell,*" and several other vessels.

At one period the corrosion of marine boilers due to the introduction of surface condensation, gave great anxiety to Shipowners and Engineers. This bug-bear of corrosion was the cry urged against the use of the Surface Condenser. It is now well known that no esurience will occur if the engineer knows his business. A single coating of lime will prevent all corroding of furnaces or "pitting" of tubes. Under fair supervision and honest examinations, the average life of a marine boiler, working at 65 lbs. and 75 lbs. pressure, and fed with surface condensed water, will be from 8 to 10 years.

Having now reached the present date of Marine Engineering from our start period of forty years ago, we naturally ask what is the actual result of this progress ? In Marine Engine construction, this progress is represented by comparing the number of makers of 1840 with those in 1880.

In 1840, there were

IN ENGLAND.

Messrs. Maudslay, Messrs. Penn, and Messrs. Seaward, London ; Messrs. Hall, of Dartford ; Messrs. Boulton and Watt, Birmingham ; and Messrs. Laird, Birkenhead.

IN SCOTLAND.

Messrs. Napier, Messrs. Caird, Messrs. Denny.

In that year, 74 Steamers were built and engined, having a total Register Tonnage of 10,150.

At the present period, the principal Marine Engine-builders are as follows:—

LONDON DISTRICT.

Messrs. Penn, Messrs. Maudslay, Messrs. Humphreys, The Thames Iron Works.

SOUTHERN DISTRICT.

Messrs. Oswald, Southampton.

WESTERN DISTRICT.

Messrs. Laird, Birkenhead; Messrs. Forrester, Messrs. Jack, Liverpool; The Barrow Engineering and Shipbuilding Co., Barrow.

EASTERN DISTRICT.

Messrs. Stephenson, Messrs. Hawthorn, Messrs. T. Clark and Co., Messrs. Black, Hawthorn, & Co., at Newcastle-on-Tyne; Palmer's Shipbuilding Co., Jarrow-on-Tyne; The North-Eastern Marine Engineering Co., Mr. George Clark, and Mr. Dickinson, at Sunderland; Messrs. Richardson and Co., Hartlepool; Messrs. Blair & Co., Stockton-on-Tees; Earle's Shipbuilding Co., Hull; or a total of 20 Firms in England.

Crossing the Border, we enter the region which was the cradle or nursery of Steam Navigation, and find that the seed which was sown there by Henry Bell, in 1812, has grown wonderfully; the following being the principal Marine Engine-builders in the

CLYDE DISTRICT.

Dumbarton.....Messrs. Denny.
Greenock ..... ,, Caird.
,, ... ,, Scott.
,, ... ,, Blackmore & Rankin.
Port Glasgow..... ,, Blackwood & Gordon.
Renfrew ..... ,, Simons & Brown.
,, ... ,, Colborn & Co.
Glasgow ..... ,, Stephens & Co.
,, ... ,, Elder & Co.
,, ... ,, Inglis.
,, ... ,, Thompson.
,, ... ,, Napier, Kirk, & Co.
,, ... ,, Barclay, Curle, & Co.
,, ... ,, The London & Glasgow Eng. Co.
,, ... ,, Henderson.
,, ...Mr. Howden.
,, ...Messrs. King & Co.

EASTERN DISTRICT.

Aberdeen .....Messrs. Hall, Russell, & Co.
Dundee ..... ,, Gourlay Brothers.
,, ...Mr. Thompson.

or a total of 20 Firms in Scotland.

The grand total of Marine Engine-builders of Great Britain being 40, (exclusive of sundry minor Firms principally engaged in tug-boat building,) and in 1878 these Firms engined 499 Steamships, having a total register tonnage of 287,080. This is the result in constructive progress.

We shall now show the result commercially. In 1840, the time occupied over a voyage to America was on an average 14 days, now it can be done in 7 days 20 hours. In 1840, the average consumption of coal was 6 lbs. per I.H.P. per hour, now it is 2 lbs. Giving an example of the work of a modern cargo steamer in the American trade, we will take the "*Alvah*," her dimensions are 300 feet × 36 feet × 21 feet load draft; the engines are Compound Surface Condensing, having cylinders 37″ × 68″ and stroke 42″, pressure of steam employed 80 lbs; I.H.P. 950 to 1000, consumption of Lancashire coal 20 tons per day. The time over her last run from Boston to Liverpool was 11 days 16 hours, dead weight of cargo carried 2700 tons, (excluding bunkers.) Reckoning these coals as costing seven shillings per ton, we have 2700 tons carried nearly 3000 miles for a *fuel charge of under* £84. Still more wonderful is the performance of a number of our modern steam colliers. Of late the experiment of burning small coals has been tried in several of them with unqualified success, and we now find vessels doing Continental, Mediterranean, and even American voyages on coals costing from two shillings and sixpence to three shillings per ton. Take an instance of a modern collier the s. s. "*Sybil*," her dimensions are 265 ft. × 38 ft. × 19 ft. load draft, the engines are Compound Surface Condensing, cylinders 37″ and 68″, stroke 42″, pressure 80 lbs., I.H.P. 950 to 1000 (the engines were duplicates of those of the "*Alvah*.") This vessel burned 320 tons of *small coal*, (costing say three shillings and sixpence per ton) during a voyage from the Tyne to Cronstadt, thence to Nieu Diep, Rotterdam, and back to the Tyne, total full steaming time over the all round voyage 16 days 22 hours, dead weight cargo carried 2413 tons, (excluding bunkers,) and this was done for a *fuel charge of under* £60. This then is the result of our Marine Engineering Progress, and

well may England be proud of her engineers, civil and mechanical, to whose energies these remarkable achievements are due, and as long as we have on the muster-roll of the steam-god such names as

Our Penns, Maudslays, Fairbairns, Rennies,
Our Napiers, Elders, Cairds and Dennys,

So long shall the engineering renown of the empire be maintained in undiminished splendour, and the heritage bequeathed to us by the fathers, James Watt, and Patrick Miller of Dalswinton, be still more extended by worthy sons, whose watchword is "Progress," and whose doctrine is "Peace on earth and good will to all men."

The labours of those men who have changed the aspect of the world in the short space of 40 years; whose battles have been ever fought under the banner of advancement; whose soul-worship has ever been at the shrine of Science;—cannot pass away. Dynasties shall be obliterated, battles of blood shall be fought and forgotten, heroes names shall shine out and then sink into the clouds of oblivion, but the triumphs of Science and Steam cannot be obscured, and shall always be the keystone of Britain's greatness; and while our isle continues to be pre-eminently productive of lovers of the square and compass, of the hammer and chisel, and of stern workers in the fields of mechanical science, the glory of our steam-sceptred empire shall endure as long as the world lasts.

In concluding this sketch, we may ask, has the perihelion of Marine Engine Progress been reached by us. Shall we yet discover in the infinite expanse of science a new motor? Shall electricity furnish the world with an easily manipulated power before which steam shall vanish? Is it at all possible that we may generate by chemical admixture, a gas which shall drive engines, or, by acting directly on the water or atmosphere, propel a vessel or locomotive without the aid

of machinery save the gas generators? These are queries which no doubt steal over the minds of our mechanical scientists. Dreams and theories are the seed of facts-to-be. Therefore we can only hope that our coming progress shall be as clearly defined and as beneficial to humanity and commerce as our past has been, that our masters of mechanics and sons of steam shall strenuously strive after new discoveries, and continue to make experiments with a view to greater improvements.

Nature trembles, aghast! at the onslaughts of our Engineers, and tacitly yields her sovereignty unto them. The mighty ocean is scorned by the majestic works of man, which, defying its wrath, speed over its troubled bosom as conquerors; and as now there is scarcely a hill, from the Himalayas to the Andes, from the Urals to the Australian Alps which has not re-echoed the shrill-sounding steam blown notes of the modern missionary of civilization bounding on his iron path, and bearing on his iron brow the white banner of peace and love, so there is not a nook or cranny in the world of waters, or a navigable stream which has not borne on its bosom a steam-propelled craft of some sort. Verily our progress of 40 years has been great and wonderful, and this grand work shall go on and on. Improvements slowly grow, Science is a silent worker, coming times shall witness its other and greater developments, therefore let the labours of engineers be ever onward and upward until it shall be said—

"Lo! every race to earth's remotest region,
Now worship Science as their new religion."

——:o:——

THE economy of all trade, as understood by business men, is to get as much value as possible for money expended. In every phase of commerce this view is always paramount. The seller endeavours to make capital out of the buyer and *vice versâ*. In other words, the friendly and pleasing war of business is carried on by each endeavouring to out-flank the other over a purchase or contract. We have in this ceaseless strife, the soul of commerce and national greatness. At the same time, this fight for life, (or rather, life of fight,) developes in mankind the inventive faculty, or that quality in human nature which urges a man on to keep pace with his neighbours, and to acquire wealth by means of what may be called, inducements to purchase. It is this faculty which has enabled mankind to prepare and sell silk mixed with whalebone or jute ; or razors which are made of cast iron, but which shave as cleanly as steel ; or cloth which is virtually shoddy, but which wears equally with wool ; the genius of under-selling developes branches of industry truly remarkable. The great desire of the world is to purchase "*Cheap*," therefore in all business the charm of cheapness is too often irresistible and quality is entirely overlooked. It may almost be accepted as a business axiom, that adulteration must exist before any business can be done ; nor are the higher or scientific forms of business exempt from this charge. In the manufacture of pig iron, plates, forgings, or chemicals, quality is too often subservient to quantity and rate per ton. In the construction of machines and engines, the same element is often found at work ; the seller constructs his machines as cheaply as possible, in order to make profit out of a purchaser, while the purchaser at the same time is under the impression he has made a good bargain ; in one sense he has, he has got a machine at his own price which will no doubt fulfil its duties

for a time, but he only finds out his mistake by the cost of its future repairs and abnormal working. Under such conditions, the fault lies entirely with the purchaser, he should have specified *a priori* for the machine and its details before concluding the contract, stating in his specification the quality of metal to be employed, and certain dimensions of the parts most liable to wear, or on which the true working of the machine depended. Were all purchasers enabled to specify for what they wanted, *and willing to pay for the article*, sellers of inferior goods would undoubtedly profit by the system, inasmuch as a loftier sense of their business would be engendered, and soon only first-class articles would be supplied by them.

So far as these ideas bear on the manufacture of Marine Engines, the purchaser, or shipowner, invariably gives his orders where he thinks he gets most for his money; at the same time, he may be getting an article whose arrangements may not be of the most perfect description. Therefore, to enable a steam shipowner to specify for his engine, we now submit a draft specification of a Marine Engine as it should be, and any dimensions which we insert, or formulæ we may submit can be relied upon. We think that all steamship owners ought to be cognisant of what is really required in an engine or engine-room. The success of their business depends entirely on their engines. We live in an age when ignorance of these matters should be no longer a reproach to steamship owners; There are no secrets about an engine, the field of engineering science should not be unknown territory to them. True Science abhors conservatism.

We now enter upon what the Specification should be.

In preparing a Marine Engine specification the greatest amount of care is imperative, it ought at all times to cover the wishes of the intending purchaser, and embrace a full description thereof, in details and arrangements, as follows :—

SPECIFICATION

of a pair of Marine Engines of the Inverted Direct-acting Compound Surface Condensing type, and to be of Horse Power Nominal collectively :—

GENERAL DESCRIPTION. Cylinders to be inverted over the Crankshaft, and firmly secured to the Bedplate and Condenser by cast or wrought iron columns ; Air, Circulating, Feed, and Bilge Pumps, to be worked by levers or crossheads. Each Engine to be perfect in itself in Air, Circulating, Feed, and Bilge Pumps.

CYLINDERS. To be of Diameter for High Pressure and of Diameter for Low Pressure, and of Stroke, to be made of hard, close-grained cast iron of a mixture of 5 of Summerlee (No. 3,) 4 of Best Scrap, and 1 of Cold Blast Iron, to be truly bored by two cuts. The High Pressure Cylinder to have a hard-cast internal liner fitted in by flanges top and bottom, no rust or wire joints to be used in securing it ; must be face and face, and held by bolts. The mixture of this liner to be of 6 of hard clean scrap, 2 of Summerlee (No. 3,) 2 of white iron and to be *re-cast* before liner is made ; the ports to be double or single, if double-ported, the cylinders to be cast as single ported, but having the double port face pinned on, if single ported, faces to be pinned on ; the faces to be of a mixture of metal similar to liner of H. P. cylinder, and to be

accurately faced and scraped for slide valves. Slide valves to be of same mixture as liner for H. P. cylinder, to be carefully fitted to spindles, and secured to same by wrought iron washers top and bottom with cutter at the top, cutter to have a copper split pin inserted, of at least $\frac{3}{4}$in. in diameter, cylinder covers to be of the box section and of ample strength. All glands to be in length equal to one diameter of rod, the depth of stuffing boxes one and a half diameter, depth of neck ring one diameter ; the glands to be bushed with gun metal, neck rings also of gun metal ; and all glands to be cast in the save-all form, or have the same fitted to them. Escape valves to be fitted to the top and bottom of each cylinder, the seats and valves to be of gun metal, the valve springs to be compressed by means of a screw with hand wheel fitted into the spring covers. Drain cocks to be fitted to the cylinder and casing bottoms, and to be secured by flanges, to be packed cocks of gun metal and of ample size, having their drain pipes leading to the hotwell ; drain cock handles to work on or in brass plates indexed to show the operation. The annular space in jacket between cylinder liners and outside cylinders to be drained, the pipes leading to the hotwell. Indicator cocks with pipes, to be permanently fitted, having all necessary gear for taking diagrams. The throttle valve and branch to be bolted to the cylinder, and to be of gun metal ; a stop valve, to be worked from the starting platform, to be fitted either to the throttle valve branch, or in any convenient portion of the main steam pipe in the engine room. Ample space for overhauling or examining the slide valves to be allowed in the casings. A starting valve to be fitted to each cylinder, and to be worked from starting platform, valves and seats or faces, also the spindles for actuating valves to be of gun metal ; bosses to be cast on cylinder bottoms for the insertion of eye bolts, these eye bolts to be permanently fitted

into each boss, and to plumb the crank-shaft keeps. The various flanges of the cylinders to be chipped and filed smooth to their respective parts. The whole of the cylinders to be covered with sheet lead, then felted and covered with well-seasoned teak wood, tongued and grooved ; the grounds for securing the teak being held to the cylinders by $\frac{3}{8}$ inch button-headed set-bolts.

BEDPLATE AND CONDENSER. Bedplate to be in one casting with, or separate from, condenser, and formed to receive square sided brasses for crank-shaft, to be strongly proportioned and sound in the casting, the mixture of metal to be similar to that for cylinders. The crank-shaft bearings are to be of gun metal, properly fitted and scraped into the recesses for same, and must be cast solid, the upper brasses to be eased off for ready withdrawal, and to have proper oil courses cut on them ; $\frac{1}{4}$th of circumference of brasses to be cleared out equally on both sides of joint ; the bearings to be held down by bright wrought iron keeps, of a thickness at least equal to diameter of bolts ; cast brass oil boxes to be fitted to the keeps. Recesses to be bored into the keeps for the keep bolt nuts entering, the nuts to be held by set pins tapped into the ends of keeps, the ends of the keep bolts to be turned down below the thread, and to be left of a length suitable for a taper pin to be fitted through and to bear on the top of the nut. The Bedplate to be secured in the ship by a sufficient number of bolts, and to be fitted down on cast iron packing pieces properly fitted.

CONDENSER. To be of ample strength, and a sound casting, its mixture of metal to be similar to the bedplate. To have proper man-holes for cleaning purposes, to have not less than two square feet per I.H.P. of cooling surface, effective length of tubes to be measured

from between inside of tube plates ; tube plates to be of brass, not less than $1\frac{1}{2}''$ thick, and to be secured to condenser (in portions exposed to the water) by Muntz metal studs and nuts; the circulating water to have not less than two currents through tubes. Tubes to be hard drawn and secured in the tube plates by cotton packing and brass screw ferrules, or Horn's patent wood ferrules ; a brass supporting plate for the tubes to be fitted in the centre of condenser ; a common jet inlet valve-box, and a copper perforated spray pipe to be fitted, in order to work the condenser on the common injection principle if required ; the auxiliary feed cock may be fitted to any convenient part of condenser. All flanges and faces to be properly chipped and filed smooth.

AIR AND CIRCULATING PUMPS. One air-pump to each engine, and to be connected to condenser ; to be of a collective capacity of cubic inches, (see Formula.) Air-pump chambers to be of gun metal not less than $\frac{5}{8}$ths thick and smoothly bored ; buckets to be of gun metal, having an area through the openings of not less than $\frac{1}{3}$rd of air-pump area ; rods to be solid Muntz metal, diameter to be inches, (see Formula) and to be fitted into the bucket by taper, and having the guard as the nut ; foot-valves to be of gun metal, and having an area through the openings of not less than $\frac{2}{5}$ths of air-pump area, and to be so fitted into the air-pump bottoms that they can be withdrawn without removing the bucket ; guard to be of gun metal, and either screwed into the foot-valve centre, or held by a strong Muntz metal stud and nut securely fixed in the foot-valve seat ; head-valves to be of gun metal, having an area through the openings of not less than $\frac{1}{2}$ of air-pump area, guard to be of gun metal ; this valve to be held down either by contact with the air-pump cover, or by Muntz metal studs and nuts screwed into the hotwell

flange; the various valves, guards, and buckets to be strongly ribbed, and the ribs of the openings to be of a sufficient section to resist the pump-strains; the buckets to be packed with hemp rope, the recess in the peripheries of the buckets to be of a depth that will allow of the hemp rope being lightly smoothed over with a hot iron, after its insertion. If the pumps are worked by levers, the air-pump rods must be fitted into the crossheads by a tapered fit, having a Muntz metal nut on the top; if wrought direct, (as in the accompanying diagram) the rods must be firmly keyed into the carrying rods, which are secured to each end of the crosshead; the glands to be bushed with, and neck rings made of gun metal, the proportions of depth to be in keeping with the diameter of the rods, (see Cylinders).

CIRCULATING PUMPS. One circulating pump to each engine, to be so arranged that the water shall be drawn through the condenser tubes and lifted overboard; to be of a collective capacity (see Formula,) the pump chambers to be of gun metal, not less than $\frac{5}{8}$ths thick, and to be smoothly bored; buckets to be of gun metal having an area through the openings of not less than $\frac{1}{3}$rd of the area of pump; the rods to be of solid Muntz metal, diameter (see Formula) and fitted into the buckets by taper, and having the guard as a nut; foot valves to be of gun metal, and having an area through openings of not less than $\frac{2}{3}$ths of the pump, and to be so fitted into the pump chamber bottoms that they can be withdrawn without removing the bucket; the foot valve guard to be of gun metal, and either screwed into the foot valve seat centre, or held by a strong Muntz metal stud and nut, securely fixed in the foot valve seat. The circulating pumps to be arranged so that water can be drawn from the bilge. The clearances between the buckets and foot valve to be the same as that between the pistons and bottom of the

cylinders; but between the buckets and head valves not more than $\frac{1}{4}$th of an inch. This proportion applies for both air and circulating pumps; the details of the circulating pumps to be in accordance with those of the air pumps, and both to be fitted with adjustable air valves.

HOTWELL. To be of ample proportions, not less than 3 times the capacity of the air pumps, and to be fitted with an overflow pipe of not less than 4″ diameter, this pipe to lead towards the bilge, and to have a screwed coupling and close cap for its end, so that in the event of working the engine as a common engine, it can be temporarily closed. The division between the hotwell and the circulating water passage to have a brass valve and seat fitted therein, not less in diameter than one circulating pump. This valve allowing of a free exit overboard, through the main discharge pipe, of accumulated water in the hotwell, either arising from leaky condenser tubes, or when working as a common engine. A man-hole door to be fitted to the hotwell.

FEED & BILGE PUMPS. One of each to each engine, the capacity of the feed pumps to be (see Formula.) Bilge pumps to be of the same diameter as the feed; all rams, valves and seats to be of gun metal. Feed valve chests to have a brass valve box door, secured with Muntz metal studs and nuts, stops for feed valves to be of brass; relief valve and spindle to be of brass, air vessel on both the feed and bilge valve chests to be not less than the capacity of both pumps, air valves to be fitted to each, the areas of valves and passages to be not less than $\frac{2}{3}$rds the area of the pump.

REVERSING & SLIDE VALVE GEAR. Link motion to be designed with plate links, forged of the best scrap iron, and having the eccentric rod and drag-link pins forged solid thereon; the eccentric rod pins to be turned with an outside collar on, and to be not less than three times the travel of the slide valve apart; dimensions of these pins to be based upon a pressure per square inch, (see Formula.) Link block to be of gun metal, and carefully fitted to the links, dimensions of link block bearing flanges, to be based upon a pressure on link edges not exceeding lbs. per square inch; link block to be adjustable, and to be carefully fitted into the valve spindle eye, to be of a diameter so that the pressure per square inch in the eye does not exceed lbs.; valve spindle eye to be adjustable to the link block, and to be primarily forged solid with the spindle. The drag link pins to be not less than $\frac{2}{3}$rds the diameter of go-ahead pins, the drag links to be double for each link, and to be bushed at both ends with steel bushes, and to be of a length between the centres of not less than twice the distance between eccentric rod pins; eccentric rods to be forged solid, of the best scrap iron; the ends at the links to be made adjustable with brasses, liners, and keeps, the keep bolts to be a tight fit in the lower portion of the bearing, and to have check nuts and through pins on the upper; the foot of eccentric rods to be well filletted, and secured to the eccentric straps by studs screwed into the strap, the ends of the studs to be turned down for $1\frac{1}{4}''$ long, so that a through pin, bearing on the nut can be fitted, and also to allow for a liner being inserted under the foot of the rod, if at any time found necessary; the eccentric straps to be of gun metal, having oil boxes cast on the same, to be carefully fitted and scraped to the eccentrics, and to be of a dimension so that the pressure on them will not exceed lbs. per

square inch. To have brass liners fitted between the lugs, the strap bolts to have check nuts and through pins inserted above them. Eccentrics to be of cast iron, of the same mixture as that for the H. P. cylinder liner, the halves to be planed with spigot and recess, and carefully fitted together and firmly bolted before being bored out and turned ; the keyway to be slotted out of the top or larger half of eccentrics, two steel set pins, having check nuts, to be fitted into each eccentric flange.

The operation of reversing to be performed either by hand or steam gear, if by hand, the reversing worm to be of wrought iron, gearing into a strongly-proportioned quadrant fitted on to the weigh-shaft. The reversing wheel to be of a diameter which will enable the operation of reversing to be performed quickly. If by steam gear, the steam cylinder to be of a sufficient diameter to overcome the resistance ; the cylinder and its valve face to be brass-lined, the piston, piston rod, slide valve and spindle to be of brass, and carefully fitted. The reversing of the starting engine to be performed either by a link motion, or single valve if the engine is to run merely one way ; if a direct steam cylinder is used, an ordinary slide valve will suffice ; whatever design is employed, it must be so arranged that over-running is obviated. All handles to the gear of the starting cylinder to work on, or in, brass plates indexed to show the operation. All the joints and bearings of the link motion, to have small brass cup lubricators fitted to same. The diameter of slide valve spindles where working through the glands to be (See Formula) ; the slide valve washers to be of wrought iron case hardened, and the lower ones to be fitted to the spindles by having a taper hole ; thickness of washers not less than two inches, their edges nearest the valves to be a close fit.

PISTONS. The pistons to be cast of a mixture similar to H. P. cylinder liner, to be of the box section, and having core holes left between the internal arms; these holes to be carefully tapped with a fine thread, and screw plugs inserted, these to be screwed in with red lead, then dressed off flush, and two screw pins fitted half in piston and plugs to prevent their coming out. The pistons to be turned tapered at the junction of the junk ring, to allow of its instant removal; the junk rings to be cast of a mixture the same as cylinders, to be of ample strength, and carefully fitted to the pistons, to be held down by set bolts screwing into brass nuts, the recesses for the nuts to be cast in the sides of the pistons, the pitch of junk ring bolts to be not more than 7 diameters of the bolts. Plate-guards to be carefully fitted between the bolts, the guards to be secured by their fitting over a square-ending stud, with a split pin through the top. The packing ring to be cast of a mixture of 3 of Summerlee (No. 3), 4 of Weardale, 12½ good scrap, and ½ of Tyne white iron; the depth of packing rings to be (as per Formula); they must be carefully turned from ¼ to ⅜ths larger than cylinders, and fitted to the pistons; a gun-metal tongue piece to be fitted to each, one end of which must be secured to the inside of the ring, the other left free, the rings to be then diagonally cut through the tongue piece opening, and fitted into their respective cylinders; four half-inch lifting holes to be drilled about half through the metal on the inside periphery of the rings for convenient lifting. The springs behind the packing rings to be carefully fitted in, and with equal compression, each spring to have a guide projection on its back, and a corresponding way cut for the same on the piston; the opening for the piston rod to be bored to a taper of say 1 in 12, the bottom side of the piston to be faced up so as to rest on the piston rod shoulder, the top side to be recessed to receive the nut circle.

PISTON RODS. To be forged of the best scrap iron, and to be a separate forging from, but secured to, the crosshead by a continuation of the connecting rod top end bolts; to be carefully fitted to the pistons, and to have one large wrought iron nut for securing the pistons hard to the shoulder on the rod; a set pin to be fitted through nut and into the rod for at least the depth of the thread thereon, the depth of the nut to be equal to the diameter of the rod over the threads; each rod to be continued through the cylinder covers; the diameter of the rods at the bottom of the thread to be as per Formula.

