Practical Advice for Marine Engineers

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PRACTICAL ADVICE

FOR

MARINE ENGINEERS

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BY

CHARLES W. ROBERTS

AUTHOR OF
"DRAWING AND DESIGNING FOR MARINE ENGINEERS" ETC.

WITH NUMEROUS ILLUSTRATIONS

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PREFACE TO THE SECOND EDITION

It is very gratifying to find that the object of this treatise has, in a measure, been attained, and that the continued demand for the book is such as to necessitate a further edition. The original matter has been thoroughly revised and considerable additions have been made, although the scope of the work has not been extended, and it is trusted that the book in its present form will be welcomed, even by those who have found the former publication of service.

C. W. R.

London, 1907.

PREFACE TO THE FIRST EDITION

In producing this little book, it has been my object merely to place together a few practical hints regarding the management of marine engines and boilers, in the hope that such would be especially welcome to junior engineers who desire to grasp the general ideas which should govern the management of steamship machinery; and