GUIDE PLATES & SHOES. To be fitted for go-ahead and go-astern motions, and to be made of a mixture of metal similar to H. P. cylinder liners; to be firmly and carefully fitted to the columns, and to be arranged for ready and safe adjustment to the shoes, without having recourse to pieces of tin; to have efficient means of lubrication fitted; the shoes to be firmly secured to the crossheads, to be of a similar mixture of metal to the guide plates, and of ample size. See Formula.

CONNECTING RODS. To be forged of the best selected scrap iron, with solid double eyes at the top end, of ample dimensions, the crosshead pin to be shrunk into the eyes, then secured with a screw pin half in eye and pin; the dimensions of the pin to be based upon a pressure per square inch not exceeding lbs. See Formula. The brasses in the crossheads to be of gun-metal and secured by keeps and bolts, the nuts to be secured by set pins, and the ends of the bolts to be turned down to admit of a taper pin being fitted; the diameter of the connecting rod at the small end to be (see Formula), having a taper towards the bottom end of $\frac{1}{4}$ inch

in 12; the crank pin brasses to be of gun-metal, securely fitted to the bottom end of the rods by keeps and bolts; the brasses to be of ample thickness, and to have liners fitted between for adjustment; curved oil courses to be cut on the inside of periphery of top halves, the bolts to be well fitted, and to have the ends turned down to admit of a taper pin being fitted above the nuts; the nuts to be also held by set pins screwed through the outer edge of the connecting rod foot into the groove on each nut; lubricators for the bottom and top ends to be carefully fitted, and to be of ample size.

CRANK-SHAFT. The crank-shaft to be forged from the best selected scrap, to be a sound forging in every respect, and to exceed Board of Trade Formula in diameter, to be in halves, each half to be an exact duplicate of the other, and secured in the centre by couplings and bolts, to be carefully and truly fitted into its bearings; the length of the crank pin to be (as per Formula); the diameter to be the same as the shaft; the length of the other bearings to be (as per Formula). The eccentric keys to be sunk in the shaft; on the engines being fitted into the vessel, the coupling up of the crank-shaft to the thrust-shaft is only to be done after the engine and other shafting are finally secured.

SCREW SHAFTING. To be forged with solid couplings from the best selected scrap. The bearings to be pitched so that they follow behind couplings; the length of each bearing to be (as per Formula); all lengths to be carefully bolted together in the shop, after the holes are fairly rimed, a short length to be fitted immediately forward of the propeller shaft, so as to facilitate the removal of the propeller. Cast iron packing

pieces to be carefully fitted under each bearing, the holding-down bolts passing through the same.

PROPELLER SHAFT. To be of the same diameter as the crank-shaft, and to be covered with a gun-metal casing in the forward and after tube bearing; the after bearing to be not less than 4½ diameters of the shaft in length; the forward or stuffing box bearing to be not less than 2 diameters in length; the thickness of the gun-metal casings to be not less than ¾ths of an inch, and they are to be carefully shrunk on to the shaft in their respective places; after being turned up, several ¾-inch brass screw-pins to be tapped through the casings into the shaft, and neatly filed off. The propeller shaft to be carefully fitted into the propeller, and to show an even bearing throughout; after being so fitted, a distinct chisel mark to be struck on the shaft as the *home* mark of the propeller, and after the fore and aft key is fitted, the shaft must enter to this mark. A templet of the taper of the shaft to be supplied to the Owners.

STERN TUBE. To be cast of ample proportions, and to be of a quality of metal similar to that of the cylinders; to be carefully bored out for the forward and after bearings; the after bearing to be cast of gun-metal, and to have dove-tailed recesses cast along its interior surface for the reception of lignum-vitæ strips, these strips are to be tightly fitted into each recess; after the strips are fitted, the bearing is to be forced tight into the end of the tube, then the lignum-vitæ is to be bored out true to the outside or turned portion of the tube; a brass plate is then to be secured to the flange on the end of the bearing; this plate is to prevent the strips working outwards. At least six one inch brass screw-pins to be fitted through the end flange

of the bearing, into the metal of the stern-tube. At the forward end of the tube a gun-metal neck ring, of a length equal to one diameter of the shaft, is to be fitted; this neck ring to have two $\frac{3}{8}$th inch spiral grooves cut in its inside periphery. The gland is to be bushed with gun-metal, and fitted into its place in the works. The propeller shaft is then to be tried in the tube. The stern tube to be a forced fit into the stern frame, and to be secured thereto by a round wrought iron nut fitting well to the threads cut on the stern tube end; the nut to have six $1\frac{1}{4}$ inch holes drilled into its periphery for a depth equal to their diameter, these holes being for tightening purposes. That portion of stern frame on which the nut rests, to be faced up true to the orifice; the inner portion of the frame also to be faced true, in order that the stern tube shoulder may bear fair thereon. The forward end of the stern tube is to be secured to the after bulkhead by through bolts of sufficient number and size. That portion of the bulkhead where the tube fits should be double or triple plated, and bored out carefully to fit the tube; a $1\frac{1}{2}$ inch cock to be fitted on to the top of the stern tube, immediately abaft the neck ring; from this cock (which should always be left open) a copper pipe, running to the after bulkhead and secured to the same, should be fitted; on the outside of the bulkhead a down-nosed cock must be fitted, so that water may be run on the gland. The whole of the stern tube work and fastenings to be of the most perfect nature.

PROPELLER. To be of the four bladed type, and to be cast of a mixture of 7 Summerlee (No. 3) 3 of cold blast, and 10 of the best scrap; the surface and pitch of the blades to be (see Formula,) to be secured to the shaft by a longitudinal key recessed into the shaft, and by a large wrought iron nut on the outer end, this nut to be

a correct fit to the threads on the shaft, and to bear fair against the propeller boss ; a through key, bearing fair against the nut, to be fitted through the shaft end, a steel set-pin (at least 1¼ inch diameter,) with check nut to be fitted through the nut ; after the outside nut is screwed up, a cavity is to be drilled into the shaft for the point of the set pin, which is then to be firmly screwed in ; it must be noted when the propeller is fitted into the vessel, that it comes up to, or passes, the *home* mark made on the shaft in the factory ; the propeller to be turned round before the ship is launched to ascertain that all the blades are clear of the stern frame.

SCREW SHAFT CARRIAGES. To be of cast iron of ample proportions, the lower halves to be cast with a ⅜ths inch dovetailed edge recess for ¾ths of its surface, this recess to be filled in with white metal of a mixture of 8 of tin, ½ of copper, 1½ of antimony, after being run into the recess, the alloy is to be *well hammered down* previous to being bored out ; the length of each bearing to be (as per Formula.) The base of the bearings to be cast so as to act as a save-all, each of them to be properly fitted on oak packing, and bolted to the stools with not less than four bolts of 1½ inch diameter ; the bolts for the upper halves of the carriages to be a turned fit and to have check nuts thereon, the edge of the upper half of each carriage, to be *let* into the lower half in order to prevent side play ; all the bearings in the tunnel to be so arranged that they may come immediately abaft the couplings of the shaft.

THRUST BEARING. To be of the collar-series design, the collars to be of gun-metal and carefully fitted into both upper and lower portions of the block ; the surface for receiving the thrust to be (see

Formula.) The upper half of the block to be cast with an oil box thereon, into which copper feeding pipes leading *through* each ring are to be fitted, this half is to be fitted to the lower half in a careful manner, by being strongly *let* into it, and having a wrought iron division piece fitted along and between the edges of the thrust rings so as to prevent moving. The bolts for the upper and lower halves to be a turned fit, their heads to be let into recesses cast into the bottom of the lower half, check nuts to be fitted to all bolts about the thrust block. The lower portion of the block is to be fitted to a thrust plate, this plate is to be truly planed on the surface where the block is fitted, and it is to be carefully packed on iron fitting pieces, and secured to the thrust seat in the ship; a strong flange is to be cast on the forward end of the thrust plate through which $1\frac{1}{4}$ inch set bolts, with check nuts are to be fitted every seven inches of its width, these bolts are to act on the thrust block for its due adjustment, the thrust block bolt holes being slightly elongated to allow for this operation; on the after end of the thrust plate, a flange is to be cast, between this flange and the after end of the block, a wrought iron wedge key is to be fitted for the whole breadth, the purpose of this key being to maintain the necessary rigidity of the thrust block. The whole of the thrust block structure and fittings to be characterised by strength and careful workmanship.

TURNING GEAR. To consist of a large worm wheel cast in halves, the face of each half to be planed, then both to be firmly bolted together; the tips of the teeth to be turned true to the centre, the wheel to be keyed on to the thrust length of shaft by two sunk keys, two $1\frac{1}{2}$ inch steel set pins to be fitted into bosses cast for

them on the wheel boss, these set pins to be tightened up to the shaft after the wheel is in its place. The worm, gearing into the wheel, to be either a continuation of its spindle, or a loose cast iron worm of strong proportions, the spindle operating the worm must be fitted so that it may be readily removed, in order to allow for the ungearing of the worm, the spindle bracket to be of ample proportions, and to be firmly secured to the engine seat top plate, or the bulkhead; the motion to be obtained either by a wrought iron ratchet and lever, or by a small engine having the necessary gear; the pitch of the teeth of the turning wheels up to four feet diameter to be not less than $2\frac{1}{2}$ inches.

BOILERS AND MOUNTINGS. The boilers to be circular and of the multitubular type. To be made according to the Board of Trade or Lloyd's rules for a working pressure of lbs. The heating surface to be not less than $4\frac{1}{2}$ square feet per I. H. P., and is to be reckoned from combustion chambers, back tube plates, tubes, and above the fire bars in the furnaces. The total steam space in boilers and domes to be not less than one cubic foot per I. H. P., $\frac{1}{3}$rd of the boiler's diameter to be above the combustion chamber top; all plates exposed to the action of the fires to be of Lowmoor, Bowling, Farnley, or iron of equal quality. The furnaces to be so made that no rivets be in the way of the fires, the top plates of the furnaces to be in one piece, and flanged back to the line of tube plates, the bottom plates of the furnaces to be in one piece continued to the combustion chamber back plates, the furnaces to be truly circular, the top and bottom plates jointed by double butt straps, the back plates of the combustion chambers to be in one piece, and carefully flanged to suit line of sides, all the edges of the furnace and combustion chamber plates to be planed, and all their holes to be drilled and well

countersunk on both sides ; all the rivets in the combustion chambers to be button-headed, so that caulking can be readily performed. The front or furnace plate to be in one piece, and carefully flanged to suit the furnaces and shell ; the tube plates to be not less than $\frac{3}{4}$ inch thick, and to be of a quality to stand sharp flanging without fracture, the holes for the tubes to be correctly drilled to guage, and to be pitched so as to leave at least $1\frac{1}{4}$ inch spaces vertically and horizontally ; the tubes to be of nine or ten guage, and to be *twice drawn*, as is done by the Caledonian Tube Company of Coatbridge. The shell to be of Tudhoe quality, free from all lamination or irregularity in section, the plates to be first rolled to the required curve, then bolted together by temporary bolts, and each landing carefully plied up, by machine or otherwise, *until the plates are close*, and to be afterwards drilled in their place ; the plates to be then taken apart and any *burr* removed, and the outside and inside edges of the holes to be then deeply countersunk. After the plates are put together again, each hole must be tested for fairness, and the plates for close contact ; no rivets to be put in unless these conditions are rigidly fulfilled ; no drifting will be allowed ; the front and back plates to be hand-rivetted to the shell ; all the circular seams to be double-rivetted ; the horizontal seams treble-rivetted and lapped, or double-rivetted and butt-strap jointed. No outside bottom landings to be inaccessible for examination or caulking. The whole of the shell plates to be planed on inside and outside edges, the other plates also to be planed on edges. No caulking will be accepted as good workmanship, if done on a chipped edge. The screw stays to be of the best scrap iron, and screwed eleven threads to the inch, the holes for them to be drilled through both plates fair, and the stays to be a tight fit ; no diagonally fitted stays will be passed ; after being screwed into their

places, the ends to be carefully and neatly rivetted over; the stay tubes to be screwed nine threads to the inch, the strain section of these stays to be reckoned below the thread, they must be a thorough fit into the back tube plates, and have a nut on the outside and inside of both tube plates. After the boilers are finished, they are to be tested by water to twice the working pressure, in the presence of the Board of Trade, Lloyds' or other inspectors whom the Owners may appoint, and to be thoroughly tight under that pressure; no cementing or painting of the shell on the inside will be allowed before testing. After being satisfactorily tested, the furnace and other mountings to be fitted; the furnace bars to have a slope of $1\frac{1}{2}$ in 12; the bridges to be built of fire-bricks and to have an over-space equal to one half of the tube area for each furnace. The whole of the shells and domes to be painted over with Torbay paint, and to be covered, either with two layers of best hair felt, laid on while the paint is wet, and lagged with well-seasoned wood, tongued and grooved, and secured with $2\frac{1}{2}$ inch iron hoops passing round the shells and domes, or, after the boilers are shipped, to be covered with an approved non-conducting composition to a thickness of $2\frac{1}{2}$ or 3 inches; this composition to extend to one foot below the normal water level, and there to rest on an angle iron secured to the shell, and to which the sheet lead or wire netting over the composition is to be fastened; below this angle iron, the boilers to be felted and lagged as described.

MOUNTINGS. Each boiler is to have two spring safety-valves of the most approved construction; one steam-stop valve, one main and one donkey feed check-valve; one (or two if the boilers are double-ended) water gauge; two gauge-cocks, one scum-cock, one blow-off cock or valve, one test cock, with a curved

nozzle, one steam-gauge cock, one whistle cock, and one two-way donkey steam-cock; and a sufficient number of man and mud-hole doors. The spring safety-valve chests to be of cast iron, their flanges to be carefully fitted to the dome tops; the spring chest and fittings in connection therewith to be of brass, *no iron bolts or spindles will be allowed*; the chests to be drained by a copper pipe, not less than 1¼ inch in diameter, this pipe to lead to the cisterns in the stoke-hole. The steam stop-valve chest to be carefully fitted to the highest part of the dome, and to be easily accessible from the engine room. All the feed-valves and chests to be of gun-metal, strongly proportioned and having their flanges stiffened by brackets between each bolt. The scum, blow-off, and gauge-glass fittings, to be also of gun-metal, and of ample strength in every detail. In all fitting on and jointing of flanges to the shell of the boiler, the joint must be made with one layer of wire gauze, and thin red lead *only*. All bolts having their heads to the interior of the boiler must be fitted with sound made grummets thereon, these bolts to have also a check-feather forged on to prevent turning. All studs screwed into the shell must be caulked at their junction with the shell, and have grummet, washer, and nut on the interior. Washers must be placed on all flanges beneath the nuts. The furnace fronts and doors to be of cast iron and properly fitted, the doors to be lock-jointed. The smoke-box doors and uptake to have an air casing of at least 1½ inch space, and to be continued round the chimney up to twelve inches from the cravat; the edges of the air casing to be neatly finished off by a cope-iron band.

PIPING AND COCKS. The main steam pipe up to ten inches in diameter, to be of No. 6 W.G., above that diameter, to be of No. 4 W.G.; feed pipe of No. 6 W.G.; blow-off pipe of No. 6 W.G.:

scum pipe No. 8 W.G.; injection pipe No. 10 W.G.; waste steam pipe of No. 14 W.G.; discharge pipe of No. 10 W.G.; donkey steam pipe No. 8 W.G.; donkey exhaust pipe No. 10 W. G. The main steam pipe to be led from the stop-valves on the boilers as direct as possible to the cylinders, the end to enter an expansion stuffing box fitted to the stop-valve on the cylinders; four long screw-studs to be fitted to the stuffing box flange and to go through a guard flange secured to the steam pipe, in order to prevent its withdrawal from the stuffing box. The waste steam pipe to be carried down to the safety-valve chests by a copper breeches pipe; no cast iron lengths of waste steam pipe will be passed. The feed pipes to be carried as direct as possible from the feed-valve chests to the boilers, and to be so arranged that the engineer can always see them. All pipes to be carried in horizontal or vertical lines to their respective terminations; sharp bends will not be allowed. All flanges of copper pipes to be of gun-metal, and faced prior to being brazed on to the pipes; after being jointed they are to be neatly chipped and filed on the edges. All bolts through pipe flanges to have washers and grummets below both heads and nuts; all nuts to be of standard dimensions for the bolts used. All steam pipes to be felted and covered with canvas carefully stitched. One main injection valve chest to be fitted on the ship's side, having its seat, valve, spindle, and gland of gun-metal; also to be fitted with a brass grating in the chest for cleaning purposes. One donkey sea-suction valve chest to be fitted, of similar arrangement to the main injection; this valve to serve the purpose of filling the tanks. One bottom blow-off cock to each boiler to be fitted to the ship's side; these cocks to be strongly made and feathered in the flanges, and so arranged in the glands that the key for opening them cannot be removed unless they are shut. One scum, one ash,

and also one journal cooling cock to be fitted of similar arrangement to the blow-off cock. All these cocks to be of gun-metal, and to have packed glands, with Muntz metal bolts and check-nuts. All the fittings through the ship's skin to be spigotted therein, and to be in a position of handiness for the engineer, and also in accordance with Lloyds' requirements. One main discharge valve chest, having its seat, valve, spindle, and gland of gun-metal, to be fitted to the ship's side, in such a position as to be at all times accessible. Discharge valves for donkey and bilge pumps to be fitted in a similar manner to the main discharge, and to have one valve for each pump. No pipe intended to be secured to the ship's side will be passed without having a valve or cock fitted to the vessel's skin.

LUBRICATION. All the bearings to have ample and efficient means for lubrication. The main bearings to have a cast brass oil-box fitted to the keeps, within which is to be placed a thin copper pipe-box for the oil. A brass or copper water service, having telescopic and universal-jointed outlets to be also fitted for the main bearings, this service to be continued through the tunnel, having a cock and pipe for each bearing; this pipe to be so fitted that it may serve as a handrail. No oil-holes for the link motion or pump levers will be passed without having a small brass cup screwed into each. The crank pins and gudgeons to be both central and end lubricated, their oil cups to be large, and the pipes to be not less than $\frac{1}{2}$ inch diameter.

BALLAST AND DONKEY PUMPS. A double acting ballast pump (if required) to be fitted, to have a cylinder inches diameter, with a stroke of inches, the ram to be inches diameter. The ram and its rod,

also the chamber in which it works to be of gun-metal, all the bearings and the eccentric strap to be of gun-metal and adjustable ; the valve seats to be of brass, and so fitted into the chest that instant removal can be obtained, the valves to be of india rubber, the guards being screwed into the centre of the seats, brass air valves to be fitted into the valve chest covers. A valve box containing the various valves leading to the tanks and bilge, to be fitted to the front of the pump chamber ; these valves, seats, spindles and glands to be of brass, and so arranged that water cannot be admitted through them into the ship ; on the top of each spindle a hand wheel to be fitted, having the compartment name cast thereon. All tank pipes in the engine room to be of cast iron, properly secured to the ship's frames.

THE DONKEY PUMP. to be of a similar design and arrangement to the ballast pump, the cylinder to be inches diameter, with a stroke of inches, the ram to be inches diameter, and to be arranged to draw from the sea and bilges, and to deliver into boilers, on deck, or overboard. A valve box containing the various valves leading to the bilges, to be fitted to the front of the pump chamber, these valves and fittings to be of the same material as those for the ballast valves ; a perforated cast iron rose box having a hand-hole lid on the top, to be fitted to the end of each bilge pipe ; the bilge pipes to be arranged for the *thorough* pumping out of the bilges during any weather. All bilge pipes to be of *medium* lead, all flanges to be well soldered on, and to have iron washers equal to their diameter, through which the bolts must pass ; the lengths of pipe not to exceed ten feet, and where running on the ship's frames, to have hard-wood rests fitted under them, and properly secured, in order to prevent the pipes being abraded. In the arrangement of the bilge and tank pipes

in the engine room, great care must be exercised, so that they are at all times easily accessible either for cleaning or repairs.

GENERAL FITTINGS & FURNISHINGS. A "Durham" Velometer with all connections to be properly fitted. The platform round the cylinders to be fitted at a convenient distance from the cylinder covers, to be made of an open wrought iron rod grating, and to be securely supported and fitted, a bright polished hand rail to be fitted round the deck casing at a suitable height from the platform ; the starting platform to be framed with angle irons, secured to the bedplate, and bunkersides, then to have chequered wrought iron plates carefully and neatly fitted down ; ladders with neat cast iron steps to be fitted from the companions to the starting platform, all ladders to have double hand rails. A large steam whistle with copper pipe, leading to the cocks on the boilers, to be fitted to the height of the flying bridge. A reply telegraph to be fitted in the engine room, having two stands, one on the flying bridge, and one on the lower, both to have night lamps fitted. Each Ventilator to be inches diameter, (see Formula,) and to have an ash hoisting winch fitted into each, with chain and bucket hooks ; an ash shoot for each ventilator to be supplied and fitted to the bulwark plates. The safety-valve easing gear to be led into the engine room, and to be fitted with easing screw and bracket, bolted in a convenient position for ready operation ; all the engine room lamps to be of copper, large and strongly made, and to be fitted to their respective positions. The gratings and ladders for the stoke-hole, to be of wrought iron and securely fixed ; the stoke-hole floors to be of wrought iron chequered plates, and to be fitted down on an angle iron frame properly supported on iron stanchions, resting on the ship's

frames. The ash buckets to have band rests fitted to the bulkhead or bunkersides, and also at the top grating ; rests to be fitted for the firing tools in the most convenient place. Condensed water cisterns for receiving the water from the safety-valve chests, to be fitted in the stoke-hole ; cocks to be fitted to the bottom of each cistern. The passage between the engine room and stoke-hole, to be covered in a similar manner to, and on the same level as the stoke-hole ; oil filling arrangements from the deck to the various oil tanks to be fitted, nut key rack to be fitted to the bunkerside in a handy position. All spare gear to be properly fitted up.

FURNISHINGS FOR AN ENGINE OF 100 NOMINAL HORSE POWER.

One Weston's 3-ton blocks
One pair of blocks, with rope fall
One spanner for the various nuts
Two shifting spanners (one large and one small)
One light spanner, for connecting rod ends and main bearings
One steel packing drawer, for the various glands
Three iron ash-buckets, strongly made
Two galvanised water pails, strongly made
Two oil tanks of 100 galls. each, fitted with lock cocks
One oil tank, small, for daily use, do. do.
One copper dish and strainer
Two oil measures (gallon and half-gallon)
One copper tallow kettle and brass stand
One cast-iron do.
Six copper oil-feeders, assorted
One globe lamp
Four engine-room lamps of ample size
Two hand lamps (bull's eye)

Four trimmer's lamps
Four tube lamps
Four hand lamps
One lamp for each gauge glass
Four firing shovels
Four trimming shovels
Four scaling hammers
Two chipping do.
One coal do.
One lead do.
One copper do.
One quarter do.
Six chisels, assorted
Six files, do.
Six drills, do.
Four half-round steel scrapers
Two flat steel scrapers
Six steel starting wedges
One vice, and iron bench with drawer
One ratchet brace, knee, and cramp
One hand brace
One 2-ton bottle-jack
One hand-saw
One axe
Two augers
Two paring chisels
One Warwick screw for cylinder cover, with roller and shackle
One portable forge, with fire tools and tongs
One anvil
One grindstone and trough
One set taps and dies, from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inch
One set tools for tubing condenser
One Dudgeon's tube expander

One ferrule compressing machine
One Richard's indicator with papers, & two spare springs
One coal measure
One set of firing tools complete
One salinometer and copper pot
One japanned wick box and scissors
One do. sulphur box
One do. emery do.
Four wire tube brushes, and handle
Four bolt tube stoppers with washers
Six wooden do.
Length of hose pipe with copper nozzle for watering ashes
One waste locker
One large do fitted with shelves
One clock fitted in engine room
One strong log slate
A coloured and varnished drawing in frame, showing all bilge and tank pipes, with their valves and respective names to be supplied, for Captain's guidance.

SPARE GEAR. To be supplied, but under a separate contract.

One half crank-shaft, finished
One propeller shaft do.
One propeller, with key and nut
One air-pump bucket and rod, complete
One do. head-valve, seat, and guard
One circulating pump bucket and rod
One do. head-valve. seat, and guard
One eccentric strap and rod
One valve spindle, complete
Two top and two bottom end connecting rod bolts & nuts
Two main bearing bolts and nuts

One set coupling bolts and nuts
One set eye bolts, complete
Four holding down bolts, and nuts
Six junk ring do.
Two dozen studs and nuts, assorted
One half-set of piston springs for each piston
Two hooks for drawing piston springs, and two for packing rings
One top and one bottom end connecting rod brass
One main bearing brass
Two thrust rings
One set of feed-valves and seats
Two sets of feed-valve relief springs
Two springs for relief valves of cylinders
One set of india-rubber valves for all pumps
Fifty bolts and nuts, assorted
Ten boiler tubes
Twenty condenser tubes and one hundred ferrules
One piece of Lowmoor plate $\frac{5}{16}$ths thick, say 5ft. × 3ft.
One half-set fire bars, four middle bearers
One two-hundred pounds spring balance
One safety-lamp
Two safety-valve springs
Twenty-four gauge glasses, in box
One pair large tin shears
One soldering bolt, with four pounds of solder
Twelve sheets of tin and one sheet of Muntz metal
One piece of chisel steel, say six feet long
One hand-vice
Two bars of iron, say 3 inches × $1\frac{1}{2}$ inch flat, and $1\frac{1}{8}$ inch round
One set of boiler caulking tools

All spare gear to be fitted in its place prior to leaving the factory.

GENERAL CONDITIONS. The engines to be upheld by the makers for a period of six months from the date of the trial trip; but such guarantee only refers to defective workmanship or material; and in such cases the cost of repairs to be borne by the Engine-builders, who shall have the power of naming the works wherein the job shall be done; but in all cases the cost shall be equivalent to the charge made for same if done at their own works, and is not to include any consequential damages. No act of carelessness on the part of the Engineers in charge during the guarantee time shall be construed into liability for costs of the same. The engineers to be appointed with the consent of the Engine-builders, otherwise the guarantee to be void. The Engine-builders shall supply the Ship-builders with plans of all seatings, tunnel, keelsons, combings round chimney, skylight, and stokehole entrances, they to complete and cover in the same in accordance with the Engine-builder's requirements. The engine seating drawing supplied to the Ship-builders must show all angle irons, pitches and diameters of rivets used, and be designed, so that no vibration of the engines will occur. The Ship-builders to supply the Engine-builders with plans of the ship in the machinery space, giving details of frames, stringers, floors, keelsons, plate landings, and midship section; also showing on the fore and aft bulkheads the position of their tank-pipe valves, and the hold bilge pipes. The engines to be tried at moorings, and afterwards painted of an approved colour, and varnished; the Ship-builders painting the bulkheads and bunkersides of an approved colour, graining and varnishing the deck casing; after completion, the vessel to be taken to sea for the official trial trip, at the expense of the Ship-builders, the Engine-builders supplying coal and engine room stores; after a satisfactory trial, and the conditions agreed upon of speed and indicated

power (if such have been made) have been fulfilled, the vessel to be taken over by the owners.

SUMMARY. Any alteration to, or departure from this engine specification, cannot be allowed without the consent of the purchaser in writing, and should the contractor find anything herein at variance with his ideas of design or material, the same should be laid before the purchaser prior to tendering; otherwise, the complete approval of the specification shall be implied. All cast iron work about the engines, must receive at least one coat of paint, prior to the engines leaving the works, and all bolts in the columns and the cylinder casing flanges, to be numbered legibly; on the engines being shipped into the vessel, great care must be observed in setting them fair to the shafting, no wood packing will be allowed under the bed-plate, which must be packed with properly fitted cast iron pieces, through which the holding down bolts must pass. The boilers must be carefully and strongly stayed from the lifters to the ship's side, and must sit on curved cast or wrought iron stools, so fitted that they will allow of repairs being done to the boiler shells, these boiler stools to be packed with teak where they fit to the boiler shells; the boilers to be kept at least six inches clear of the ship's floors. The cravat must be fitted not less than twelve inches above the deck casing, and have a wash guard fitted thereon; the funnel to be painted as desired by the owners, and to be supplied with a sufficient number of chain stays, which will be secured to ring bolts by the Ship-builders, four jewel blocks to be permanently fitted through the top bead of the funnel. The waste steam pipe brackets to be lined with sheet lead where spanning the pipe; screw down ventilators to be fitted by the Engine-builders into the casing top above the boilers, at the option of the Owner.

HAVING now submitted a draft specification which will be found to embody the most modern practice of Marine Engineering, it only remains with the Shipowner to have the same (with any additions his inspector may deem necessary) printed, and to receive tenders thereon. On the acceptance of the tender, a legal agreement binding the Engine-builder to construct according to the specification, and to deliver in a specified time, and binding the purchaser to terms of payment, should be drawn up and mutually endorsed. On the order being thus placed, the next stage of the contract comes under the head of

INSPECTION.

That a Marine Engine during its course of construction, should be thoroughly inspected by the Owner's representative, admits of no gainsaying, notwithstanding the inspection of Lloyds or the Board of Trade representatives. On the Owner's inspecting engineer rests the onus of seeing that all details in workmanship, quality of material, fitting on board, and engine room arrangements are in keeping with the specification.* To inspect a Marine Engine properly, the principal things the inspector should attend to are,—noting that the arrangement of the engine in design, detail dimensions and strengths, are in accordance with the specification and

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* No inspector or consulting engineer should insert in the specification "Drawings to be submitted for approval"; such a procedure is simply an injustice to an engine builder, and implies a want of faith in his knowledge of his business, besides, should any untoward event occur, the Engine-builder gets the blame, but if everything is satisfactory the consulting engineer takes the credit. Inspecting engineers who design, should always submit their own drawings to be tendered upon, and distinctly state that all responsibility of results will rest with the designers.

pressure employed,—that the boilers are, in steam and cleaning spaces, fire-grate and combustion chamber areas, staying and rivetting, in accordance with the specification and pressure employed. To facilitate the passing of the boiler drawing, a memorandum of data, showing heating surfaces, steam spaces, shell and dome strengths, also stay strains, should be written in the corner of the drawing by the draughtsman ; and although the boiler is passed by Lloyds, which means, that its strengths are to their requirements, the Owner's inspector should satisfy himself on the important point of spaces. The inspecting engineer, having now seen the engines fairly in hands, and knowing the Works number of them, should from time to time pay a visit to the works, noting carefully the manipulation of the various details belonging to his contract. He must satisfy himself as to the mixture of the metal used in the castings, the dates when the cylinders, bedplate, condenser, and propellers were cast, and their dates of removal from the pit or mould. (On this latter point a great deal depends, on which we will treat anon). After the castings are in the works, he must satisfy himself that the designed thicknesses of metal are carried out ; this can be readily determined by getting a $\frac{3}{8}$ inch hole drilled through various portions of the casting, which can be afterwards tapped and plugged.

Should the Engine-builder get his heavy forgings from any forge not connected with his works, it should be the duty of the inspector to visit the forge at various periods, for the purpose of satisfying himself as to the nature of the material used in the shafting, and the way in which it is manipulated ; this part of his duty is of paramount importance to a shipowner, as many shafts fail in a very short period beyond the usual guarantee given by the Engine-builders. The various portions of the engine, while being

machined, should receive close attention, not so much to check any oversight on the part of the Engine-builder's foremen, as to satisfy himself that the material shows soundness; any flaw or dirt mark should be carefully tested; the depth of those on the crank and other shafts can invariably be determined by cutting in, or what is better, by merely hammering (with the "paen" of the hammer) about $\frac{3}{4}$ of an inch from the mark; if the mark is deep, the edge rises. If a crank-shaft shows a longitudinal or other mark, (and these are generally found in the bearings by reason of the mode of forging,) a hot bearing will either extend it or open it out, if of any depth. It should be borne in mind that crankshafts are a forged mass of thousands of small pieces of scrap iron (and these sometimes not very clean) and are therefore liable to show dirt marks; in any doubtful case, condemnation should only take place with the sanction of the forgeman, and on the basis of "*if bad, we pay, if not, you pay*;" then the shaft should be immediately slotted through, and the extent of the supposed flaw determined. Indiscriminate condemnation of forgings for a slight mark is an injustice to the Engine-builder and forgeman.

Confining ourselves still to engine inspection, the inspector should note the quality and thickness of his main bearing brasses, connecting rod brasses, valve spindle blocks, thrust rings, pump liners and buckets, and the propeller shaft shell, these brasses should all be of the very best quality, possessing a tough hardness suitable for long wear, and not liable to crack. Throughout this work when the term "gun metal" is used, it implies a metal composed as follows:—Copper 34, Tin 6, Yellow Brass 10, Old Brass 50. This alloy will be found better without any addition of zinc. All boiler mountings in cocks and valves, should be of the same material, otherwise rapid deterioration ensues; the cocks or valves in connection with the ballast

tank and bilge pumping arrangements, may be made of a slightly cheaper composition; the inspector should note that the arrangements of all piping in the engine room should be based on the principle of giving the engineer in charge, the least possible trouble or inconvenience; cocks and valves placed in out of the way corners should be avoided, in fact, all cocks or valves should be got at from the platform in the engine room, bilge and feed valve chests fitted close to the bilges can never be properly examined in dirty weather, these should be so arranged that the engineers can overhaul them at any time, and without risk of getting a "ducking" from bilge water; we have found it a good plan in practice to fit an additional delivery or check valve in the bilge valve chests, to ensure a safe cleaning of the lower suction and delivery valves when at sea, as in our sea experience we found that the delivery valve on the ship's side was very liable to be off its seat, and leaky, thus ensuring for the engineer a thorough soaking on his endeavouring to get the "pump to draw." The feed check valves on the boilers should be within easy reach of the engineer, for the steady regulation of the feed water, no feed check valves should be fitted where they cannot be easily handled or overhauled; all bilge and tank suctions in connection with the auxiliary pumps, should have their valve boxes contiguous to the platform, so that in the event of shipping a heavy sea, or any untoward accident occurring, the engineer can safely set his auxiliary pumps at work in the least possible time; many steamships have foundered by reason of the pumping arrangements being badly designed, valve boxes placed in the bilges are soon covered with water, and the engineers not getting handily to them are apt to conclude that the situation of the ship is worse than it really is.

We have known a brand-new Mail steamer of the

highest class, and fitted with all modern appliances for safety, compelled, while on her maiden voyage, to put back to port by reason of supposed leakage ; the true cause lay in *not being able to pump the water away which was kept running on the main bearings, they being hot;* the engineer thinking his bilge pumps were acting properly, but seeing the water gaining, naturally came to the conclusion the vessel was leaking. It may always be acceptedas an engineering axiom :—*To keep the water down, place the valves up.* Engine-builders, as a rule, have never put in a curriculum at sea, and consequently know little of the anxieties, care, and worry of a sea-going engineer's life, or how a slightly different arrangement of the piping, platforms, or valve-boxes, as the case may be, would ameliorate his condition ; hence, the practical inspector should see that all is arranged in the best possible manner for the convenience of those in charge.

BOILERS.

The attention of the inspector should also be regularly directed to the progress of the boiler construction; he should note very particularly that all flanged plates show no sign of fracture ; that all rivet-holes are perfectly fair ; that all screw-stays are a fit, having their holes fair ; that the screwed holes for the stay-tubes are of full-thread and fair for the tubes; that the *bottom* rivets are head-caulked inside and out, also all shell landings; that all joints previous to rivetting are *iron to iron.* From the neglect of this latter point arises all leaky joints or seams ; the surfaces being brought close together prior to rivetting, prevents any "give" when the boiler is warmed, besides offering no lodgment for water ; no seam can be truly right or tight where mere caulking is depended upon.

The inspector should always look upon the construction of boilers as his most important engineering duty; all boilers should be the *ne plus ultra* of workmanship and material no boiler will leak or give trouble if properly made. The practice of sub-letting the manufacture of the boiler to the foreman or platers, at so much per ton, or so much per foot for caulking, or so much per hole for screw-stays, &c., &c. is very reprehensible; the engine builder is then virtually paying a premium for work liable to be scamped, while the foreman naturally overlooks or closes up palpable flaws, so that his income may not be diminished; besides, such a practice weakens the position of the foremen towards the men, and tends to prevent their being conscientious. Every boiler should be built by the genuine work of genuine men only, as it is on its durability that the weal of the vessel and all therein depends; on the boiler being finished and ready for testing by water, which is usually done to twice the working pressure, the inspector should note carefully every sign of leakage, more especially in the combustion chambers, should he observe any corner leaks, say where the tube plate flange is secured to the furnace top plate flange, he must satisfy himself that the leaking is not from a crack, or lamination; if an edge leak, he may be sure that the plates are not well fitted; now as these corner leaks give the engineers a great deal of trouble at sea, and generally end in very costly repairs, it should be the inspector's duty to insist on having them made good, either by the plates being renewed, if cracked, or laminated, or the rivets taken out, and the seam made iron to iron; failing either of these being done, he should be guaranteed that, if from the places noted during test, any leakings occur after the boiler has been in use say for twelve months, the Engine-builder will put them right to his satisfaction. As the boilers will no doubt be under "Lloyds Survey," it will be as well

to say a few words at this juncture on

BOARD OF TRADE AND LLOYDS SURVEYS.

Surveys of hulls or machinery during construction, either by the Board of Trade or Lloyds surveyors, are very anomalous, and, in general, come far short of being in strict accordance with the true meaning of the term "survey." There are in mechanics, two applications of the word, viz. *superficial* and *searching*; the former is, in our experience the application generally employed by the departments or guilds named. In the case of Board of Trade surveys during construction, the surveyor confines himself to his "Instructions"; these Instructions are all very well in their way, and limit the servant to the duties named therein, and also give certain formulæ for boiler strengths, size of spring steel for safety-valves, shaft strengths, and spare gear considered necessary for a ship; but although the owner pays the usual machinery survey fees, and feels satisfied that all is bound to be right with his Engines, when surveyed by a Board of Trade official, the question arises, "What do the surveyors do for the money?" this is answered by saying, "They see that the boiler in all details is up to their 'Instructions', that the shafting is ditto, that the valves and cocks on ship's side are in certain positions, that the safety-valves are tested, and that the 'Instruction' spare gear has been supplied." These items embrace what is generally done in a Board of Trade survey of machinery during construction.

We shall now ask, What is it the Board of Trade Surveyors do not do? To answer in extenso, would be to present an array of "things undone which ought to be done," that might appear somewhat damaging to the guardians of those who go down to the sea in ships. Writing comprehensively, we may state, that no Board of Trade

Surveyor calls in question the factors of workmanship or material, the former may be as indifferent as possible, the latter may be of the poorest description imaginable, yet a certificate is duly granted; the well-fitted engine, having every detail of the best possible material, is thus on a par with the rugged breed of marine motors which pass inspection more by virtue of their paint-daubed exteriors, than their genuineness of construction and material; one case of this system of non-inspection or indifferentism to construction, will suffice to show our readers the fallacious nature of such "Surveys." Marine Engines are passed by the Board of Trade Surveyors, when the crank-shaft bearings are fitted with *cast iron* keeps, in some cases *cast iron* feed, nay, even *cast iron steam pipes* are passed; if Shipowners and the public have the same margin of safety in these ancient modes of engineering, all we can say is, that it would be only fair to insert an "Article" in the book of "Instructions," stating that *cast iron* steam and feed pipes, feed-check and blow-off valves, crank-shaft keeps, pumps, levers, crossheads, &c. will be passed by the Board's Surveyors; one other point, strikingly illustrative of our charge; we have never known in all our experience a Board of Trade Surveyor examining the fastenings of an engine to the seating, or even noting the construction of the seating itself, the engine may be held down in such a way that vibration and steam pipe breaking will be the result, yet these points are entirely unnoticed. It behoves Steamship-owners therefore to place more reliance on their own inspectors than on the Board of Trade Surveyors.

Of late the marine guild, known as Lloyds, have incorporated Engine with their Hull inspection. Under an able and modern-minded Chief Engineer, who has a staff of really practical men at the different ports, their system of inspection and machinery classing has been gradually developing

itself. The aim of their operations undoubtedly is, to have a uniform and higher standard of efficiency in arrangements than has been in vogue ; boiler tracings are examined, the pumping arrangements from holds and tanks carefully noted; boilers are tested under their supervision and duly stamped; safety-valves are adjusted; steam trials are attended, and a general and praiseworthy inspection given to an engine from its commencement to its completion. Notwithstanding all these efforts to have the machinery of vessels what it should be, Lloyds (like the Board of Trade) inspections are imperfect —they do not go far enough in the direction of their "Special Surveys;" workmanship and material are ignored; an engine secured down on pine packing and having a single collar-thrust on the after bearing of the crank-shaft, whereby the thrust is taken up by the holding-down bolts of the bed-plate is passed without comment; boilers with close-pitched tubes and contracted steam and cleaning spaces in the boilers are passed; light W. G. of piping and cast iron keeps on crankshaft bearings, are unnoticed; engines without brass neck rings or brass lined glands in stuffing boxes, ditto; engines secured down to a seat which is unsecured to the ship's frames, ditto, and so on; these are the points of non-inspection which render Lloyds surveys anomalous; we admit that their efforts are tending in the right direction, but their advancement is miserably slow; they see and know the shortcomings of almost every engine made in the United Kingdom, yet, they fear to define what constitutes a "Special Survey." Were the distinctive nature of a Special Survey made public, it would prove an incalculable boon to the Steamship-owner and Engine-builder, the former could then insert in his specification "to Lloyd's Special Survey," and the latter would know exactly what it meant. We can bear testimony to the value of Lloyds surveys, even as they are, to the Owner, inasmuch as the pumping arrange-

ments, in the event of leakage, have, under their attention, been brought to the most practical and efficient issue of design. It only remains for their Committee to make Workmanship, Material, and Design, the basis of all M. C's. in Red. We have no doubt, that ere long this much-needed desideratum will be consummated, notwithstanding the objections which will naturally be raised by those Engine-builders who prefer to jog-on in the old grooves. Until Lloyds Engineering Department has taken this position, the Owner's Inspector must survey for himself ; on him alone will depend the efficiency of details in material and workmanship, and in him alone should the Owner trust.

Previous to the vessel being launched the inspector should visit the ship, and note that the sea cocks, stern tube, and propeller, are properly fitted in their respective places ; he should also satisfy himself that the engine seating is in accordance with the Engine-builder's tracing, that the rivetting and plating is thoroughly done ; on this latter point a great deal might be written with reference to the utter neglect of both the Board of Trade and Lloyds Surveyors, who, as before stated, do not make engine seatings part of their survey business ; hence we find that many engines when at sea, have a vibratory motion calculated to snap steam pipes, and cause hot bearings, the onus of which is generally relegated to the Engine-builder, while a little reflection on the part of the Owner would convince him that Engine-builders not being scrutineers of Ship-builders' work, are in no way responsible for shaky seatings. Were such matters, (which are undoubtedly part of the duties of the Board of Trade and Lloyds surveyors,) surveyed as they should be, steam Ship-owners and Engine-builders would be greatly profited thereby, while implicit confidence in the genuineness of their surveys would be engendered in

the Mercantile community; a higher standard of workmanship, a better quality of material, and improvements in detail arrangements would be the result, and under these conditions, insurances effected upon vessels having passed a high class survey ought to be less; we fear however, that the present indiscriminate mode of Insurance tends greatly to make an Owner indifferent to the arrangement of his engine, as a badly designed and beggarly fitted engine is granted the same value of Insurance safety, as one having all its parts well proportioned, and fitted for purposes of thorough efficiency and long wear.

The Owner's inspector having satisfied himself that the stern-tube, propeller, propeller shaft, and sea cocks or valves, are properly fitted, should then turn his attention to

FITTING OF THE ENGINES IN THE SHIP.

The work to be done in fitting a Marine Engine into a vessel is of a nature which requires very careful attention, however well the engine may have been fitted in the shop—however true the shafting may have been turned, and bolted together, if carelessly fitted in the vessel, the good work of the factory is of little moment. On the vessel being berthed to receive her machinery, the shafting is generally the first portion to be shipped; each length being put into place, (beginning from aft,) in conformity to the shop marks, and being supported by the intended carriages, which are set on temporary wedges, the bedplate, with crank-shaft in place, (and in some instances, the whole engine,) is then lowered and adjusted to the thrust coupling. The crank-shaft being set fair to the thrust coupling determines the correct position of the engine on its seat—the couplings being left say $\frac{3}{8}$ths apart, any shifting of the engine during erection on board, or in being bolted down, is

at once determined. As mentioned under the head of "The Specification," the engine and shaft carriages should be bolted down on iron packing pieces, *hard to hard.* We are of opinion, judging from a great many cases which have come under our observation, that one of the reasons for crank-shaft fracture, and the rapid wearing down of propeller shafts, is in the fact that the shafting is not in line—an incalculable strain can be brought to bear on a shaft when working a twist; hot bearings are also concomitants of this state of *untruth*; it becomes therefore the duty of the inspector to see that the crank-shaft coupling is exactly fair to the thrust coupling before being screwed up. It is a good practice to have from four to eight holding-down bolt holes drilled in place in the bedplate flange and through the seating, making the bolts a turned fit; this tends to ensure no lateral movement in the bedplate.

On the boilers being lowered into their place, the inspector should satisfy himself that they are properly secured to the ship's side; it is a good practice to have the boiler seating so arranged, that in the event of any bottom repairs the operation of rivetting may be readily performed; for this purpose removable stools offer the greatest advantages; the engineer will find no difficulty in withdrawing a light yet strong stool at any time, for the purpose of repairing the boiler bottom. The inspector should note that all the piping runs square, and with as few bends as possible; it gives an engine room an unscientific look, to see piping shooting about at all angles, merely for the purpose of saving a few inches of it. The stokehole flooring should also command the attention of the inspector; it may be either of cast or wrought iron chequered plates, but it should always be laid on an angle iron base—the angles bolted to bulkhead and

bunkers, and borne up by iron struts resting on the ship's bottom. A wooden base for the stokehole floor invariably rots soon, and gives trouble. All the suction-valves in connection with holds, tanks, or stokehole bilges, should be above the flooring.

On the gauge glasses being fitted, the inspector should note their position in relation to the combustion chamber tops, and the engineer who is to take charge should be duly informed of this. If more than one boiler is fitted on board, the connecting steam pipes should be fitted with expansion stuffing boxes, and in all cases the leading pipe to the cylinder casing should have an expansion stuffing box fitted, either to the throttle valve case or on the boiler, without this precaution many steam pipes crack at the brazing round the flanges ; this often arises from the strain of the sudden expansion of the pipe, combined with the slight but continuous tremor which always prevails with machinery in motion. The inspector should note also if the platforms are so arranged that the operation of oiling, can be readily performed, and that sufficient guard rails are fitted, also that the stop valves are reached either by platform or ladder. On steam being got up for the primary trial of the engines and safety valve adjustment, by either the Board of Trade or Lloyds surveyors, the inspector should carefully examine the boiler shells, marking any leakage, to have it made good prior to the cleading or covering composition being put on. All pipe flanges should then be dressed off and filed smooth, the steam pipes covered with felt and canvas, the oil-cups and lubricators fixed, the store room fitted up, furnishings and spare gear carefully stowed away under the supervision of the engineer in charge, the engines and engine room neatly painted, and all is then in order for the

TRIAL TRIP.

Of this most important matter it may be stated at once, that it *should never take place unless the vessel is laden and in her normal sea-going condition.* To have a trial trip with a light ship is simply an injustice alike to Owner, Ship-builder, and Engine-builder, for no reliable data can be obtained as to indicated horse power and speed of ship; but with a laden ship, fairly approximate data as to the power and speed can be obtained, and the Owner knows what is the real value of his engine for propelling the vessel, and can therefore calculate with a near certainty when she will arrive at her ports of destination. Light trial trips are always unsatisfactory, inasmuch as a vessel going ten knots light, might not do eight knots laden; it is better therefore that the vessel be duly laden and ready for sea prior to having her trial trip, it prevents disappointment and the Owner knows what his vessel can do. Every Owner's inspector should make this point a *sine quâ non*, and during the run, which should not be less than six hours full speed steaming, he should carefully note—

1st. If the boilers generate steam steadily and with easy firing
2nd. If the draught is sharp
3rd. If the water in the guage glasses is steady
4th. If any parts of the engine have a tendency to heat
5th. If there is any knocking about the cylinders or pumps
6th. If the propeller works smoothly
7th. If the vacuum is steadily maintained
8th. If the guide shoes are bearing fair
9th. If the indicator diagrams show well
10th. The vessel's actual speed, by two or three logs being put overboard, it being always best to have at least two, so as to check any error.

11th. The actual indicated horse power

12th. The consumption when the engines are in their normal working.

The inspector, during the trial trip, should work out a set of diagrams, so as to enable him to form an idea of what the engines will really do when at sea ; knowing this, and the vessel's speed, the *absolute vessel value* if we may so term it, is satisfactorily established, alike for his own and the Owner's information and guidance ; on the trial trip being completed, the machinery virtually passes out of the hands of the Engine-builder, and becomes the Owner's property, its future cost to him now depends solely upon its

MANAGEMENT AT SEA.

NOTWITHSTANDING the care with which a Marine Engine may be constructed in the factory—notwithstanding its amplitude of proportions, or its efficiency of design—if not properly looked after when at sea, all the care and trouble of its erection, and all the scientific and practical thought expended upon its production are virtually thrown away. All engineers of a vessel should be certificated by the Board of Trade ; why this is not so we cannot understand ; a third engineer is as responsible a person on watch as his chief. The indifference of an engineer in charge to the working of the engines will often, in one watch, entail a heavy loss to the owner, besides bringing premature old age upon the job ; when an engineer is not fully alive to the trust reposed in him, the engines, being as it were, sensible of the injustice done to them, begin to lose their pristine energy. By allowing the bearings to get hot, sundry ominous knockings are heard before they have been at work two days ; by neglecting to lubricate the pistons, shrieks and groans of disgust are heard in the cylinders, as if the

spirit of power were protesting against its usage; by neglecting to go into the tunnel and examine all bearings, a continuous dull whistling is heard in the region of the stern-tube; by neglecting to regulate the feed water, the boilers begin to show signs of revolution, and fling off sundry spurts of water which find their way into the cylinders; by neglecting to determine whether the bilge pumps are working, water begins to accumulate in the bilges; by neglecting to test the density of the water in the boiler, an accumulation of scale is being rapidly deposited, or the boilers are being worked too fresh, which is more dangerous than the former evil; and by general indifference and laziness on the part of the engineer, the once beautiful specimen of mechanical skill is suddenly transformed into a groaning, knocking, wheezing, bubbling, dirty, mass of motion, which is kept hammering away until some port is reached, when a lazy man's repairs are done, by letting the worn, cut, and cracked brasses together in a shuffling mode; by putting a fresh turn of packing, without removing the old, into the glands; by the springs in the pistons being set out to such an extent that undue wear is continually taking place with the packing ring or cylinder liners; and by not blowing out his boilers and making an internal examination of them. Withal, this type of a sea-going engineer will not hesitate to pad his reports, he will state in his log, that the steam never varied in pressure, that the engines worked without a hitch, that the revolutions were unvarying, and everything was in order, &c. But the coals consumed and time taken over the voyage tell another tale, for which the engineer blames the coal or the captain's steering.

Under this mode of engineering at sea, no Marine Engine can perform its duty efficiently or economically, but with a little attention and care how different is the result,

under the eyes and hands of a really genuine engineer, everything is looked after in an earnest manner, the engine itself seems to appreciate the attentions bestowed upon it by working with a will, and virtually shows itself to be doing its best, no hot bearings take place, no knockings or groanings are heard, the water in the boilers is being silently converted into steam, the firemen are deliberately and without any fuss supplying the fuel-food to the fiery maws of the fire-god, the bilges of the vessel are comparatively dry, the trial trip pressure and revolutions are steadily maintained, the engineers for the first few days willingly sacrifice a few hours of their bunk-blessedness so as to keep their charge in order, no grumblings or expressions of discontent are heard from them, their actions tell that their hearts are in their work, and that the efficiency of the engine is their delight. On getting into port, everything is cleaned up, every job is thoroughly done, and every examination is carefully made and truthfully entered in the log. It is invariably found that rigid attention to the working of the engine for the first few days is a panacea for all port repairs; it may be accepted by steamship Owners as a fact, that detentions, or bills run up in foreign ports for engine repairs, &c., are solely due to the inattention of the engineers during the voyage; a good engineer scorns to have the vessel detained by reason of engine repairs, or to have accounts charged to his department. In the case of a fair breakdown it is different, but in trifling jobs where the engine room staff are capable, it is very reprehensible for the engineer to be above doing the necessary trifles due to wear and tear. We have known some chief engineers so much above doing any jobs to their machinery, that they would not even mandril a leaky boiler tube, but gave the job out. We know others again whose sense of duty and right is so manly that they never give a job out at any outport, preferring to do

it themselves. It should be a fixed rule with all steamship Owners that none of their engineers be allowed to give out work, unless it be proved to have been beyond their power to do it themselves. We cannot realise the fact of *repairs* being necessary to a Marine Engine that is fairly proportioned and of good material and workmanship: the necessary letting together of brasses, the re-packing of pump buckets, the adjustment of piston springs, the scaling of the boilers, or cleaning condenser tubes, are all the ordinary wear and tear jobs incurred, and surely these can be done by the engine room staff; the thorough engineer on getting to port endeavours to keep his engine up to its original condition, he immediately makes good all evidences or intimations of wear, rather than wait until they have developed into the state of slackness which necessitates ship's delay and shore expense; he fills up his log sheet, stating engine and boiler condition, and despatches it with the diagrams from the engine to his inspector, who is thereby made cognisant of any evidences of rapid failure or weakness about the engine, and who, on the vessel's return to a home port, verifies his information by personal examination.

The boiler is, with a thorough engineer, of paramount interest to him, its condition internally is his constant care, and to get a light coating of deposit on the tubes, when first starting his voyage, is his endeavour, he not only regulates the necessary auxiliary feed, but is regularly testing the density of the water, and occasionally blowing down (say half glass,) from *the bottom*, so as to ensure a first coating on the tubes; when the condenser is tight, and the engineer jealous of any salt being seen about the gauge cock nozzles, it may be taken for granted that *no* deposit is forming inside, the result of this will be clean tubes and tube plates, but they will be corroding

away ; many engineers do not blow their boilers out on coming into port, this is a gross error of judgment, for if not done, the tubes, tube-plates, shells and furnaces will suffer. We know a case in which new boilers were not blown out during a whole India voyage, with the result that every tube was pitted from end to end, and the Owners put to the great expense of re-tubing the boilers on the vessel's arrival home. It should be every engineer's endeavour to get a coating on the tubes, its thickness can be easily regulated afterwards. We consider that the boilers in the Navy and Mercantile Marine would last much longer than they do at present were their bottoms and sides of furnaces, covered with a thin coating of Portland cement. When it is found that the tubes and tube-plates are not coated as usual, it is a good practice to put a bucket or two of water, in which a lump of lime has been slaked, into the hotwell ; this will be found to have the desired effect in coating the tubes and preventing their rapid corrosion. The engineer should always make it his duty to have the boiler fronts, (at the stoke-hole contact,) scraped thoroughly and often painted ; in this portion rapid deterioration sets in by reason of the hot ashes and clinkers being deposited there on the fires being cleaned, which burn away the paint, and expose the landings and plates to the direct action of the heat and also of the cooling jets, hence rusting is produced ; we think it would be a good practice to baffle-plate the lower fronts of all boilers. The top of the boiler should always be swept down clean when in port, and its covering white-washed, an accumulation of dirt in this region is reprehensible, and indicates carelessness ; in port also, the bilges should be thoroughly cleaned out, all grease and ashes removed, so as to ensure a free action of the bilge pumps at all times, thus preventing trouble during stormy weather, it is always an indication of thorough engineering to find on the vessel's arrival home, that cleanliness is paramount, a clean

engine room, and stoke-hole, in every part, may be accepted as a tell-tale of how the machinery is; in fine, no one should have charge of a Marine Engine who is not capable and willing to keep every portion of it in good order.

Efficiency of marine engine management at sea lies solely in attending to every sign of wear or leakage in their *first* stage. A leaky boiler landing should never be pared or caulked without determining whether it arises from bad plating or rivetting, in either case caulking is of little avail, for if the leaky portion is not tight after being caulked it should be rivetted afresh, as it is possible to pare a landing and spoil it, or prepare it for an unsightly, leaky patch. A leaky screw-stay should never be caulked, its leakage indicates a bad fit, therefore it should be taken out and a somewhat larger one inserted after tapping the plates anew. A blister on a furnace or combustion chamber plate should never be cut away until prepared to patch it; on the engineer seeing the appearance of a blister he should drill a $\frac{1}{4}$ inch hole into it, this will prevent its rising or extending until he is prepared to put a well-fitted patch on it. The plate for a furnace patch should be of the best iron, and not more than $\frac{3}{8}$ths thick; the rivetting should be well done, and both sides countersunk. A cracked tube-plate may be temporarily patched, but this is a difficult and unsatisfactory operation; therefore the tube-plate should be removed as soon as possible. In re-tubing boilers, all the holes should be rimed, and the screw-stay ones tapped afresh, so as to ensure a circular fit for the new tubes. The safety-valves and gear should be taken out and overhauled once in six months. The gauge cocks, with their pipes, should be thoroughly cleaned every three months; the combustion chamber bottoms should be cleaned out at every port. The original height of the bridges (which every engineer should

know) should always be maintained : increased consumption and defective draught often arise from this simple matter being overlooked. No water should be thrown into the ash-pits. No fireman should be allowed to tamper with the feed valves or scum cocks.

While on watch, the engineer should always be on the move—a sitting engineer is of as much use to the ship as a blind pilot. An engineer should be "all eyes and ears" on watch. His first duty on taking charge of the watch should be to note the height of the water in the gauge glass, pressure, and vacuum ; he should then see that every bearing in the tunnel is cool and well lubricated ; also that every bearing about the engine is in the same condition. No water should be run on the bearings. If a bearing inclines to heat, something is amiss, which should be determined at once. He should put a little oil down every tube once an hour, and keep the oil boxes half full, noting that the worsted feeders are free. Regularity in "feeling" and oiling each bearing prevents heating and waste of stores. No junior engineer should alter the "set" of the throttle valve, auxiliary feed, or injection, when once fixed by the chief engineer. The normal pressure of steam should be uniformly maintained ; to do this, the engineer on watch must see that the firemen fire regularly, and keep the fires and ash-pits clean. About the middle of his watch he should try the density of the water, and note the same, with the revolutions, pressure of steam, and vacuum, on the log slate. He should also observe that the bilge pumps are working freely, and that no accumulation of water has taken place in the bilges. Before his watch is up, he should examine every bearing from the stern-tube to the engine inclusive, and leave them well lubricated and cool, entering in the log slate their condition. The ashes from the fires

cleaned in his watch should be ready for heaving up by the relieving watch of firemen, and the stoke-hole should be cleaned up and left in order.

It should always be a rule with an engineer never to leave the engine room while on watch : a moment's delay in stopping or reversing the engines when required may entail the loss of the ship. A captain or chief engineer who allows this practice to obtain is to be condemned. A bridge or bulwark engineer is untrustworthy.

While off watch, the engineers should be ever ready to turn out when called upon. For this purpose a gong should be fitted in every engineer's berth, having a communicating handle in the engine room ; so that, in the event of anything of an untoward nature occurring, the engineer on watch can immediately summon the others. The chief or second engineer generally attends to the engine overhauling in port ; while it is the junior engineer's duty to see that the boilers and fittings are duly opened out and thoroughly cleaned, making all ready for sea again. To do this efficiently demands his strict attention : he should see the internal condition of the boilers for himself before and after being cleaned ; he should also examine every combustion chamber, noting the appearance of the tube ends, tube-plates, &c., and give the chief engineer a report on the whole. It bodes well for the future position of a junior engineer to mark him earnest and attentive to his duties, however dirty or disagreeable ; he should know that any engine room work performed in a perfunctory manner cannot be hidden, and only entails increased labour and danger ; the smallest job should be done in a thorough manner ; he should never be above learning, nor should he ever be satisfied with his own knowledge. Engineering egotism in a youthful

aspirant to engineering honours, is the bane of true progress ; hence, we find that such youths seldom become chief engineers : their "going to sea" being more a matter of fun than fortune; their spare moments being generally spent in loafing about the deck, instead of learning the principles on which the engines work. Many chief engineers instruct their juniors in diagram taking, and explain the purposes involved; junior engineers should merit and appreciate this instruction. A mere hammer and chisel engineer will, ere long, be a creature of the past; the advancement of the age demands something more from the sons of steam; and it behoves them during their apprenticeship, to master the laws of heat, and the principles of mechanism ; if not done then, their future will be marked with the ignorance accruing from misspent time, and their advancement will assuredly be marred.

THE INDICATOR.

We write on the assumption that every sea-going engineer knows the use and application of the indicator; it would therefore be superfluous to give here a description of its mechanism, or explain the mode of taking off diagrams. No engineer, first, second, or third, should be allowed to have charge of a watch in the engine room, who cannot manipulate the Indicator. Shipowners and inspecting engineers place too little value on the truths given by the diagrams ; hence we find this part of an engineer's watch-duty too often neglected. Weather permitting, indicator diagrams should be taken every day-watch, or at least once a day ; the chief engineer should then work up the actual engine power, and compare it with the actual consumption of fuel. One watch in the day should be given to strict fuel

weighing, by which regularity of management the engineer can determine at once if the engines are working economically, or if the quality of the fuel is faulty. After working up the engine fuel-value, the result should be noted on the back of the diagram, which should then be pinned within a Diagram Book, which should be supplied for this purpose by the Owner or his inspector; were a book of this nature regularly kept on board of every vessel, the engine efficiency could be determined over any period of its working, and the best check obtained to statemental fuel results. The Indicator is therefore the Owner's friend, and any inspector or chief engineer who is careless of its daily application to the engines cannot speak with any degree of confidence upon the working of the engines, neither can any of his statements or logs be implicitly relied upon. Even in this advanced age of marine engineering, we question very much if there is an inspector of a company, or a chief engineer on board of a ship, who can conscientiously state the vessel's consumption per I. H. P. over a period of six or twelve months. In such cases of neglect the fault lies with the Owner, who, not troubling himself with causes of expenditure, is willing to accept statements unsupported by evidence. Increase or decrease of fuel expenditure in a vessel can always be checked by the Indicator, that is to say, if the diagrams are carefully taken and calculated up, and the coals properly and carefully weighed, an Owner can determine whether the fault lies in the fuel or the engine. It is a simple matter to keep every steamer's power and fuel value over a voyage or for a given period, and no Owner should be satisfied without knowing this, and having it always before him, such data is of great importance to him in making ship or engine contracts. Having thus far expressed our views on Marine Engine management at sea, we may now enter upon a few

GENERAL REMARKS.

In all that we have written upon engine surveys by the Board of Trade or Lloyds Surveyors, we do not think we have advanced any opinions, contrary to facts, holding as we do, that all surveys of machinery should be thorough and not superficial, we feel sure, unbiassed readers will endorse our statements concerning the anomalous nature of the present mode of these surveys, for which a very respectable pecuniary charge is made; the mere fact of giving a few commonplace formulæ for boilers or shafts, or in "*passing*" a boiler tracing (for which another charge is made,) do not, nor ever will, constitute, a survey; we therefore state, that Ship-owners will ultimately discard such modes of "looking after their interests" even at the expense of losing M. C. in Lloyds Book; it is the delusive nature of these so-called surveys which prompted us to dwell so much on the necessity of the Owner's inspector seeing for himself, as in his attention alone can his employer feel the safety which arises from confidence, therefore he should see and know everything about the engine he inspects, else he occupies a wrong position; a monthly visit for half an hour to the factory, only betrays his heedlessness to his master's interests, and reflects on his engineering attainments. Engine-builders guage an inspector by his mode of inspection. We have always found that the careless inspector never gets well served in the engine room, hence many expenses incurred which are attributed to the chief engineer, might with more propriety be assigned to his inspector, who on the vessel's departure or arrival, is found more frequently in the cabin than in the engine room, and who exhibits a kind of philosophic indifference to the complaints or reports of the chief engineer, who is thereby (and quite naturally too), disgusted with his inspector, and allows his engines to run as they like. We have invariably

found that sea-going engineers do not remain long under an indifferent or pseudo inspector, the reason is self evident, inspectors of this type in order to save themselves, blame the engineers, hence their dismissal, whereas if the Owner were to look into the causes of complaint, the reverse issue would likely occur. Those steamship companies, whose machinery is inspected in a masterly manner, command the respect and attachment of the engineers and generally pay good dividends, one reason being, that a contented and careful engineer can in his department alone, save a considerable sum per annum, on fuel, stores, and repairs, while a careless engineer can be so wasteful as to cause an expenditure per annum, which would often pay a fair dividend on the ship's value.

Having thus freely expressed our views on Inspectorship and Management at Sea, we shall now give some

FORMULÆ OF PROPORTIONS.

In giving the following calculations we have endeavoured to show, in plain figures, the dimensions or proportions of the principal parts of a Marine Engine. To those possessing even a mere elementary knowledge of arithmetic, the working of them will be found a matter of no difficulty. We have also studiously avoided giving any rule-of-thumb data, such being of no use in engineering, the *reason why* of every thing connected with a Marine Engine having always a scientific and calculable base. It is pitiable now-a-days to observe men possessing certain claims to engineering knowledge, giving vent to such expressions as these, "steam pipes should be $\frac{1}{4}$th of the H. P. cylinder's diameter," "piston rods should be $\frac{1}{10}$th of the L. P. cylinder's diameter," "air-pumps should be $\frac{1}{24}$th of the L. P. cylinder's area," &c., &c., utterly ignoring in the cases given—1st, the piston speed and velocity of steam; 2nd, the pressure of steam; 3rd, the fact that no calculation can be given for air-pump proportions.

It is our object to give, without the mysticism of figures, a few primary calculations upon which the proportions depend, and which will be found useful not only to Steam-ship Owners, but also to sea-going Engineers, and the young students of the profession.

In the construction of Marine Engines, the fixed portions of the structure, such as cylinders, columns, bedplates, &c., are generally made of cast iron. The strains upon the cylinders, columns, and bedplate during the working of the engine, are the alternate strains of tension and compression (or crushing); and as cast iron possesses the peculiar property of resisting crushing strains in the ratio of five to one over tensile strains, it follows that its lesser limit must always be calculated for. The mean ultimate crushing strain of cast iron is 90,000 lbs. per square inch; the mean ultimate tensile strain is 18,000 lbs. per square inch; and the limit of tensile strain should not exceed $\frac{1}{20}$th of the ultimate, or 900 lbs. per square inch. Lighter sections of the parts than found by this factor of safety are sometimes adopted by the insertion of webs or ribs into a pattern; but, keeping in view the many alternate strains, shocks, and vibratory effects which bedplates and columns have to resist, it is not safe, even under the conditions

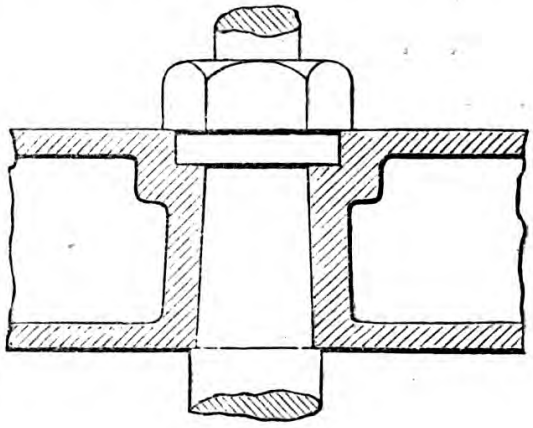
of web or rib strengthening, to reduce a cast iron section below its calculated requirements.

Those parts of a Marine Engine most liable to fracture, are the moving or wrought iron portions; and in those subject to tensile strain only, it is safe to limit that strain to 5000 lbs. per square inch, or about $\frac{1}{10}$ of the ultimate or breaking strain of the iron. Bolts in cylinder and steam chest covers, and those in the top and bottom of the connecting rods, are the most important instances of such parts, but with the main keep bolts the strain limit is reduced to 3400 lbs. per square inch, because all the bolts may not be equally strained. The area of the bolts on *both* sides of the crank is always determined. In all cases it is the area under the thread which is referred to.

In the following calculations we will always confine ourselves to the typical 100 N. H. P. Compound Marine Engine, viz. Cylinders H. P. 27 inches, L. P. 50 inches, stroke 33 inches, pressure 80 lbs., indicating in ordinary working with 65 to 66 revolutions, 450 I. H. P.; and in the various calculations, we make *Indicated Horse Power* the data from which to work, because, in high-class marine engineering, the engine is built to drive the ship some specified speed, and consequently to indicate some determined power, and also, because it enables the Formulæ to be expressed precisely.

PISTON RODS.

All parts of a piston rod below the piston are in tension and compression alternately ; but that part within the piston rod nut is in tension *only* ; and if this part under the thread is not strained to more than 5000 lbs. per square inch, and the portion fitting in the piston have a taper of $\frac{3}{4}$ inch to 1 inch per foot, and the bottom of the taper part ends in a collar of $\frac{1}{4}$ inch all round,—it will be found that the body of the piston rod is of quite sufficient section to resist compressive and breaking bending strains. There ought always to be a shoulder or collar at the bottom of the taper part of the piston rod, as it prevents the piston being injured by the tightening up of the piston nut. (See Diagram.)



If D=diameter of cylinder
and d= ,, of piston rod under the thread
and p=pressure on the piston

Then, $d = D\sqrt{\frac{p}{70}}$

or in the case of our 100 N. H. P. the

equation would stand $d = 27\sqrt{\frac{80}{70}}$

Where 27 inches is the diameter of the H. P. cylinder, and 80 lbs. the pressure.

To reduce it to the actual answer for our case, it becomes $d = D\frac{9}{70}$ nearly.

or $d = D \times \cdot 128$

or $d = 3 \cdot 5''$ at the bottom of the thread.

In other words—the square root of the pressure divided by 70 constant, and the quotient multiplied by the diameter of the cylinder, gives the diameter of the piston rod below the threads.

In Compound engines, and for the sake of uniformity, both piston rods are made of the same diameter; and generally the determination of diameter for the H. P. is quite sufficient for the diameter of L. P. piston rod, where a certain initial pressure and vacuum effect would have to be assumed.

PISTONS.

In general terms it may be stated that the depth of the piston should be according to the piston speed; this is self-evident, for when the piston is shallow and runs at a high speed, it wears rapidly and passes steam; therefore the depth of the *packing ring* should not be less than is found by $D = \frac{S}{80 \text{ to } 85}$

Where D=the depth.

S=speed of piston.

Our 100 N.H.P. running their usual piston speed of 360 feet per minute, would require a packing ring depth of $D=\frac{360}{80}=4{\cdot}5$ inches.

When D is determined, the total depth of the piston follows from it.

CONNECTING RODS.

Connecting rods are considered (as to strength) to be in the condition of struts or pillars, loose at both ends.

The area in square inches at the small end being found by $A=\frac{P}{C}$

Where P = greatest thrust through the rod.

and C = a constant corresponding to the ratio $\frac{\text{Length}}{\text{Diameter}}$

The following carefully prepared Table gives C for all ratios likely to be required in practice.

Ratio.	C.	Ratio.	C.	Ratio.	C.
10	3176	20	2348	30	1610
11	3100	21	2267	31	1578
12	3020	22	2189	32	1522
13	2938	23	2111	33	1469
14	2854	24	2038	34	1416
15	2769	25	1964	35	1368
16	2683	26	1893	36	1320
17	2600	27	1825	37	1275
18	2514	28	1761	38	1230
19	2430	29	1697	39	1190

In the case of our typical 100 N. H. P. with 33 inches stroke, the length of the connecting rod would be two strokes or 66 inches. No connecting

rods should be less than twice the stroke of the engine in length.

Now to determine the area of the small end of the connecting rod for 100 N. H. P.

we have $A = \frac{P}{C}$

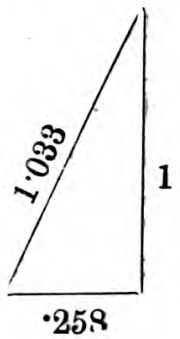
P or the greatest thrust through the rod is = area of piston × pressure × 1·033

in our case = 572·5×80 lbs.×1·033 = 60914 lbs.

We now assume a ratio of diameter to length which will approximately correspond to the quotient of $\frac{P}{C}$, thus assume 13 as the ratio of diameter to length, opposite 13 on the table is C 2938 and 60914 ÷ 2938 = 20·7=5·1 inches diameter, and length 66 inches ÷13 (the ratio)=5. Had we assumed say 16 as a ratio, then C = 2683 and 60914 ÷ 2683 = 22·7 = 5·39 inches diameter, but 66÷16 =4·1 proving that the last assumed ratio is wrong.

The greatest thrust through the connecting rod and on the guides, when the length of the connecting rod is twice the stroke, is as per diagram,

where 1 =strain on piston rod
1·033= ,, ,, conn. rod
·258= ,, ,, guide



Having thus found the diameter of the small end of the rod, a taper of $\frac{1}{4}$ inch to one foot is generally given, which will determine the diameter of the bottom end of the rod. The

foregoing formula will be found to give a well proportioned rod, capable of bearing with safety, all the jerks and strains that can be brought upon it. The diameter and length of the gudgeon at the top end of the rod, should be so proportioned as to have not more than 600 lbs. mean pressure on each square inch, with more than this it has been found in practice that the lubricant is squeezed out; though the strain through the connecting rod is a varying quantity, still the greatest possible strain must be taken *a priori* in its calculation; but in the case of a gudgeon, it is not a question of *strain*, but of *lubrication*, therefore as the strain varies, it is good practice to calculate upon the *mean* pressure on the piston, which in our case we fix at 45 lbs. i. e., 80 lbs. initial, and 45 lbs. mean; therefore a gudgeon for our connecting rod, having 600 lbs. mean pressure per square inch on it will be $572{\cdot}5 \times 45 = 2576{\cdot}5 \div 600 = 42$ inches or 7 inches long × 6 inches diameter; we consider that these bearings should always be at least $\frac{1}{4}$th longer than their diameter. The mean pressure on the crank-pins should never exceed 300 lbs. per square inch, with more than this it will be found a difficult matter to keep them cool, from 250 lbs. to 300 lbs. is good in practice.

Let P=total pressure on the pin
S=speed of piston in feet
I.H.P=power of *one* cylinder
then $P = \frac{\text{I.H.P.} \times 33000}{S}$

In the case we have adopted the total Indicated horse power is 450; for the H. P. cylinder 225.

Now, 225 × 33000 = 7425000
and 7425000 ÷ 360 speed of piston = 20625
and 20625 ÷ 250 lbs. = 80 fully.
or say the pin should be = 9 in. × 9 in.

In the case of the main bearings the most important element in their proportion of length to diameter, lies in the fact that the shaft should be held *firmly* and that it should not wear slack; $1\frac{1}{4}$ to $1\frac{3}{4}$ times the length of the crank-pin are usually given to the main bearings, in good practice however it is found, that to keep the main bearings in an efficient condition, the strain limit should not exceed 100 lbs. per square inch. Taking our 27 inch cylinder with 45 lbs. mean pressure on the piston,

we have 572·5 area × 45 = 25762·5
and 25762·5 ÷ 2 (bearings) = 12881
and 12881 ÷ 100 lbs. strain limit = 128 inches,
or 9 inches diameter × 14·2 inches long.

Main bearings based on this proportion of strain limit will be found in practice to give no trouble.

CROSSHEAD SHOES.

In the case of crosshead shoes, it is a source of infinite trouble to the engineer in charge when they are inclined to heat. On setting the engine away full speed, the strain limit on the guide shoes should not exceed 60 to 70 lbs. per square inch. In a

great many engines the slipper or go-ahead guide arrangement is adopted. Now, we hold that if a certain amount of surface is required for the go-ahead thrust, the same is required for the go-astern. It may be argued that the engines run very seldom a-stern, which is true; but if the vessel gets on a sand-bank, they may require to run a-stern for days, and, under such circumstances, with a diminished guide thrust surface, the engines could not in all probability be driven full speed. We believe it is the best practice in engineering to meet all possible contingencies by good designs, and having the same measure, or factor, of safety in go-astern as in go-ahead working. Why there should be a different formula for these conditions we cannot understand, unless on the ground of single or go-ahead guide fitted engines being cheaper to manufacture. Go-ahead and go-astern shoes should not have less area than what is found by the following formula :—

$$A = 2 \frac{R}{L} \text{ I.H.P.}$$

Where A=Area of shoe.

And R=Radius of crank. } in the same
„ L=Length of Connecting Rod. } units.

„ I.H.P. = Indicated horse power transmitted through the piston rod, for which the shoes form a guide.

In the case of our 100 N.H.P. we have

I. H. P. of one cylinder = 225
Radius of crank = 16·5 in.
Length of connecting rod = 66 in.

therefore, the area of shoe should be

16·5 in. ÷ 66 in. = ·25
and ·25 × 2 = ·5
and 225 × ·5 =112·5 inches,
or say a shoe 8 inches broad × 14 inches deep.

This proportion for go-ahead and go-astern guide shoes will be found to work admirably, without any tendency to heat, and will give the engineers no trouble or annoyance.

VALVE GEAR.

It would not perhaps be possible, nor is it necessary, to give formulæ for the dimensions of all the parts of valve gear, as the various designs are so numerous; it will, we think, be sufficient to give the greatest strains per square inch on the several parts, which have been found to work satisfactorily, and with little wear of the surfaces, pins, &c. The best proportioned engine is that one whose parts wear longest and are easiest kept up; from our data of wear, we find that valve gear proportioned or strained as follows will give an engineer little trouble, and put an owner to little cost for repairs.

On the valve spindle eye	250 lbs.	℔ sq. in.
Go-ahead eccentric rod pins	300 to 400 „	„
Go-astern „ „	450 to 600 „	„
Link edges	250 „	„

The area of the bearings of the pins on the links and gear, is taken as length × diameter. When the area of a bearing is to be increased, it is better and more scientific to increase the length, when it can be done, rather than the diameter, as already pointed out in connection with crank-pins and cross-head gudgeons. The stress on the valve gear and eccentric rods, is induced by the resistance to motion of the slide-valve on its face; the greatest value of this resistance is obtained when the slide valve is being moved *up*, and is calculated as follows :—

(Area of exhaust port or ports in slide-valve + area of one steam port in cylinder) × difference of pressure between steam and exhaust side, × by co-efficient of friction + weight of valve and spindle.

The co-efficient of friction is usually taken at ·25.

It is customary with engineers to calculate the resistance of a slide-valve by the formula

$$A \times P - a \times p$$

Where A = total area covered by valve.
P = the pressure on steam side.
a = total area of exhaust.
p = the pressure at exhaust side.

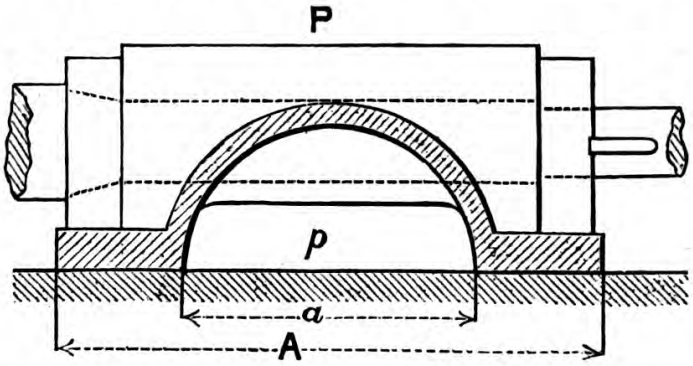
We hold that the resistance is simply

$$a \times (P - p)$$

and as one steam port is generally covered by the valve, (with the exception of the time of opening to steam,) in our calculations we include its area, therefore, from the formula

$$a \times (P - p)$$

applied to the H. P. slide-valve of our 100 N. H. P., we find the following dimensions of parts, allowing the strain per square inch to be as given in the table.



Exhaust port in slide-valve	=	17 in. × 7 in.
One steam port in cylinder	=	17 × 2
	=	17 × 9
	or =	153 square in.

Now the co-efficient of friction = ·25
the working pressure = 80 lbs.
the weight of valve, spindle, and block, say = 351 lbs.

therefore, (153 sq. inches × ·25 × 80 lbs.) + 351 lbs. = 3411 lbs.

which is the resistance of the valve to *upward* motion.

Now, the area required for the link edges, with a strain of 250 lbs. per square inch, is

$$3411 \div 250 = 13{\cdot}6 \text{ inches}$$
$$\text{or for two edges} = 7 \text{ ,, long}$$
$$= 14 \text{ inches} \times 1 \text{ in. broad.}$$

And the area required for the valve spindle eye, with a strain of 250 lbs. per square inch, is

$$3411 \div 250 = 13{\cdot}6 \text{ inches.}$$
$$\text{or say} = 2{\cdot}75 \text{ in. long} \times 5 \text{ in. diam.}$$

And the area required for the go-ahead pins on the links, with a strain of 400 lbs. per square inch, is

$$3411 \div 400 = 8{\cdot}52 \text{ inches}$$
$$\text{or for each pin} = 4{\cdot}25 \text{ ,,}$$
$$= 2 \text{ in. diam.} \times 2 \text{ in. long.}$$

And the area required for the go-astern pins on the links, with a strain of 450 lbs. per square inch, is

$$3411 \div 450 = 7{\cdot}7 \text{ inches}$$
$$\text{or for each pin} = 4 \text{ ,,}$$
$$= 2 \text{ in. diam.} \times 2 \text{ in. long.}$$

It is of the utmost importance in the designing of valve gear, to arrange for the travel of the working parts to be small, for this purpose, the distance of the centres of the go-ahead and go-astern eccentric rod pins on the links should never be less than three times the travel of the eccentric, and the drag links should generally be as long as can be arranged.

DRAG LINKS.

The strain on the drag links will then be in P lbs.

$P = R\left(\frac{d}{D} + \cdot 25\right)$ nearly, for each set of links.

Where

R = resistance of slide-valve to upward motion.

D = distance between go-ahead and go-astern pins on links.

d = distance between go-ahead and go-astern *eccentric centres.*

Now, R in our 100 N. H. P. = 3411 lbs.
D ,, ,, ,, = 20 inches.
d ,, ,, ,, = 5 ,,
Co-efficient of friction = ·25 ,,

therefore, $3411 \times \left(\frac{5}{20} + \cdot 25\right) = 1705$ lbs.
or P on each drag link = 850 ,,

Therefore, 850 lbs. being the strain on each drag link, its dimensions can be obtained from the article on connecting rods.

Both sets of drag links being coupled together, and the reversing gear, having to move both over, should exert about $1\frac{1}{2}$ times P upon the drag links.

Note.—It is good practice to make the dimensions of the L.P. valve gear the same as found for H. P.

ECCENTRIC RODS.

When the effort required to move the slide valve has been calculated as shewn ; the area for the smallest end of the rod can be obtained from the table given for the connecting rods.

Note.—If the section of the eccentric rod, or drag link, is not circular or square, the least dimension of the section must be taken for the ratio of length to diameter.

ECCENTRICS.

The diameter of an eccentric is made as small as possible for the purpose of reducing the amount of friction, and its *minimum* length in inches is given by

$$L = \frac{R \times N}{100{,}000 \text{ to } 125{,}000}$$

where R = the effort in lbs. to move the slide valve
N = the number of revolutions of the engines.

In the 100 N. H. P. engine, the effort to move the slide valve is 3411 lbs.

Number of revolutions of the engine 66
therefore, $3411 \times 66 = 225{,}126$
and, $225126 \div 100{,}000 = 2{\cdot}25$ inches as the length of eccentric.

Note.—In designing engines it should be observed that where (as in engines of small power) there is no want of space or room in the arrangement, in order to attain greater durability and sometimes greater

rigidity, these and other parts may be conveniently made larger than is required by our formulæ, which, it must be understood, give the *minimum* surfaces and sections allowable.

AIR PUMPS.

Let C A = total capacity in cubic inches of single acting air pumps,

then, $C\,A = \frac{I.H.P}{N.} \times 600$ to 700

where N = the number of revolutions.

By this formula the diameter of the air-pump, with 16 inches stroke for 450 I. H. P. engines will be

I. H. P. = 450

revolutions 66 and $\frac{450}{66} = 6{\cdot}8$

and $6{\cdot}8 \times 600 = 4080$

and 4080 ÷ 16 inch stroke = 255=18 in. diameter.

If the air-pump has a stroke equal to that of the engine, then the diameter will be

4080÷33 in. stroke=123 fully=12·5 in. diameter.

If there are two air pumps having a stroke equal to that of the engine, then $\frac{1}{2}$ C A must be taken for each.

In practice the capacity of air pumps varies very much, and they are not unfrequently found of less capacity than is given by 600 as a factor in the formula. In many of these cases, however, it is

not unlikely that it might have been increased with advantage. The capacity required depends on so many circumstances that *no theoretical determination of it can be made.* The efficiency of air pumps will be greater in proportion as the following conditions are observed.

1st. The air valves in connection with the air and feed pumps should be opened as little as is requisite, or altogether closed, if possible.

2nd. All pipes, chests, doors, &c. appertaining to feed pumps should be quite tight.

3rd. The opening of the feed suction pipe in the hot-well should always be under water.

4th. The condenser tubes should be tight.

5th. The clearance between the bucket and head and foot valves should be as little as possible.

6th. No more auxiliary feed water than is required should enter the hot well.

Note.—All air pumped into the boiler tends to vitiate the vacuum-effect, because it must find its way into the condenser.

For the area of passages through the buckets, head and foot valves, see Specification.—Article Air and Circulating Pumps.

CIRCULATING PUMPS.

C C = Total capacity in cubic inches of the circulating pump.

$$C\,C = \frac{I.H.P.}{N.} \times 300$$

N retains the same signification as in the Air Pump formula, and the calculation is carried out in a similar manner.

The circulating pumps should always be provided with large air valves, as they conduce to make them work smoothly and without shocks; the employment of air valves having a diameter as great as $\frac{1}{5}$th that of the pump will be found beneficial to the working of the pumps.

PUMP RODS.

The diameter of the pump rods will be found from the following :—

$$D = \sqrt[4]{\frac{L}{C}} \times \sqrt{l}$$

where D = The diameter of the rod in inches.

L = The load on the pump.

C = { 3,000,000 for wrought iron.
{ 1,000,000 „ Muntz metal.

l = The length of the rod in inches.

For example, say the length of a Muntz metal pump rod is 84 inches,
and the diameter of the bucket is 16 „
the load on the pumps is always taken at 30 lbs. per square inch.

therefore we have

area of 16 inches = 200 square inches,

and 200 × 30 lbs. = 6000 lbs. gross load.

and $D = \sqrt[4]{\frac{6000}{1{,}000{,}000}} \times \sqrt{84}$ inches in length.

or $= \sqrt[4]{\frac{6}{1000}} \times 9$ nearly.

or $= \frac{1{\cdot}6}{5{\cdot}6} \times 9$

$= 2{\cdot}6$ inches diameter for Muntz metal.

The sign $\sqrt[4]{}$ means the fourth root, or "the square root of the square root"; that is, in the calculation the square root of $\frac{6}{1000}$ and the square root of the quotient, or 1·6 as the result for the 6, and 5·6 as the result for the 1000; to be more explicit, the square root of 6 (or $\sqrt{6}$) equals 2·5 nearly; the square root of 2·5 equals 1·6 nearly; the square root of 1000 or ($\sqrt{1000}$) equals 31·6 nearly; and the square root of 31·6 equals 5·6 nearly.

FEED PUMPS.

It is the general practice to make *each* feed-pump of a capacity sufficient to supply the boilers, then the capacity for each in cubic inches will be found from the formula,

$$\frac{\text{I.H.P.}}{\text{R.}} \times 20 \text{ to } 25.$$

Where R = number of revolutions.

For example :—

The revolutions being 66 and I. H. P. 450

we have $\frac{450}{66} \times 20$

or $= 6{\cdot}8 \times 20$

$= 136$ cubic inches.

and the stroke being in our case 33 inches.

$136 \div 33 = 4{\cdot}1$ section of ram.

$= 2{\cdot}5$ inches diameter nearly for each feed-pump ram.

BILGE PUMPS.

No calculation of the requisite capacity of bilge pumps can be made, practice however has decided that they should be the same as the feed pumps.

STEAM PIPES.

The diameter of steam pipes can be determined from the following:

where, D = Diameter of H.P. cylinder.

S = Speed of piston.

d = diameter of steam pipe.

then $d = D \sqrt{\frac{S}{70 \text{ to } 80}}$ { 70 as a divisor when the steam pipe is above 12 ft. in length.

For Example.—The diameter of 100 N. H. P. engine H. P. cylinder is 27 inches, speed of piston 360 feet per minute, what should be the diameter of the steam pipe ?

Therefore we have,

$d = 27 \sqrt{\frac{360}{80}}$

or $= 27 \frac{19}{80}$

$= 6{\cdot}4$ inches diameter fully.

INJECTION PIPES.

The diameter of the injection pipe can be determined from the following :

$$d = \sqrt{\frac{\text{I.H.P}}{13}}$$

where d = diameter of the pipe.

For example :—With 450 I. H. P. we have

$$d = \sqrt{\frac{450}{13}}$$

$$\text{or} \quad = \sqrt{34{\cdot}5}$$

$$= 5{\cdot}9 \text{ inches.}$$

SHAFTING.

For compound engines with two cylinders, the formula adopted by the Board of Trade for the diameter of the crankshaft, generally obtains with engine builders, it is as follows :—

$$\sqrt[3]{\frac{(d^2 \times \text{P}) + (\text{D}^2 \times 15)}{f} \times \text{C}}$$

where, d = Diameter of high pressure cylinder in inches.

D = ,, low ,, ,,

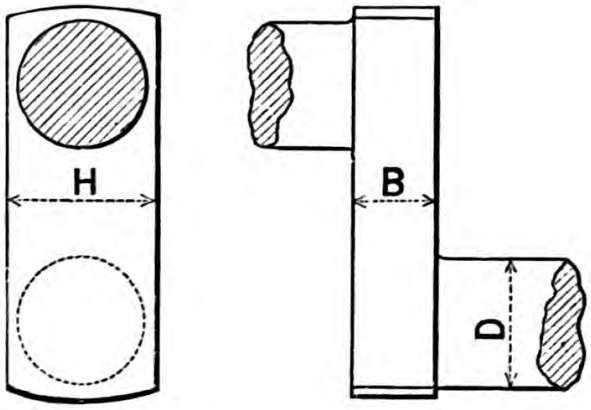
P = Boiler pressure.

C = Length of crank in inches.

f = Constant = 2468 when the angle of the cranks is 90°.

In the best practice $\frac{1}{4}$ inch to $\frac{1}{2}$ inch, according to the size of the shafting, is added to the diameter as given by the above, to quote the Board of Trade Book of "Instructions to Surveyors." "It will be found that first-class makers generally put in larger shafts than those found by this formula."

CRANK SHAFT WEBS.



The relation of size of webs and diameter of shaft for equal strengths, is expressed by

$$\cdot 9\ D^3 = B\ H^2$$

COUPLING BOLTS.

The relation between the diameter of the tunnel shafting, and the number and diameter of the coupling bolts, is expressed by the formula

$$\tfrac{1}{2}\ D^3 = N\ d^2\ V$$

Where,

D = diameter of tunnel shafting.
N = number of bolts.
d = diameter of bolts.
V = diameter of bolt circle.

$$d = \sqrt{\frac{\frac{1}{2}\ D^3}{N\ V}}.$$

By this formula the bolts have $\frac{1}{10}$th of the shearing strain.

Example :—The shafting in the tunnel is 9 inches in diameter, the number of bolts to be used

in couplings 5, the diameter of the bolt circle is 18 inches, required the diameter of the coupling bolts ?

therefore we have $d = \sqrt{\frac{\frac{1}{2} \quad 9^3}{5 \times 18}}$

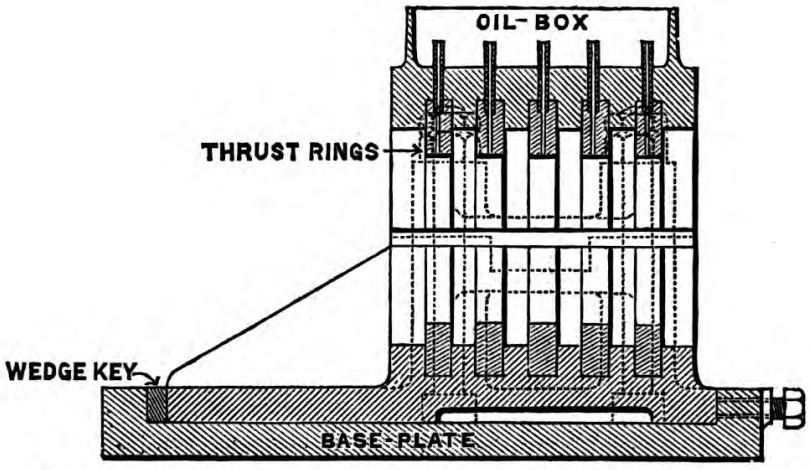
or $= \sqrt{\frac{3\ 4}{90}}$

$= 2$ inches diameter.

THRUST SURFACE.

The thrust surface should be designed so that the strain per square inch on the rings, or surface, will not force out the lubricant. The best form of thrust block in practice, is one in which the thrust is received on a series of rings, the block is made adjustable fore and aft so as to take up any wear. The surface in square inches will be found from the formula

$$\cdot 6 \frac{\text{I.H.P.} \times \text{M}}{\text{P}}$$



Where M = mean diameter of rings in inches.
P = pitch of propeller in feet.

Example :—The I. H.P. is 450, the pitch of the propeller is 14 feet, and the mean diameter of the rings is 10·25 inches, required the number of rings ? (the shaft diameter being 9 inches)

$$\text{therefore the surface} = \cdot 6 \ \frac{450 \times 10{\cdot}5}{14}$$

$$\text{or} = \cdot 6 \times 330$$

$$= 198 \text{ inches.}$$

Now, as the mean diameter of the rings is 10·25 inches, the least and greatest diameters will be 9 and 11·5 inches respectively ; therefore

$$\text{Difference of areas} = 40 \text{ inches}$$

$$\text{and } 198 \div 40 = 5 \text{ rings.}$$

SCREW SHAFT CARRIAGES.

In practice the tunnel bearings are generally placed 20 to 24 diameters apart ; the length of each bearing block in inches will be found by the formula

$$\frac{T \ R}{12 \text{ to } 15}$$

Where T = tons supported by each carriage.
R = number of revolutions per minute.

STERN TUBE.

The proportions of bearings in the stern tube should be large in comparison with other bearings. It should be remembered that stern tube bearings are seldom seen, and cannot be overhauled or lined up unless the vessel is in dock.

The inside bearing (not including stuffing-box length) should be as per formula given for tunnel bearings. The outside, or lignum-vitæ bearing should not be less in length than is found by

$$\frac{T\ R}{6 \text{ to } 8} = L \text{ in inches}$$

Where T = weight of propeller and propeller shaft in tons.

PROPELLER.

The taper in the Boss is generally $\frac{3}{4}$ inch to $\frac{7}{8}$ inch per foot. The propeller ought always to be secured to the shaft with a large nut, (either right or left-handed, as no importance attaches to a preference), bearing fair against the boss, and having a strong key prolonged through the shaft, and bearing fair against the after end of the nut ; to prevent this key slipping out, it should have a couple of straps spanning the shaft and secured through the key ends. If no through key is fitted, then a check nut bearing fair against the chief nut should be employed.

The driving or longitudinal key should be firmly and fairly bedded into the shaft, and should fit closely, both on the sides and *top* of the keyway in the boss ; this key should be of a length (L) and breadth (B) in accordance with formula

$$\left.\begin{array}{rl} \cdot 38\ D^2 = & L\ B \\ \text{if} \quad & B = \cdot 25\ D \\ \text{then} \quad & L = 1 \cdot 5\ D \end{array}\right\} \text{ where } D = \text{diameter of shaft.}$$

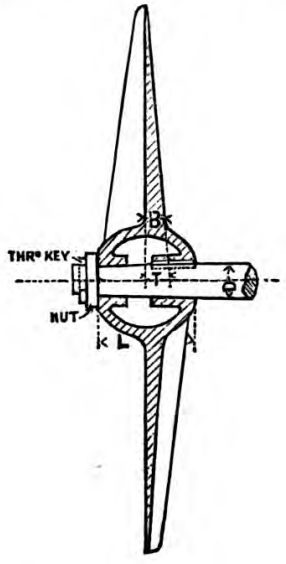
The depth of this key ought to be ·7 B, that is ·35 in the shaft, and the same in the boss. When two keys are used, they ought to be fitted opposite to each other, and not at right angles as is often done.

THICKNESS OF BLADES.

The thickness of blades in *cast iron*, at the root (or B) where it joins the boss, (measured *exclusive* of the fillets,) should be such that if the blades were continued to the centre of the shaft, the thickness there (T) is

$$T = \sqrt{\frac{D^3\ 5}{L\ N}}$$

where D = diameter of shaft.
N = number of blades.
L = length of blade in inches where it joins the boss in a direction parallel to the axis of the shaft.



Example :—The propeller shaft is 9 inches in diameter, the number of blades to be used is 4, and the length of the blades on the boss 27 inches, required the thickness of the blade at T ;

$$T = \sqrt{\frac{9^3 \times 5}{27 \times 4}}$$

$$\text{or} = \sqrt{\frac{3645}{108}}$$

$$= \sqrt{33{\cdot}7}$$

$$= 5{\cdot}8 \text{ inches.}$$

DIAMETER OF PROPELLER.

The most effective diameter of a screw when the length, breadth, and load draft of the vessel are given will be found from the formula

$$D = \sqrt{{\cdot}013 \times L \times (B + 2D)}$$

where L = Length of ship on load line.
B = Breadth.
D = Draft (mean.)

Note.—The diameter of a propeller is by many determined by the draft of the ship, irrespective of engine or ship's dimensions, hence, we often find engines of large power, with propellers of small diameters (or in keeping with the draft of water) giving very poor speed results. We hold that the efficiency of propellers lies more in large diameter and fine pitch, than in small diameter and coarse pitch.

Example :—Suppose a vessel to be 300 feet long × 36 feet broad × 21 feet draft ; required the most effective diameter of propeller ?

therefore, we have $D = \sqrt{\cdot 013 \times 300 \times (36 + 2 \cdot 21)}$

or $= \sqrt{\cdot 013 \times 300 \times 78}$

$= \sqrt{304 \cdot 2}$

$= 17 \cdot 27$ feet diameter.

AREA OF BLADES.

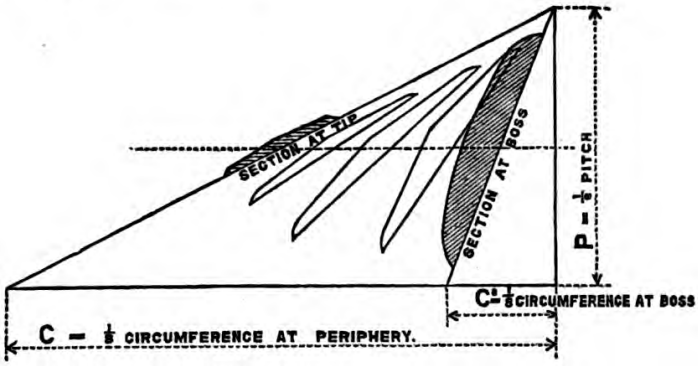
The projected area of the blades upon a plane transverse to the axis of the propeller, should not exceed ·25 of the effective disc area, that is, the area of the circle taken to the tips of the blades, minus the boss circle area. If this proportion is much exceeded the water does not appear to get away clear of the blades, the result being that a "churning" action is induced which renders the propeller very inefficient.

See calculation of I. H. P. for further elucidation of this question.

MOULDING A PROPELLER.

Propellers are moulded without having recourse to a pattern. The mode of procedure is very interesting, and we think it will not be out of place in a work like this, to describe it. The first operation consists in making a loam clay boss of the drawn size ; after this boss has been dried, it is

placed in the centre of the plate on which the blade bases or walls are built, these bases are merely a work of bricklaying, the angle of build is determined as per sketch.



P = a line representing the pitch.

C = ,, ,, the circumference at the tips

C′= ,, ,, ,, ,, at the boss

These diagrams can be drawn to any scale, the hypothenuses at tip and boss circumference show the angle of the blade for the given pitch. Wood templets or angle boards are made off and to these angles ; the one for the boss is placed close to the boss, that for the tips on the end of the base plate at a distance out equal to the radius, both the centres of the templets being in keeping with the form of the blade desired, this being done, the building up of the brick base or wall commences, after being nearly up to the level of the angle boards, the bricks are faced with a thick coating of loam clay, the clay is cleaned down or scraped to the angle by simply drawing radially over its surface a chamfered-

edged straight edge resting on the angle boards; after each face is swept the whole is hard dried. The form and thickness of the blade are now made in green loam upon each of the dried faces, the thickness at different sections of the blade being fixed by corresponding templets pinned to the surface of the face. (It must be borne in mind that the under side of the blade is the "driving" or go-ahead face, the thickness portion being the "go-astern" side of the blade.) On the pattern blade being made up in the green loam, it is then skin dried. The covering plates are now prepared, i. e., they are filled up with loam clay; on this being done, they are laid in their moulding position on to the loam blade face, *consequently the imprint of the dry sand blades is made in the loam clay of the covering plates.* The covering plates are removed, then touched up, dried and blackened over; the sand pattern of the blade is now scraped off each face, which is also blackened and smoothed over, the loam boss is then broken up in its place, and its imprint touched up, dried, and blackened; the boss core is now placed and secured to the centre of the base plate; the covering plates of the blades and boss are now put on, and firmly secured to the base plate "lugs," and the mould is then ready for casting. Propellers after being cast should be allowed to cool off; if exposed to the air in a heated condition and irregularly cooled, blade fracture is often the result.

BOILERS.

HEATING SURFACE.

The heating surface in a marine boiler should not be less than from 3·75 to 4 square feet per I. H. P., but 4·5 square feet will be required if the tube plates are reckoned.

STEAM SPACE.

The steam space in a marine boiler should not be less than from 1·0 to 1·2 cubic feet per I. H. P., about $\frac{6}{7}$ths of which ought to be exclusive of domes.

GRATE SURFACE.

The grate area, in properly proportioned marine boilers, fed with fuel of a fair quality should be from ·12 to ·14 square feet per I. H. P.

FUNNEL.

The sectional area of the funnel in square feet should be from ·2 to ·3 that of grate area. The relation of length and diameter will then be found from the formula

$$A \sqrt{H} = \text{I. H. P.} \times \cdot 23 \text{ to } \cdot 25$$

where H = the height in feet *from level of fire bars.*

and A = sectional area in square feet.

Taking our 100 N. H. P. engine as indicating 450 H. P., the grate area would be I. H. P.

$$450 \times \cdot 12 = 54 \cdot 00 \text{ square feet,}$$

then the sectional area of the funnel

$$54 \times \cdot 3 = 16 \cdot 2 \text{ square feet,}$$

or diameter 4 feet 7 inches, and

$$\text{the height would be} = \left(\frac{\text{I. H. P.} \times \cdot 25}{16 \cdot 2}\right)^2 = \left(\frac{112}{16 \cdot 2}\right)^2$$

$$= 6 \cdot 9^2 = 47 \cdot 6 \text{ feet from bars.}$$

TUBES.

Now, where H = height in feet of funnel from bar level.

A = area of funnel.

A_1 = area through tubes.

S = heating surface in tubes.

S_1 = other heating surface exclusive of tube plates.

L = length of tubes in inches.

D = internal diameter of tubes.

The most effective length of tube to diameter will be found by the expression

$$\frac{L}{D} = 4 \sqrt{H} \times \frac{A}{A_1} \times \frac{S}{S + S_1}$$

Where A or area of funnel equals A_1 or area through tubes, which is generally the case, and where S or heating surface in the tubes equals ·8 of the total heating surface, or $S + S_1$, we get for our 450 I. H. P. engine.

$\frac{L}{D} = 4 \times 6{\cdot}9 \times 1 \times {\cdot}8$

or, $\frac{L}{D} = 27{\cdot}6 \times {\cdot}8$

$\frac{L}{D} = 22$ as being the most efficient ratio of length to diameter of tube.

The foregoing formulæ of chimney and tube proportions, have been carefully deduced from the investigations and experiments of MM. Peclet, Despretz, Dulong and others, upon the velocity and temperature of gases, and the rate of transference of heat through thin plates.

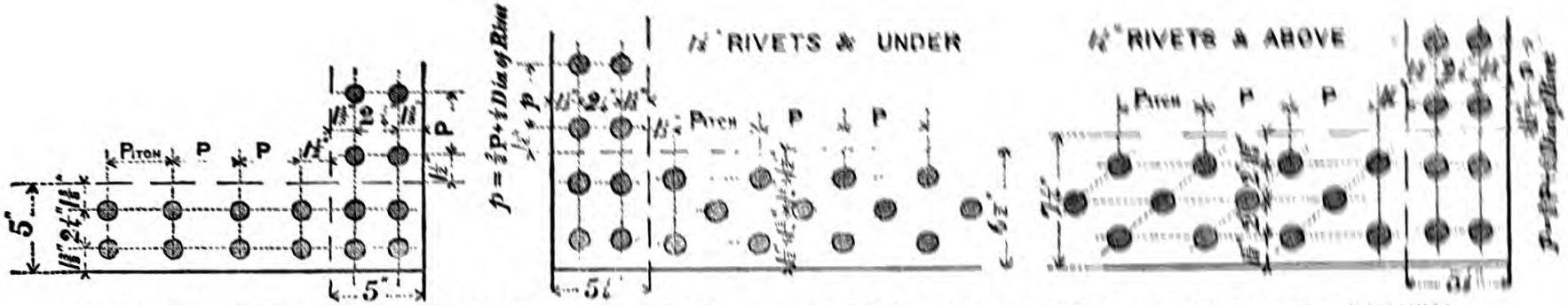
VENTILATORS.

To ensure sufficient air for complete combustion of coal, the sectional area in square feet of the ventilators should not be less than given by the formula

$$\frac{\text{I. H. P.}}{150}$$

for the 450 I. H. P. engine, we would have 3 square feet, or two ventilators of 16 inches diameter.

We append a table showing the diameters, thickness of plates, pitch and diameters of rivets for 70 lbs. 75 lbs. and 80 lbs. pressure, calculated according to the Board of Trade formula, and embracing their allowance for drilled holes, the factor of safety for double rivetted joints being 5·3 and for treble rivetted joints 5·2 as shown.



DOUBLE RIVETTED, FACTOR OF SAFETY $= 5 + K \cdot 2 + S \cdot 1 = 5 \cdot 3$

TREBLE RIVETTED, FACTOR OF SAFETY $5 + L \cdot 1 + S \cdot 1 \quad 5 \cdot 2$

	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
THICKNESS OF PLATE		$\frac{5}{16}$		$\frac{11}{16}$		$\frac{3}{4}$		$\frac{13}{16}$		$\frac{7}{8}$		$\frac{15}{16}$		1		$1\frac{1}{16}$		$1\frac{1}{8}$
DIAMETER OF RIVET		1		1		1		$1\frac{1}{8}$		$1\frac{1}{8}$		$1\frac{1}{8}$		$1\frac{1}{8}$		$1\frac{1}{8}$		$1\frac{1}{8}$
PITCH OF RIVET		$3\frac{1}{2}$		$3\frac{1}{2}$		4		$4\frac{1}{2}$		$4\frac{1}{2}$		4		$4\frac{1}{2}$		$4\frac{1}{2}$		$4\frac{1}{2}$
GREATEST EXT. DIA. 70 LBS....	9	$6\frac{1}{4}$	10	$1\frac{3}{4}$	12	$2\frac{3}{4}$	13	3	14	3	14	$10\frac{3}{4}$	16	2	16	10	17	8
GREATEST EXT. DIA. 75 LBS....	8	$10\frac{3}{4}$	9	$5\frac{1}{4}$	11	5	12	$4\frac{1}{2}$	13	$3\frac{3}{4}$	13	$10\frac{3}{4}$	15	$1\frac{1}{2}$	15	$8\frac{3}{4}$	16	$6\frac{3}{4}$
GREATEST EXT. DIA. 80 LBS....	8	4	8	$10\frac{1}{2}$	10	$8\frac{1}{2}$	11	$7\frac{1}{4}$	12	$8\frac{1}{4}$	13	0	14	2	14	9	15	$6\frac{1}{4}$
LEAST % OF LANDINGS.....	71·4 P.		69·2 P.		75 P.		75 P.		75 P.		73 P.		74·4 P.		72·9 P.		73·2 P.	

The above is calculated from the following Board of Trade Formula

$$\frac{47{,}000 \times \text{LEAST \%} \times \text{TWICE THICKNESS OF PLATE}}{\text{WORKING PRESSURE} \times \text{FACTOR OF SAFETY.}} = \text{greatest internal diameter.}$$

with 2 thicknesses of plate added.

SHIPS' SPEED.

Although great labour and research have been expended upon the investigation of this subject, and though many formulæ have been devised in relation thereto, still it is impossible to predict accurately the speed of a particular vessel with a given I. H. P.; there are so many elements to be carefully considered, and so many occult actions or influences affecting a vessel's speed, that any rule for I. H. P. to give a certain speed or *vice versâ* must always be considered as only an approximation. The form of ship, lines of the bow and stern, proportion of length to breadth, draft of water, form, diameter, and pitch of screw, head of water over the screw, are all elements which undoubtedly determine speed results upon a given I. H. P. The investigations and experiments of the late Professor Rankine and Mr. Froude are invaluable, but their deductions and formulæ are, nevertheless, merely approximations to actual effects; as their operations were chiefly confined to vessels of fine lines, their formulæ must necessarily be modified in dealing with full lined or ordinary merchant steamers. By comparing the results of a great number of clean-painted vessels of the screw-collier or cargo-carrying type, we have framed a formula (based upon frictional or skin resistance, in agreement with the latest authorities) for the

determination of speed in knots, on a given I. H. P. or *vice versâ*, as follows :—

$$S = \sqrt[3]{\frac{I.H.P. \times 20,000}{L \times B + 2D \times 91}}$$

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

S = Speed of ship in knots.

L = Length on load line in feet.

B = Breadth in feet.

D = Load draft.

We will give a few examples of ships' speeds and powers calculated from the above formula, and compare them with the actual results obtained at sea in ordinary voyaging.

1st—The S. S. "SYBIL."

DIMENSIONS.

Length on load line	265 feet
Breadth of beam.....	38 feet
Load draft	19 feet

ENGINES.

H. P. cylinder.....	37	inches diameter
L. P. „	68	„ „
Stroke	42	inches
Pressure of steam	75	lbs.
Calculated I. H. P.	950	

The question with an owner now is :—Given a vessel of the above dimensions, with engines capable of developing 950 H. P., what speed may he expect on the above draft ?

We have therefore,

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

$$\text{or} = \sqrt[3]{\frac{19{,}000{,}000}{18{,}327}}$$

$$\text{or} = \sqrt[3]{1036}$$

$$\text{or} = 10 \text{ knots fully.}$$

Now this vessel has steadily maintained at sea, in favourable weather, a speed of $10\frac{1}{4}$ knots.

To make the matter clearer, we will suppose a Shipowner decides on a vessel say, of the above dimensions, and wishes her to go 10 knots, he will naturally ask what power will be required ? The formula then becomes

$$\text{I. H. P} = \frac{S^3 \times L \times B \times 2D}{20{,}000}$$

$$\text{or} = \frac{18327400}{20{,}000}$$

$$\text{or} = 916 \text{ I. H. P.}$$

We will now take a vessel of different dimensions and power,

The S. S. "CORONILLA."

DIMENSIONS.

Length on load line	258 feet
Breadth of beam	32 feet
Load draft	19 feet

ENGINES.

H. P. cylinder	28	inches diameter
L. P. „	54	„ „
Stroke	33	inches
Pressure of steam	75	lbs.
Calculated I. H. P.	500	

With a vessel of these dimensions and power, what speed may be expected ?

By the formula,

$$\text{Speed} = \sqrt[3]{\frac{500 \times 20{,}000}{258_{L} \times (32_{B} + 38_{2D}) \times \cdot 91}}$$

$$\text{or} = \sqrt[3]{\frac{10{,}000{,}000}{16434}}$$

$$\text{or} = \sqrt[3]{608}$$

$$\text{or} = 8{\cdot}47 \text{ knots.}$$

The normal sea speed of this vessel, in favourable weather is 8 knots. To determine the power necessary to propel such a vessel 8 knots, proceed as explained in the case of the "Sybil."

We will take a vessel of another ratio of dimensions to power, and see how far our formula holds good in practice.

The S. S. "ALVAH."

DIMENSIONS.

Length on load line	300 feet
Breadth of beam	36 feet
Load draft	22 feet

ENGINES.

H. P. cylinder	37 inches diameter
L. P. „	68 „ „
Stroke	42 inches
Pressure of steam	80 lbs.
Calculated I. H. P.	1000

With a vessel of these dimensions and power, what speed may be expected ?

By the formula,

$$\text{Speed} = \sqrt[3]{\frac{1000 \times 20{,}000}{300 \times (36+44) \times \cdot 91}}$$
$$\text{L} \quad \text{B} \quad \text{2D}$$

$$\text{or} = \sqrt[3]{\frac{20{,}000{,}000}{21840}}$$

$$\text{or} = \sqrt[3]{915}$$

or = 9·7 knots.

The actual sea-going speed of this vessel is $9\frac{1}{4}$ knots.

We will now take a few examples of fine-lined Mail steamers; but in their case the formula becomes

$$S = \frac{\sqrt[3]{I.H.P. \times 20{,}000}}{\sqrt{L \times (B+2D) \times \cdot 71}}$$

$$\text{or } I.H.P. = \frac{S^3 \times L \times (B+2D) \times \cdot 71}{20{,}000}$$

With a vessel of say 475 feet long on load line.
44 ,, breadth of beam.
26 ,, draft.
Indicated H.P. 4500

What speed may be expected?

$$S = \frac{\sqrt[3]{4500 \times 20{,}000}}{\sqrt{475 \times (44+52) \times \cdot 71}}$$

$$\text{or} = \frac{\sqrt[3]{90{,}000{,}000}}{\sqrt{32376}}$$

$$\text{or} = \sqrt[3]{2779}$$

or = 14 knots fully.

The vessel in question, under ordinary circumstances, steams on an average $14\frac{1}{4}$ to $14\frac{1}{2}$ knots.

Another case of a Mail steamer of the following dimensions:—

Length on load line	455 feet
Breadth of beam	45 feet
Draft.....	26 feet
I. H. P	4500

this vessel's speed will be

$$\text{Speed} = \sqrt[3]{\frac{4500 \times 20{,}000}{455 \times (45 + 52) \times \cdot 71}}$$

$$\text{or} = \sqrt[3]{\frac{90{,}000{,}000}{31{,}335}}$$

$$\text{or} = \sqrt[3]{2872}$$

$$= 14 \cdot 25 \text{ knots.}$$

The vessel in question steams on an average $14\frac{1}{4}$ knots.

We shall take a case of one of the large Mail steamers at present being built, leaving the future to verify our formula.

Length on load line, say	520 feet
Breadth of beam	52 feet
Ordinary steaming draft	27 feet
Assumed indicated power of engines	9000

Under these conditions, what speed may be expected ?

$$\text{Speed} = \sqrt[3]{\frac{9000 \times 20{,}000}{520 \times (52 + 54) \times \cdot 71}}$$

$$\text{or} = \sqrt[3]{\frac{180{,}000{,}000}{39135}}$$

$$\text{or} = \sqrt[3]{4600}$$

$$= 16 \cdot 65 \text{ knots.}$$

The vessel in question may be relied upon (if the most efficient propeller is employed) to steam $16\frac{1}{2}$ to 17 knots continuously.

DIAMETER OF CYLINDERS.

Having shown the mode of determining the approximate indicated horse power to propel a given vessel at a certain speed, we shall now proceed to show what the cylinder diameters and strokes should be, so that the required power may be obtained. Let us say that an owner finds he will require 450 I. H. P. to give certain results, and say he wishes to do this, using 75 lbs. pressure of steam. What has now to be determined, is the actual mean pressure of the steam in the cylinder, under a certain ratio of expansion; after finding this mean pressure, it must be referred to one cylinder, that is to say, we must suppose the work of 450 I. H. P. to be done in one cylinder. Again we must assume a certain piston speed on which to realise this 450 H. P.; now, as the *modus operandi* of determining mean pressures under a certain ratio of expansion, is somewhat tedious and complex, we subjoin a carefully prepared table, for boiler pressures ranging from 65 lbs. to 100 lbs. boiler pressure of steam, the *absolute* pressure is the boiler pressure plus 15 lbs. or atmospheric pressure. In calculations of this nature it must be borne in mind that the absolute pressure is always taken.

Absolute pressure Boiler pressure + 15.	Ratio of Expansion.	Ratio of Cylinder L. P. to H.P.	Cut-off *		Actual Mean Pressure referred to one Cylinder.
			H. P. cylin.	L. P. cylin.	
					lbs.
80	8	3·18 to 1	·48	·43	20·1
85	8·5	3·3 to 1	·47	·42	20·4
90	9	3·42 to 1	·45	·40	20·7
95	9·5	3·54 to 1	·44	·37	21·0
100	10	3·66 to 1	·43	·36	21·3
105	10·5	3·78 to 1	·43	·36	21·6
110	11	3·9 to 1	·42	·34	21·9
115	11·5	4·02 to 1	·42	·34	22·2

The table given shows the *most effective* ratios of cylinders and expansion for boiler pressures, ranging between 65 lbs. and 100 lbs. They are calculated for a velocity of steam *through the ports* of about 12,000 feet per minute, and if this velocity is much exceeded, the effective mean pressure given in the table will have to be decreased. We can now, by the aid of this table, calculate the diameters of cylinders required for an engine to indicate a certain I. H. P. *with a given piston speed.*

As an example :—Suppose an owner finds he will require 450 I. H. P. to drive a given vessel a certain speed, he fixes on his boiler pressure, say 75 lbs., and piston speed say 360 feet per minute,

* The cut off here given is the cut-off by the valve. The ratio of expansion however, is that actually obtained, thus, taking the ·48 (or cut off for 80 lbs.) this corresponds to the actual cut-off of ·39 then, $\cdot 39 \times 3{\cdot}18$ or ratio of cylinders = 8 nearly or ratio of expansion as given.

and he now wants to know what diameter of cylinders will give this power under the most effective conditions ? Now, as one horse power is equivalent to 33,000 lbs. raised one foot high in a minute, the units of work required will be

$$\text{I. H. P. } 450 \times 33000 \text{ lbs.}$$

and this again must equal

Speed of piston 360 ft. × area of L. P. cylinder × effective mean pressure.

As the boiler pressure to be used is 75 lbs., the absolute pressure is 90 lbs., and with a ratio of expansion of 9, the mean pressure is 20·7 lbs.

therefore we have

$$\frac{450 \times 33000}{360 \times 20{\cdot}7} = 1993$$ square inches area of L. P. cylinder.

As the ratio of the cylinders is 3·42 to 1

$$\frac{1993}{3{\cdot}42} = 582$$ square inches area of H. P. cylinder.

therefore, 582 = 27·2 inches diameter of H. P.
1993 = 50·4 „ „ L. P.

We shall now suppose that an indicated horse power of, say 4500 is required, and that the piston speed is to be 600 feet per minute, and the boiler pressure 90 lbs.

We should then have units of work required
$= 4500 \quad 33000$

and this must equal 600 × area of L. P. cylinder × effective mean pressure, the boiler pressure being 90 lbs., the absolute pressure is 105 lbs., and with a ratio of expansion of 10·5 times the effective mean pressure is 21·6 lbs.

Therefore, $\frac{4500 \times 33000}{600 \times 21{\cdot}6} = 11458$ square inches area of L.P. cylinder.

then as the ratio of the cylinders is 3·78 to 1

$\frac{11458}{3{\cdot}78} = 3031$ square inches area of H.P. cylinder.

Therefore 11458 = 120 inches diameter for one cylinder,
or 85·4 inches diameter for two.
and 3031 = 62·1 inches diameter for one cylinder,
or 44 inches diameter for two.

The engine may therefore be designed with

One H. P. cylinder	62·1	in.	dia.	A Two cylinder engine.
and				
One L. P. „	120	„	„	

or with

One H.P. cylinder	62·1	in.	dia.	A Three cylinder engine.
and				
Two L. P. „	85·4	„	„	

or with

Two H. P. cylinders 44 in. dia.		A
and		Four cylinder
Two L. P. „ 85·4 „ „		engine.

The fixing of the piston speed is a matter chiefly dependant upon the space available, type of engine and cost; the stroke generally depends on the same conditions. As a matter of practice, the piston speed in feet per minute, is to the stroke in inches as 10 is to 1. In the examples given the respective strokes would be 36 inches and 60 inches, and as the number of revolutions follows from piston speed, the propeller must be made of a pitch and surface suitable for that number of revolutions, and the speed of the vessel.

We shall now, (as a summary to the calculations of Ships' Speed, Indicated Power and Engine Sizes,) fix upon a vessel and determine I. H. P. cylinder diameters, stroke, and pitch of propeller to drive her the desired speed.

Let us take a cargo boat of ordinary lines, say 300 feet × 36 feet × 21 feet draft, which it is desired to propel at 9 knots per hour, what would be the I. H. P., diameter of a two cylinder compound engine, length of stroke, and pitch of propeller? The pressure of steam to be employed say, 80 lbs., and piston speed say, 400 feet per minute.

We have first to determine the I. H. P. required to drive the vessel 9 knots, on a draft of 21 feet.

Therefore

$$\text{I. H. P} = \frac{\overset{\text{Speed}}{S^3} \times \overset{\text{Length}}{300} \times (\overset{\text{Breadth}}{36} + \overset{\text{Two drafts}}{42}) \times \cdot 91}{20{,}000}$$

$$\text{or} = \frac{729 \times 300 \times 78 \times \cdot 91}{20{,}000}$$

$$= \quad 780 \quad \text{I. H. P. nearly.}$$

Now, under the most effective ratio of expansion the mean pressure of 80 lbs. boiler pressure, (or 95 lbs. absolute pressure) is 21 lbs., and this pressure referred to one cylinder gives

$$\frac{780 \times 33000}{400 \times 21} = 3064 \text{ square inches as L. P. cylinder area}$$

or 3064 = 63 inches diameter nearly

and as the best ratio of cylinders for 80 lbs. pressure is 3·54 to 1

$$\text{we have } \frac{3064}{3 \cdot 54} = 865 \text{ square inches as H. P. cylinder area}$$

or 865 = 33 inches diameter nearly.

Therefore, the engine to develop 780 H. P. with a piston speed of 400 feet per minute, and working under the most effective conditions of cylinder proportions and expansion of steam, will require to be

L. P. 63 inches, H. P. 33 inches, and stroke 40 inches, ($\frac{1}{10}$th of piston speed.)

Now with a piston speed of 400 feet per minute, and 40 inches stroke, the revolutions will be 60, and as

9 knots × 6080 feet in a knot
= 54720 feet per hour
= 912 „ „ minute

The pitch of propeller to give this
= 912 ÷ 60 revolutions
= 15·25 feet.

SLIP.

It must be borne in mind that the pitch thus found, viz. 15·25, is the pitch *equal to the speed of the ship*, neglecting the matter of slip, which is a quantity too often allowed for by some empirical per-centage on the pitch as found above.

"Slip" per revolution is the difference between the length of the column of water passed through the propeller's disc, and the distance the propeller itself advances during one revolution. This last distance (the advance of the propeller through the water) must be measured *relatively to the water* in which it moves, because the water itself may have had some motion either in the direction of that of the propeller or in an opposite direction.

The length of the column of water which passes through the propeller's disc *must* exceed the distance which the propeller advances, in order that there

should be a *re-action* on the propelling instrument in the direction of its advance. This difference of length, or *slip per revolution*, is the cause of the re-action, for that is the *velocity* given to the water which passes through the propeller in a direction opposite to that of the propeller. It is plain that *velocity* must have been given to water if any *force* has been exerted upon it; being a mobile substance it can offer no *resistance* without being *moved.* The *Re-action*, therefore, is due to *Slip*; without slip there can be no re-action, and *without slip no vessel can be propelled.*

Some vessels are propelled with *apparently* no slip, this is probably due to the propeller working in water which already has a motion in the direction of the vessel's advance.

We hold that the product of slip by the square of the pitch of propeller varies directly as the I. H. P., and inversely as the product of the revolutions squared by the effective disc area, and probably may be expressed by the following :—

$$\sqrt{S} \times (P + S) = \frac{C}{N} \times \sqrt{\frac{I.H.P.}{D.}}$$

Where S = Slip in feet per revolution.

P = Pitch without slip, i.e. distance ship goes in one revolution.

N = Number of revolutions.

D = Effective disc area.

C = Constant, 780 to 800 depending on efficiency of the engines.

Taking the case given we have 780 I. H. P.

Number of revolutions	60
Diameter of screw, say	17 feet
Pitch without slip.....	15·25 feet
Effective disc area.....	217·5 feet

[The disc area of a propeller is the area equal to its diameter, minus the area of the boss.] The *slip feet* to be added to the pitch, would therefore be as follows :—

There is no exact solution for S in this expression, but it is approximately found by trial, thus taking 2 feet as the slip feet to be added, we have in this instance

$$\sqrt{S} \times (P + S) = \frac{C}{N}\sqrt{\frac{I.H.P.}{D.}}$$

$$\sqrt{2} \times (15{\cdot}25 + 2) = \frac{800}{60} \times \sqrt{\frac{780}{217{\cdot}5}}$$

$$\text{or } 1{\cdot}4 \times 17{\cdot}25 \quad = 13{\cdot}3 \times 1{\cdot}87$$

$$\text{or } 24{\cdot}150 \quad \text{and} \quad 24{\cdot}860$$

which nearly coincide ; had we assumed a greater or less amount of slip feet, the greater or less would have been the divergence from the product of

$$\frac{C}{N} \times \sqrt{\frac{I.H.P.}{D.}}$$

therefore the actual pitch of the propeller in question becomes

$$15{\cdot}25 + 2 = 17{\cdot}25 \text{ feet.}$$

To elucidate the factor of slip still further, we shall now show the thrust work *in foot pounds* due to the slip of the two feet, which is added to the pitch due to the vessel's speed.

The effective disc area as shown is = 217·5 feet

A cubic foot of water = 64 lbs. nearly.

The pitch + slip = 17·25 feet

The slip = 2 feet

The accelerating effect due to gravity = 32 nearly.

We have therefore a 17·25 feet column of water driven through a space of 2 feet in one revolution, the area of this column is 217·5 feet, and the re-action

$$= \frac{\overset{\text{Slip}}{2} \times \overset{\text{Pitch}}{17{\cdot}25} \times \overset{\text{Lbs.}}{64} \times \overset{\text{Feet}}{217{\cdot}5}}{32}$$

$$= 15007{\cdot}5 \text{ lbs.}$$

and $15007{\cdot}5 \times 17{\cdot}25 = 258879$ foot lbs. per revolution

and as 60 revolutions are made in a minute, we have

$$\frac{258879 \times 60}{33000}$$

$$= 470 \text{ H. P.}$$

The effect of the slip is therefore equivalent to 470 H. P., and as the engines indicate 780 H. P., the difference is taken up by overcoming resistances and friction.

We shall take the case of a vessel designed to go 18 knots, and to do this, say, the engines are designed to indicate 9000 H. P. on 60 revolutions, we shall assume that the diameter of the propeller is 26 feet, and its boss is 4 feet 6 inches in diameter.

The area of 26 feet	= 530
,, ,, 4 feet 6 inches	= 16
The effective disc area	= 514 feet

Now the pitch (without slip) for a speed of 18 knots, with 60 revolutions, will be 30 feet, and as the formula is

$$\sqrt{S} \times (P + S) = \frac{C}{N} \times \sqrt{\frac{I.H.P.}{D.}}$$

We have for

$$\frac{C}{N} \times \sqrt{\frac{I.H.P.}{D.}}$$

$$\frac{800}{60} \times \sqrt{\frac{9000}{514}}$$

$$\text{or} = 53$$

Now 53 should be equal to *the pitch plus the slip* × *the square root of the slip*

$$\text{or } \sqrt{S} \times (P + S) = 53$$

$$\text{or} \qquad \text{Slip} \quad = 3 \text{ feet}$$

The pitch of the propeller will therefore require to be 30 + 3 = 33 feet. As in the previous case, we have here a 33 feet column of water driven through a space of 3 feet per revolution, the area of this column being 514 feet, the re-action

$$= \frac{\overset{\text{Slip.}}{3} \times \overset{\text{Pitch.}}{33} \times \overset{\text{Lbs.}}{64} \times \overset{\text{Feet.}}{514}}{32}$$

$$= 101772 \text{ lbs.}$$

then

$$\frac{101772 \times 33 \times 60}{33000} = 6000 \text{ H.P.}$$

The effect of the slip in this case, is equivalent to 6000 H. P., and as we assumed the engines indicating 9000 H. P., the difference is absorbed in overcoming resistances and friction.

It must be understood that the water passed through the propeller's disc is taken always at the *rate per second.* In the cases given we employed 60 revolutions, or one per second. Suppose the engines were running 50 revolutions, the rate per second would be

$$S \times \frac{50}{60}$$

Say we had 3 feet slip and 50 revolutions, the slip per second would be

$$3 \times \frac{50}{60} = 2{\cdot}5 \text{ feet.}$$

The question may naturally be asked, What becomes of the water set in motion to the extent of the slip at each revolution of the propeller ? It is commonly thought that it continues its motion backwards in the form of a straight column. A

little consideration will show (since motion always follows the line of least resistance) that each particle of water sent back from the propeller will rise in a curved line to the surface at no very great distance from the screw; the converse of this is the supply of this water from the surface in front of the propeller flowing towards it by similar lines. The result of this action upon the surface of the water is to cause, however slight, a depression before the propeller and elevation behind; in other words, a following wave.

We trust that the foregoing explanation of the term "Slip," will convince our readers of two things, 1st, that Slip is the cause of propulsion; 2nd, that the screw when in motion is not continually sending along a column of water, which avails itself of the dock walls of the port of departure for its *abutment*. Many hold such views, but they are fallacious.

RELATION OF POWER TO SPEED.

We have often found Shipowners dissatisfied with speed results, arising from no other cause than having too little power to do the work. Can't you get "another half knot" out of her? is the query often propounded to the inspector. We will show what this "half knot" really means. It must always be kept in view that *the I.H.P. varies as the cube of the speed.*

In the previous example we required 780 I.H.P. to propel a vessel 9 knots. Suppose the owner wished the same vessel driven $9\frac{1}{2}$ knots, the increase of I. H. P. required would be as

$9^3 : 9\frac{1}{2}^3 :: 780$ I. H. P. : required I. H. P.

or $= 729 : 857{\cdot}3 :: 780 : 916$ I. H. P.

therefore for 9 knots 780 I. H. P. is required

„ „ $9\frac{1}{2}$ „ 916 „ „

or 136 I. H. P. additional.

This increase representing say 3 tons additional consumption of fuel per day.

———:o:———

DIMENSIONS OF COMPOUND ENGINES.

N.H.P. Formula $\frac{D^2 + d^2}{2000}$ (L.P.) (H.P.) / 30 + str. in in.		Diameters of Cylinders.		Stroke.		Heating Surface.	Cooling Surface.	Diameters of Air & Circulating Pumps.				Areas of Cylinders.	
								Two with stroke of engine.		Two with ½-stroke of engine.			
								Air.	Cir.	Air.	Cir.		
		in.		in.				in.	in.	in.	in.	H. P.	L. P.
COMMERCIAL HORSE POWERS.	100	27	&	50	2 9	2000	1000	10½	6½	15	9	572·5	1963 5
	110	28	,,	52	2 9	2200	1100	10½	6½	15	9	615 7	2123 7
	120	29	,,	55	2 9	2400	1200	11	7	15½	10	660 5	2375 8
	130	31	,,	57	2 9	2600	1300	11½	7½	16	10½	754·7	2551·7
	140	31	,,	58	3 0	2800	1400	12	7½	17	10½	754·7	2642·0
	150	32	,,	59	3 0	3000	1500	12	7½	17	10½	804 2	2733 9
	160	33	,,	61	3 0	3200	1600	12½	8	17½	11	855·3	2922·4
	170	33	,,	62	3 3	3400	1700	12½	8	17½	11	855·3	3019 0
	180	34	,,	64	3 3	3600	1800	13	8	18	11	907·9	3216 9
	190	35	,,	65	3 3	3800	1900	13	8½	18	12	962·1	3318 3
	200	35	,,	66	3 6	4000	2000	13½	8½	19	12	962·1	3421 2
	210	36	,,	67	3 6	4200	2100	13½	8½	19	12	1017 8	3525·6
	220	37	,,	69	3 6	4400	2200	14	9	20	12½	1075·2	3739 2
	230	38	,,	70	3 6	4600	2300	14½	9	20	12½	1134 1	3848 4
	240	39	,,	72	3 6	4800	2400	15	9½	21	13	1194·5	4071·5
	250	39	,,	72	3 9	5000	2500	15	9½	21	13	1194·5	4071 5
	260	39	,,	74	3 9	5200	2600	15	9½	21	13	1194·5	4300 8
	270	40	,,	75	3 9	5400	2700	15½	10	22	14	1256 6	4417 8
	280	41	,,	76	3 9	5600	2800	15½	10	22	14	1320·2	4536·4
	290	42	,,	77	3 9	5800	2900	16	10	22½	14	1385·4	4656·6
	300	42	,,	77	4 0	6000	3000	16	10	22½	14	1385·4	4656·6

ACCIDENTS, USUALLY CALLED "BREAK-DOWNS."

In cases of partial disablement to vessels at sea, the Officers should be ready to adopt temporary methods of repair, whereby the voyage may be prosecuted until some port is reached. When a vessel is dismasted, we find jury masts are immediately rigged from the spare spars; when the rudder is damaged or carried away, a pole rudder is made from a yard or spar, and fitted over the quarter; many instances are recorded of captains passing or keel-hauling a thrum sail under their ship, to prevent the inflow of water from a leak, &c., &c. We believe that questions, principally based upon cases of emergency, form no inconsiderable portion of the examination for captain or mate. Officers ready in resource in moments of danger are invaluable.

In the case of damage to, or break-down of the machinery of a vessel, the engineers should be ever ready to attempt to meet the emergency with the limited means at their disposal. It is to be regretted that no official record is kept of engine break-downs at sea, with the modes of their temporary repair. Many instances have occurred where the genius of the engineer alone has saved the ship and cargo; we

think that such cases of mechanical skill ought to merit official recognition. Orders are instituted and decorations given for Valour, and for saving life under various conditions, but in cases where lives have been saved solely by the application of the practical skill of the engineers on board of disabled vessels, no notice whatever is taken, and their deeds of true heroism—the heroism of the practical mind—are unrecorded save in the breasts of those directly benefitted by their acts. We believe that this phase of saving life has never received the consideration it merits from the powers that be. We hope that the day is not far distant, when some public recognition of such services shall be made.

To define modes of temporary repairs to engines under certain disasters, would be a difficult matter, so much depends on the nature and position of the accident, the means at the engineer's disposal, and above all, the ability and knowledge of those in charge. We may, however, describe sundry "break-downs," which have come under our observation, with the modes adopted by the engineers to keep the engines going, and hope that some ideas may be gleaned therefrom which will prove of service to others placed in similar circumstances.

HIGH PRESSURE CYLINDER DISABLED.

During a voyage from Spain, with a cargo of ore, the engines of the L ——— of ——— broke down ; the cause of the accident was the slackening

back of one of the nuts on the top end of the H. P. connecting rod, hence, both bolts gave way, with the result of smashing the cylinder cover, and bending the pump gear, in fact, a complete disablement of the H. P. cylinder. The moment the accident occurred, the engineer proved himself master of the situation by his coolness and energy ; a heavy sea was running, the vessel was off Cape St. Vincent, and slowly driving on a lee shore, yet in the short space of two hours she was under weigh and drawing off the land. The *modus operandi* pursued by the engineer was as follows :— He immediately disconnected the connecting rod of the disabled engine from the crank, then had the H. P. casing cover lifted, and withdrew the slide-valve, and plugged up the *steam* ports of the disabled cylinder with wood and canvas, then re-jointing the casing cover, he admitted steam through the H. P. exhaust port into the L. P. casing, with the result that the engine started and continued working until the vessel reached her port of destination in the North of England.

CYLINDER COVER BROKEN.

While the A —— of L —— was on a voyage to the Cape of Good Hope with mails and passengers, and when to the Southward of the Cape Verde Islands, one of the cylinder covers broke. In this case again, the engineer showed himself worthy

of the name. In eight hours he had the cover patched, jointed to the cylinder, and the engines started, the patched cover doing duty on the home voyage ; on the cover giving way, he immediately stopped the engines, and got the pieces laid alongside each other, then he had recourse to a piece of *plate off the bunker side*, which he cut to the required form, and drilled through the pieces of the cover to suit the plate, countersinking the undersides of the holes, and bolting the whole together with a double layer of canvas and red lead ; after the patch was put on, the cover was actually stronger than in its original condition ; we believe that the admiration of the passengers on board took a tangible form as a reward for the skill and aptitude of this engineer.

PROPELLER LOOSE ON SHAFT.

The M ——— of L —— while on a run from Woosung to Hong Kong, gave every evidence that the propeller was loose on the shaft, a heavy knocking being heard, which gradually got worse ; the engineer determined to see what was amiss, and if possible, to remedy any defect without running up a heavy bill, or detaining the ship ; previous to getting into Hong Kong, he constructed a long canvas tube from a tarpaulin, the bottom of which was formed by the end of a barrel, to which the canvas was carefully secured ; he stitched several

hoops of ½ inch round iron in the interior of the tube; at a convenient height from the bottom he had two arm bags stitched on, and also a side-light glass carefully sewn in. On the vessel reaching Hong Kong, he had all in readiness for his feat, so after placing sundry weights in the bottom, he got in himself, the arm bags were secured round his wrists, and he was lowered over the stern, where he found the propeller nut almost off the end of the shaft; a hammer being lowered to him, he secured the nut in its place, and actually fitted in a new through key. A cheap and simple mode like this for examining propellers is worthy of notice, and speaks volumes for the genius of the engineer.

CRANK PIN DEFECTIVE.

The engineer of the C —— of N —— S —— on examining the brasses at G —— in the Mediterranean, discovered a flaw line in the forward crank pin, the mark ran round the pin, and looked suspicious, as it undoubtedly was; on reporting the discovery to the captain, a consultation was held, and the engineer undertook to make it safe enough for working; the necessary gear was soon rigged up, and a 1½ inch hole drilled by ratchet through the webs and pin, then a bar with a 3½ inch cutter was entered and sent through, after this, the ends of the hole were recessed for the bolt head and nut, which

was got from the shore and duly fitted in; the whole time over the job being 76 hours, and the cost was the price of the $3\frac{1}{2}$ inch bolt and nut; the vessel made her voyage without hindrance, and on reaching a home port, the crank pin was examined and found in order. The vessel is still running with this pin through the crank pin.

STERN TUBE BROKEN.

The propeller shaft of the M —— of L —— broke when the vessel was nearing Constantinople on a homeward voyage from the Black Sea; in breaking, it fractured the stern tube; in fact it was split in two; the vessel came to anchor at Constantinople, and the engineer set about repairing the disaster, fortunately there was a spare propeller shaft on board, so work was commenced by lightening the ship aft, which was soon accomplished; the propeller was then disconnected from the shaft end, and hung from the quarter, the broken shaft was then drawn in, but the broken tube was the difficulty to surmount without having recourse to a new one, which at Constantinople would have cost £400 or £500. The engineer observed that the fracture was angled and a clean break, so he concluded that if he could get a sleeve over the tube, it would hold if well wedged. With characteristic promptitude the idea of securing the

pieces of the stern tube together, took a practical form ; the engineer went ashore, and was fortunate enough to discover an old dome which at one time belonged to a locomotive boiler, this he purchased for a few shillings and brought it on board ; having withdrawn the end piece of the tube, and also the forward portion, a sufficient distance to enable him to slip the dome or sleeve on, the tube was again inserted into the opening in the stern frame and screwed up ; he then secured the sleeve round the fracture by tight wedging, and was thus enabled to bring the vessel home without putting the owners to the cost of detention over a new stern tube.

THRUST SHAFT BROKEN.

While on a homeward voyage from the Black Sea, and between Malta and Gibraltar, the thrust shaft of the O —— of S —— gave way, with a diagonal break, in the thrust block. On examination it was found that the after collar on the shaft was intact and beyond the line of break. The engineer immediately determined to secure the shaft ; for this purpose he cut four broad dove-tailed keyways through the rings and fitted a tight-driven key into each, having withdrawn all the thrust rings from the block save the one bearing on the sound collar, which received the thrust, he got the engines

started again, and so well was the job done, that no difficulty was experienced in bringing the vessel home ; the cutting of the keyways and fitting in the keys were accomplished in the short space of six hours.

LOW PRESSURE PISTON BROKEN.

While on a voyage to London, the low pressure piston of the B —— D —— of S —— gave way, the engines being of the type having one air and one circulating pump, the air pump worked off the L. P., and the circulating pump worked off the H. P. crosshead ; the engineer, under this disaster, showed a remarkable degree of mechanical aptitude, he immediately disconnected the L. P. connecting rod, and lifted off the L. P. casing cover, then endeavoured to start the H. P. engine, which was accomplished although exhausting into and through the skylight, in this condition the vessel reached her destination without incurring any unnecessary expense. Had the engines been designed with an air and circulating pump to each cylinder, the difficulty of starting the H. P. engine would have been lessened, for, by the withdrawal of the L. P. slide valve, (thus leaving a clear passage from the H. P. exhaust into the condenser,) the H. P. cylinder would then have been a condensing engine.

ECCENTRIC STRAP BROKEN.

The go-ahead eccentric strap of the L —— of N —— S —— broke while the vessel was on a voyage from Liverpool to New York ; in this case, the engineer stopped the engines, and transferred the go-astern strap to the go-ahead eccentric, and slung up the go-astern eccentric rod ; setting his engines away again, they arrived safely at New York ; this was accomplished in half an hour.

CYLINDER PACKING RING GAVE WAY.

During the home voyage from Bombay, and when nearing Aden, the packing ring of the L. P. cylinder of the C —— of —— G ——of G —— gave way ; the indication of a mishap having occurred with the L. P. piston was painfully evident to the engineer by the clatter and metallic rattle within the cylinder ; he immediately stopped the engines, and had the L. P. cylinder cover lifted ; the cylinder showed signs of being newly scored or cut ; the junk ring was lifted, when the packing ring was found to be in pieces ; there was no spare packing ring on board, so the engineer, with the aid of the ship's carpenter, improvised a packing ring by adopting the original packing for pistons, viz. *wood.* Segments of hard wood were cut and fitted in, with a turn of hemp rope behind, the junk ring was then secured down, and the engines set

a-going; the L. P. piston worked smoothly and with no perceptible leakage. The vessel reached her destination safely. This was accomplished in five hours.

BOILER WING FURNACE COLLAPSED.

One of the boiler wing furnaces of the B —— of H —— collapsed, i. e., the crown plate of the furnace being over heated through shortness of water, was forced down almost to the fire bars; the boiler had four furnaces, and on the accident occurring, the engineer immediately eased his safety valves, and kept the engines going at full speed so as to get the steam down; after stopping the engines, he examined the hammock-shaped bulge of the furnace, then withdrew all the bars and bearers, and to enable him to get steam up again without incurring any danger or risk from the damaged plate, he shored the bulge from the bottom of the furnace, and happening to have some bridge bricks and fire clay on board, he utilised them by building the whole furnace up solid; under these conditions steam was got up again and the vessel proceeded on her voyage, reaching her destined home port safely.

DISCHARGE PIPE BROKEN.

During a strong gale of wind, and while a heavy sea was running, the discharge pipe of the engines of the I —— of G —— gave way at the brazing

of the flange bolted to the discharge valve box, the end of the pipe fell down, the water from the sea and from the engines rushing into the ship; at this juncture, the presence of mind of the second engineer, on whose watch it happened, was remarkable; without stopping the engines, he immediately closed the discharge valve, and almost closed the main injection valve; he then put on the donkey pump to draw from the bilges, and was gratified to observe that the water coming from the discharge was readily kept down; and although there were a good many passengers on board, the occurrence was not known to them. The vessel ultimately arrived safely at her port of discharge.

From the foregoing instances (and many more could be cited) of the practical skill and intrepidity of marine engineers in moments of danger and break-downs, it must be conceded that there are heroes in the Mercantile Marine as well as in the Navy; were either of the deeds named performed on one of Her Majesty's Ships, the result would be promotion or decoration to the engineer. It is unnecessary for us to enumerate the possible break-downs of a marine engine; as the unexpected often happens, it must be apparent to a Steamship Owner that his vessels should never be without a few handy pieces of plate and bar iron, tackles, tools, and assorted bolts and nuts; an engineer having

these at hand is, in a sense, prepared to combat minor mishaps, which otherwise might jeopardise, or even result in the loss of the vessel. There is no necessity for having a duplicate engine on board of any ship, large and costly pieces of spare gear will be generally found stowed in some out of the way corner, where they remain corroding away, and when required, are invariably found not to fit their intended places; it is quite sufficient that the engineer has on board the appliances for a make-shift repair, leaving his own practical knowledge to surmount the difficulty.

We conclude by expressing a hope that a return of marine engine break-downs at sea, giving all particulars and the modes of repair, will be issued annually, either by the Board of Trade, or Lloyds; such a record would be of incalculable value to Marine Engine Builders and Steamship Owners.

MACHINERY OF S. S. .....

ENGINEER'S REPORT AFTER EXAMINATION.

	Date and Place when examined.	Condition when examined, and what was done.
CYLINDERS		
PISTONS		
SLIDE VALVES ..		
PUMPS & VALVES		
CONDENSER		
ENGINE BEARINGS....		
COCKS & VALVES DONKEY PUMPS		
BOILERS		
DECK WINCHES AND PIPES		

STATEMENT OF REPAIRS ON ARRIVAL HOME.

Dated at this

day of 188

Certified Correct, Chief Engineer.

N. B.—This Schedule and annexed Abstract must be filled up at EVERY Port of DISCHARGE and LOADING, and sent to the Office.

Abstract Log of the S.S. .....

Day of Week.	DATE.	Hours under Steam.	Winds.	Courses.	Revolutions per minute.	TIME.		Consumption of Coal per Day.		Distance run in 24 hours.
						Steam ordered.	Steam ready.	Tons.	Cwts.	
							Total			

Certified Correct. ..... Chief Engineer.

from ..... to .....

Average Vacuum.	Average Pressure.	Indicated H. Power.	Draft on Departure and Arrival. Forward.	Draft on Departure and Arrival. Aft.	Quality of Coal.	REMARKS.	Memorandum of Departures, &c. Place.	Sailed. Arrived. Passed.	Dat .	Hour.	

COAL STATEMENT.

	Tons.
Coals on board, as per last account,	
,, got at	
,, got at	
,, got at	
,, got at	
Total,	____
Deduct,	
Coals Expended, as per Statement..	
Coals for Donkey and Ship's use.. ____	____
Balance left on board	____

Signed, ... Master.

INDEX

TO

THE DRAWING OF

COMPOUND MARINE ENGINES.

The numbers refer to the parts printed in Roman letters; each part keeping the same number throughout the different views on the Drawing.

PASSAGE OF THE STEAM FROM THE BOILERS.

Reference No.

Steam from the boilers enters at the

1 Throttle Valve, *passes into the*

2 Steam Jacket, *from which through the*

3 Passage *it enters the*

4 High Pressure Steam Chest, *and passing through the*

5 High Pressure Steam Port, *enters the*

6 High Pressure Cylinder, *and forces the piston to the bottom of the cylinder, allowing it to return by escaping through the same port by which it entered, the steam then passes into the*

7 High Pressure Exhaust Port, *through which it escapes into the*

8 Low Pressure Steam Chest, *and passing through the*

9 Low Pressure Steam Port, *enters the*

10 Low Pressure Cylinder, *and forces the piston to the end, escaping by the same port into the*

Ref. No.

11 Low Pressure Exhaust Port, *and thence by way of the*

12 Exhaust Column *into the*

13 Condenser.

STEAM, WHEN CONDENSED.

Here the steam by contact with the outside of the tubes is condensed, the condensed water is raised by the

14 Air Pump, *and discharged into the*

15 Hotwell, *from whence it is drawn through the*

16 Feed Pipes *into the*

17 Feed Pump Chest *by the*

18 Feed Pump, *and discharged through pipes into the boilers again.*

COLD WATER COURSE.

The condensing water from the sea enters by

19 Injection Inlet, *thence through bottom set of*

20 Condenser Tubes, *and returning through the top set, enters*

21 Circulating Pumps, *which discharges it through*

22 Discharge Pipe *overboard.*

SLIDE VALVE MOTION.

23 High and Low Pressure Slide Valves *regulate the admission of steam into the high and low pressure cylinders respectively, and are actuated by means of*

24 Eccentrics,

25 Eccentric Rods,

26 Slide Valve Rods. *By means of the*

27 Reversing Wheel *the*

Ref. No.

28 Links, *are placed in position for going ahead or astern, connecting the Wheel and the Links are the*

29 Reversing Quadrant,

30 Reversing Levers *and the*

31 Drag Links.

32 Reversing Bracket *for supporting spindle to which the wheel is attached.*

ACTION OF THE STEAM.

The steam on entering the cylinders, (6) and (10) acts on the

33 Pistons, *which are connected to the*

34 Crossheads, *by means of the*

35 Piston Rods. *The crossheads are kept in a vertical plane by the*

36 Guides. *By means of the*

37 Gudgeons, *the crossheads (34) are attached to the*

38 Connecting Rods, *and by means of the*

39 Crank Pins, *the connecting rods to the*

40 Cranks, *by which means the*

41 Crank Shaft *is rotated.*

THE ENGINE PUMPS.

All the pumps are driven direct from the Crossheads (34)

42 Air Pump Rods.

43 Feed Pump Rods.

44 Circulating Pump Rods.

45 Bilge Pump Rods.

The water is drawn from the Bilges into the

46 Bilge Pump Chest *and after passing through the*

47 Bilge Pump *is discharged overboard through the*

48 Bilge Discharge Pipe.

CYLINDER DETAIL GEAR.

Ref. No.

49 Starting Valves *are provided for admitting steam to either side of the pistons in order to start the engines, if the main valves (23) happen to cover steam ports. The steam for these valves is taken from the high pressure cylinder jacket (2) and enters the forward valve through the*

50 Branch. *The steam for the after valve passes through the*

51 Steam Pipe, *each of these valves is worked by hand from the*

52 Starting Valve Handles, *and through the*

53 & 54 Starting Valve Gear.

55 Drain Cocks *for letting condensed water out of the Cylinders, Steam Chests, &c. are worked through the*

56 to 59 Drain Cock Gear, *from the*

60 Drain Cock Handles.

The Throttle Valve (1) is for the purpose of shutting off the steam from the Cylinder, and is worked by hand from the

61 Throttle Valve Handle *and through the*

62 to 65 Throttle Valve Gear.

ENGINE AND CONDENSER DETAILS.

66 Jet Injection Valve *on the Exhaust Column (12) is in connection with the sea, and is for the purpose of admitting a spray of cold water through a perforated pipe into the column when it is desired to work "Jet Condenser."*

Ref. No.

67 Hotwell Over-flow Valve *for opening a communication between the Hotwell (15) and the Discharge Pipe, when working "Jet Condenser," or when there is an unusual quantity of water lifted by the Air Pump. (14)*

68 & 69 Handle and Cover *for the Hotwell Over-flow Valve.*

70 Main Bearings *for supporting the Crank Shaft (41)*

71 Keeps *for holding down brasses in Main Bearings.*

72 Keep Bolts.

73 Keeps *for Connecting Rods.*

74 Keep Bolts *do.* *do.*

75 Brasses *do.* *do.*

76 Feed Stop Valve *in the Feed Pump Chest for closing communication between Feed Pump (18) and the Hotwell. (15)*

77 Feed Pump Safety Valve (*in the Feed Pump Chest*) *through which the feed water would return in case of the feed valves on the boilers being closed when the feed pump is working.*

78 Condenser Tube Plate *into which the ends of the Condenser Tubes are fastened.*

79 Condenser Doors.

80 Bilge Injection Inlet *to Circulating Pump (21) for allowing this pump to draw water from the Bilges in case of necessity.*

81 Mudhole Doors *for cleaning condenser bottom.*

82 Guide Columns *or supporting the cylinders, and to which are fastened the guides (36)*

83 Crosshead Shoes *working between the guides.*

84 Safety Valves *for cylinders loaded by means of springs.*

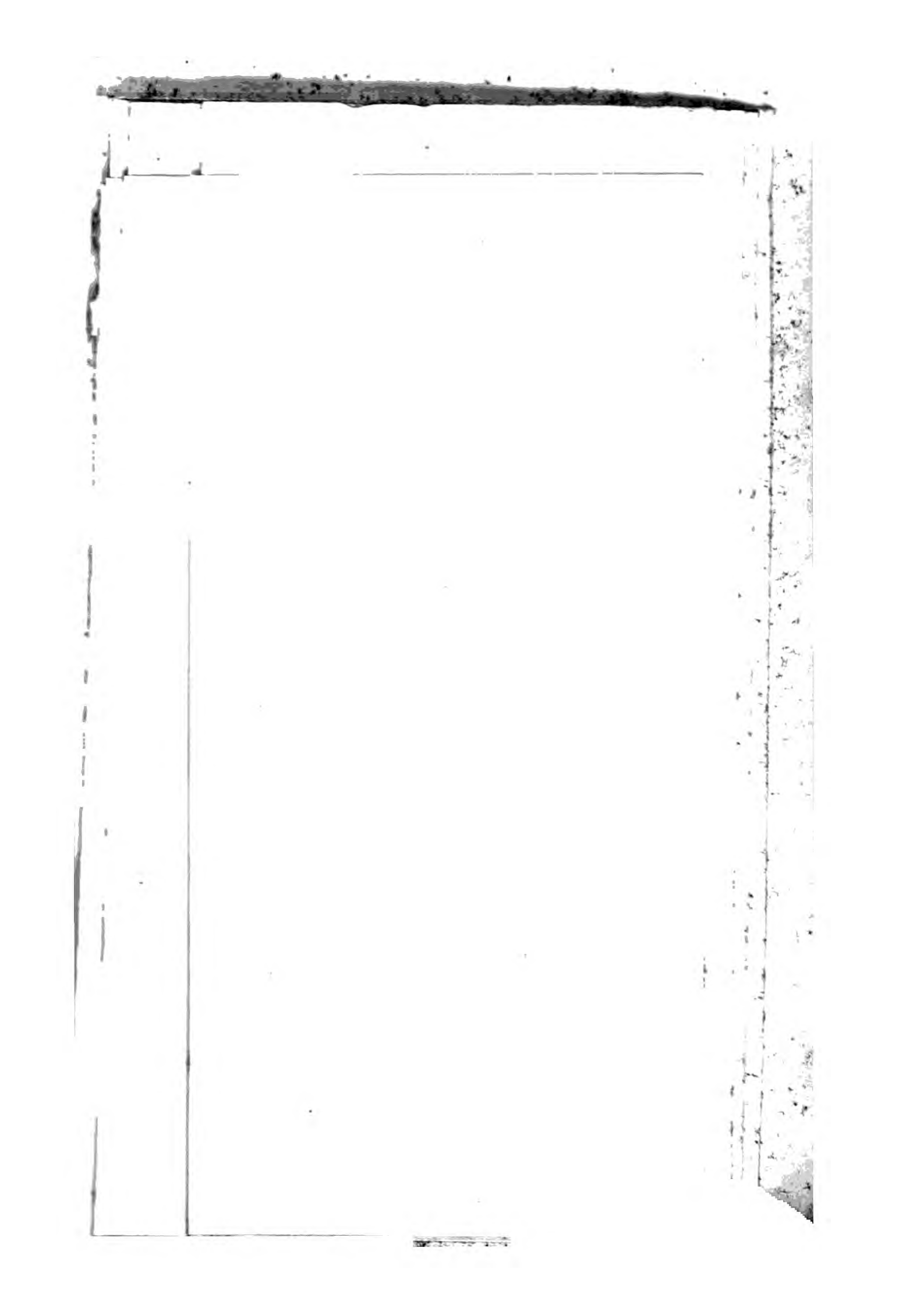
85 Piston Rod Glands *are pressed tightly by means of screws into*

86 Stuffing Boxes, *which are filled with packing to prevent the steam from escaping.*

INDEX TO LETTERS OF ST. PAUL

See in

- 2 Through Plain Red Glass, for the same purpose as those in the cylinder form.
- 3 Through Plain Red Glass, one thickness of the plain rods, and one carried through the
- 4 Cylinder Camera by means of the flexible
- 5 Wide Tube, filling three rows with fluid and pumping out the
- 6 Wide Tube Glasses are passed safely into them to prevent the same from escaping.
- 7 See Screws for adjusting glasses 2
- 8 See Screw for holding receiving apparatus in its required position.



Ref. No.

87 Through Piston Rod Glands, *for the same purpose as those on the cylinder bottom.*

88 Through Piston Rods *are a continuation of the piston rods, and are carried through the*

89 Cylinder Covers *by means of the glands.*

90 Slide Valve stuffing boxes *are also filled with packing. and the*

91 Slide Valve Glands *are pressed tightly into them to prevent the steam from escaping.*

92 Set Screws *for adjusting guides* (*36*)

93 Set Screw *for holding reversing quadrant in its required position.*

———:o:———

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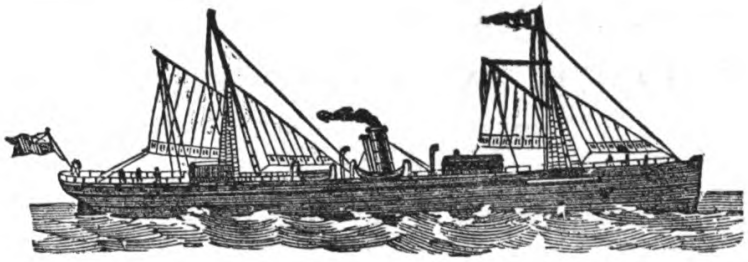

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(CONTINUED.)

The Proprietors wish to make known the many important advantages this Cement possesses over the Salammoniac Cement, at present generally in use.

It is well known that Salammoniac destroys Iron in any form very rapidly, and that a mixture of this with Iron Borings becomes a Cement *only* by corroding the part to which it is applied, thus producing a mass of *Iron Rust.* If a flange joint be put together with such Cement, it will be found that in a short time, particularly if any moisture be present the bolts connected with it have become injured, and will eventually be destroyed; nor does its injurious effects end here, the water leaking from the joint thus injured, or water merely dropping over the joint, and thence on to the other iron work, will corrode and destroy that also.

The Anti-Corrosive Cement has none of the faults complained of in Salammoniac Cement; instead of injuring the metal, it most completely defends it from corrosion. A joint may be made with this composition and subjected to immediate heat, and in three or four hours it will become nearly as hard as the metal itself; and as it neither expands nor contracts with the variations of temperature which steam joints have to undergo, it remains perfect, without injury to the bolts. Another quality which renders it superior to every other Cement is, that being immersed when just made it will harden under water, and when once hardened no art can soften it.

It has been used by Boiler Makers in the form of a thick paint laid over the joints in the inside of New Boilers, and will be found better than anything hitherto applied to prevent what are called blows or leaks.

Old Boilers have been kept in good working condition for many years, after having been pointed inside with this Cement, in cases where the greatest inconvenience would have been felt from their excessive leakiness; and even slight fractures have temporarily been stopped, where serious losses would have followed the total failure of a Boiler.

Directions for Mixing and Using Scott's Original Patent Anti-corrosive Iron Cement, also Vulcan, Scotch, Diamond and Holdfast Cements.

Take as much of the Cement as you want, and mix or beat it into a VERY STIFF Paste with BOILED LINSEED OIL, and it is fit for use. The smaller the quantity of OIL used the better, so long as you preserve the tough or adhesive state. For packing a joint where it has to be beat in, clip a quantity of hemp, about half an inch long, and mix it with the Cement: with this addition you will be able to caulk the joint in much less time.

S. & G. beg to aquaint their customers that they supply OIL expressly prepared for mixing their Cement with, and where it is convenient for persons to use this kind, they will find it possesses great advantages over ordinary Boiled Oil. THEY BEG TO CAUTION THEIR CUSTOMERS AGAINST BUYING MIXED OIL FOR THEIR CEMENT, AS THEY HAVE HAD COMPLAINTS AGAINST THE CEMENT NOT SETTING AS IT DID FORMERLY. When they came to test the Oil they found it to be very inferior in quality. The fault did not end here, as they found it contained rather more than one-fourth of common Paraffin Oil. This mixture will spoil the best Cement ever made.

N.B.—If mixed on a warm plate it will take less Oil, and harden sooner.

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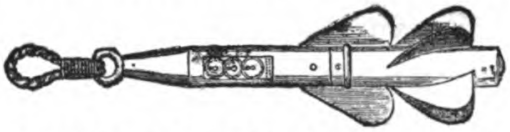
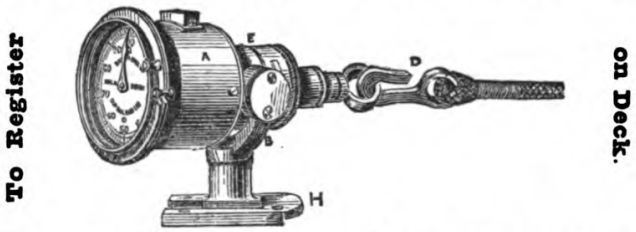


Walkers Patent A. 1. HARPOON Ship-Log is far superior to all other Patent Logs in use, being much more compact, less liable to get out of order, and from the fact of the principal cause of friction (the pressure on the front end of the Rotator) being removed, is the most accurate Log hitherto invented.

WALKER'S PATENT

TAFFRAIL SHIP-LOG.



The engraving represents the Registering Apparatus which is fixed on the taffrail of the vessel, the rotator being in the water, and attached by a long towline to the hook D. The case A contains a bell which rings constantly at short intervals, thus giving notice of the working of the Log, and indicating the "present speed" of the vessel; the total distance being recorded on the large dial. A spare rotator is sent with each Log.

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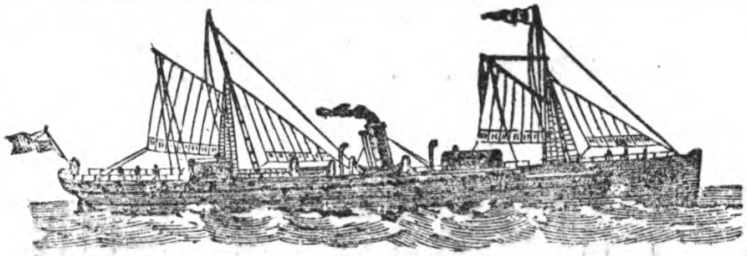

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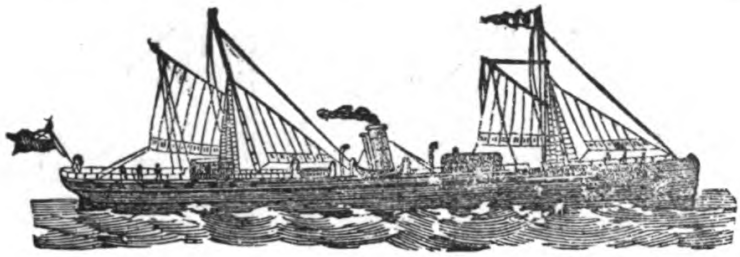

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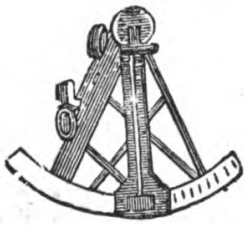

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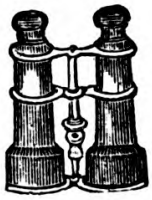

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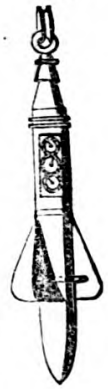

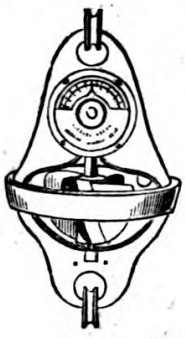

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The L's stand for the Seamen's motto, "Log, Lead, and Look out," and no Logs but those thus marked are Genuine.

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Award of the £100 Prize offered by the Editor of the "Nautical Magazine."

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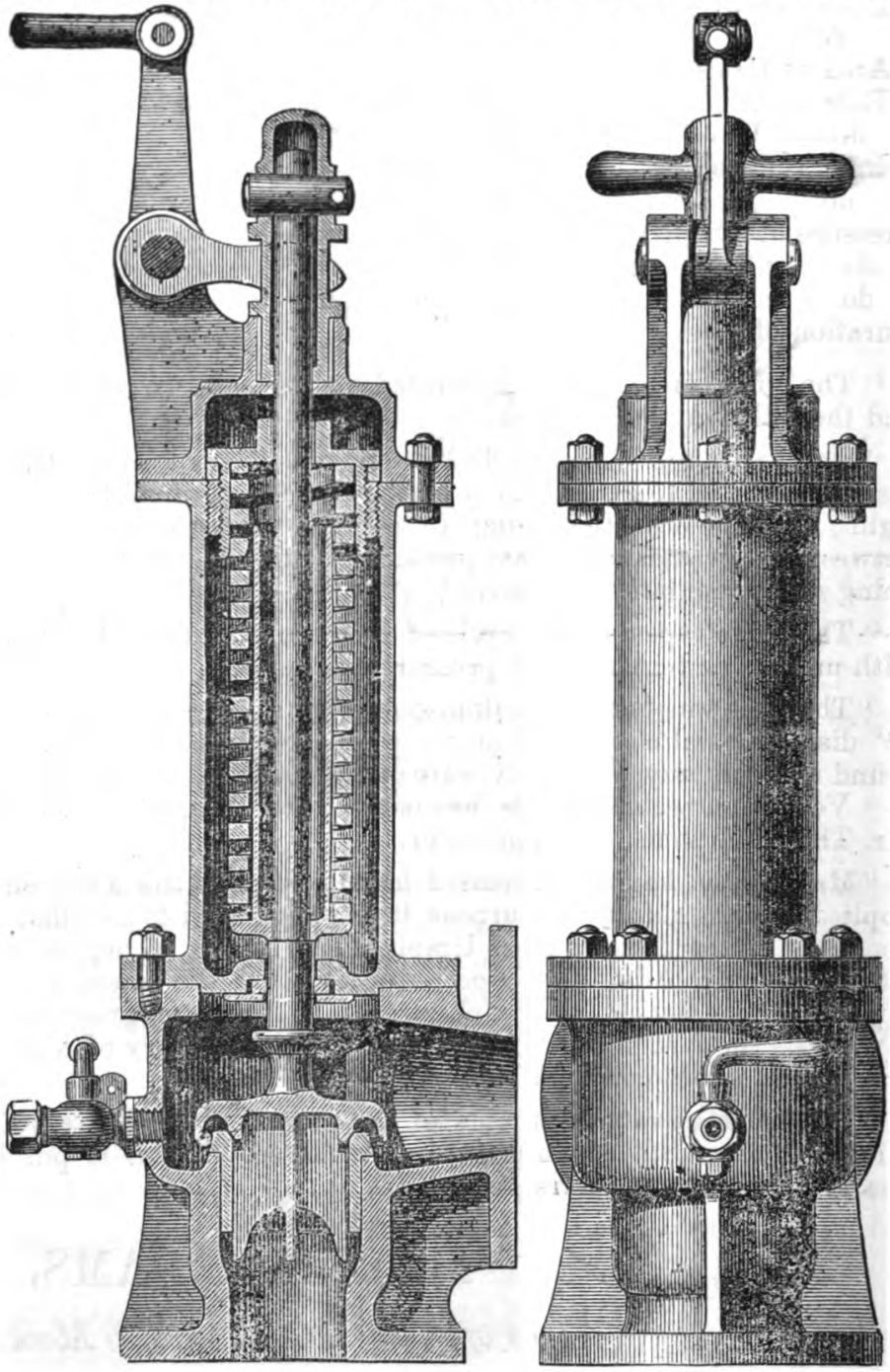

The following is an Extract from the NAUTICAL MAGAZINE, *of November, 1878:—*

"Eight Valves entered for the Editor's Prize of £100, and the drawing shows the valve 'Vena Contracta,' for which the prize has been awarded.

CONDITIONS OF THE TEST.

Diameter of Valve	3″
do. of Waste Pipe	3″
Area of Grate	14 sq. feet.
Rate of Combustion per sq. foot of grate per hour	20 lbs.
do. of Evaporation per lb. of coal	8¾ lbs.
Temperature of Feed Water (constant)	100° Fahrt.
do. of Waste Gas in smoke box	670° do.
Pressure at which Valve was loaded	60 lbs.
do. in Box above Valve while blowing	4 lbs.
do. in Waste Steam Pipe, 4 feet above	3 lbs.
Duration of Test	One hour.

"The whole of the steam generated had to pass through the valve, and the following is the result:—

"On the gauge showing 60 lbs. the valve went off. The gauge instantly started to go gradually back to 59·4 lbs., when the valve closed tight; the time occupied being 13 seconds, and the mean difference between the greatest and least pressures being ·6 of a pound. (There being no accumulation whatever.)

"The valve repeated this cycle of operations during the hour's test with unvarying regularity of pressure and time.

"The time was taken simultaneously by all the arbitrators from a 15″ diameter dial clock fixed on the wall, having a second hand moving round its periphery, and they were unanimous in awarding the prize to 'Vena Contracta,' which has since been claimed as the valve of Mr. Thomas Adams, of Manchester.

"Mr. Adams having expressed his desire that the £100 should be applied to some charitable purpose, it was suggested to him that the late Secretary of the Committee of Umpires had left three orphan children, whereupon Mr. Adams at once requested that the amount might be applied for the benefit of the children. It affords us great satisfaction thus to be the means of paying a tribute to the memory of a gentleman strictly honourable and hard-working.—Ed. *N. M.*"

N.B.—This valve was capable of beating all the other seven valves put together. Steam Shipowners should see that it is put in their specifications when ordering new ships or new boilers.

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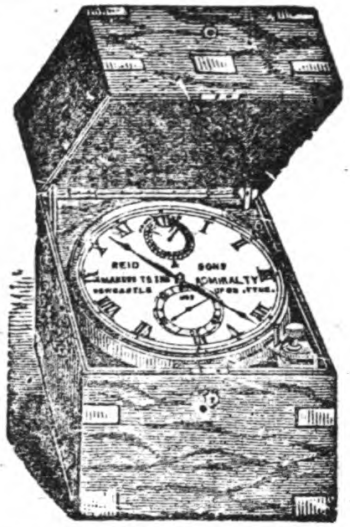

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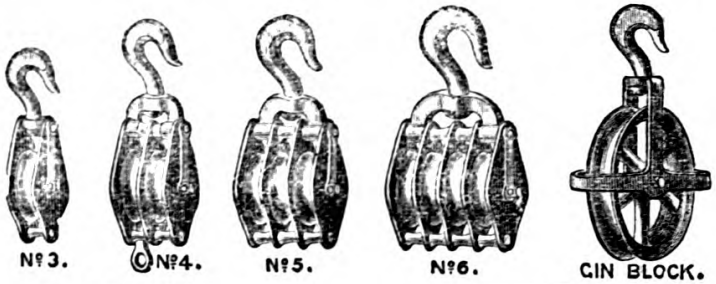

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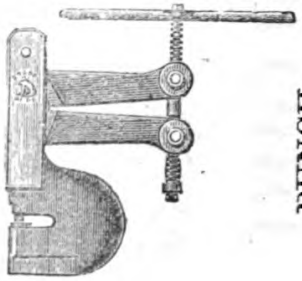

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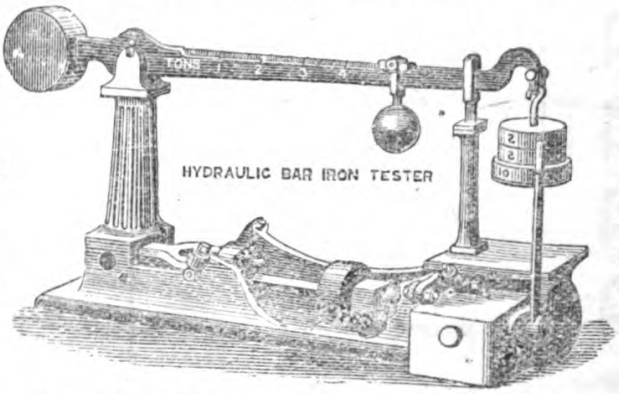

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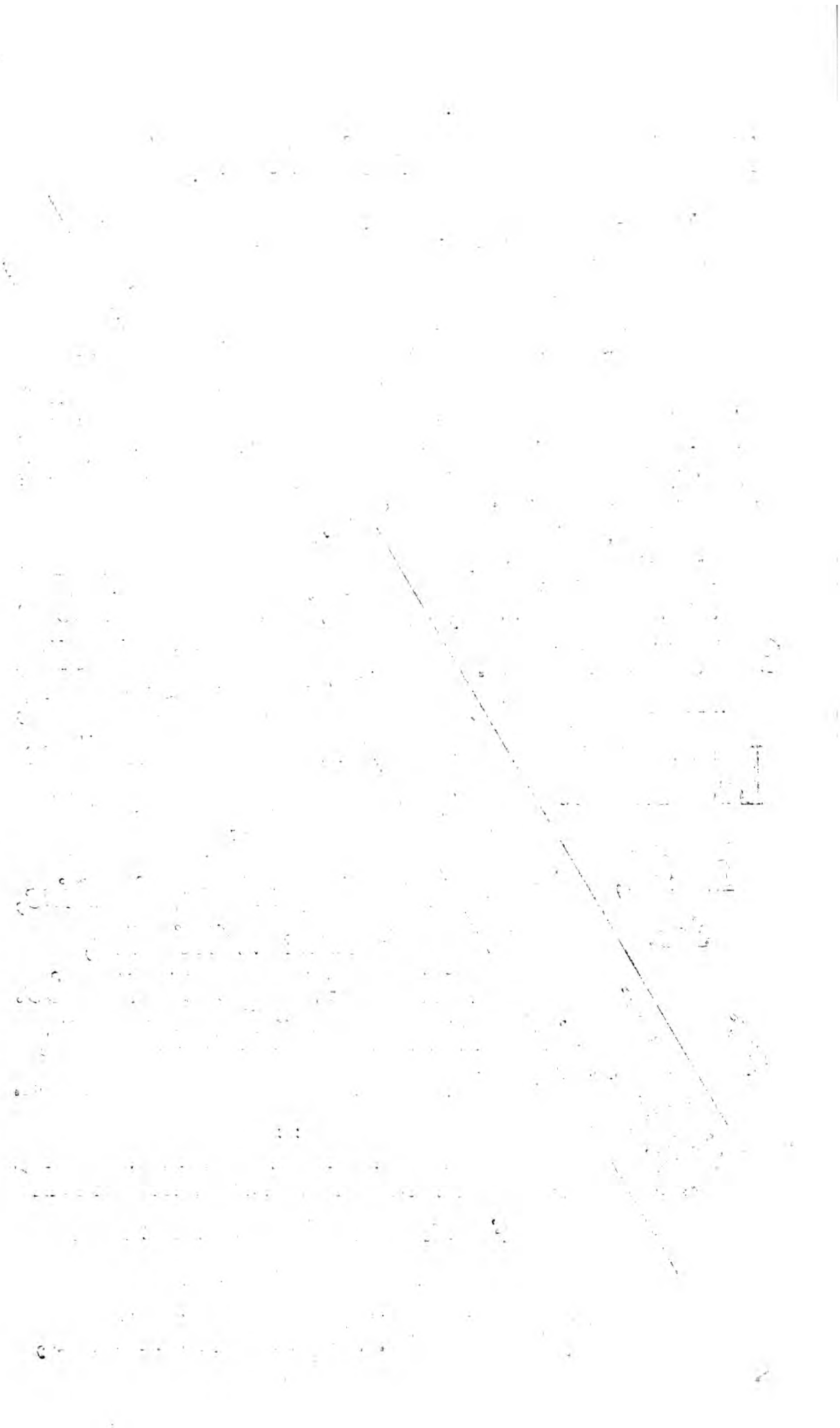

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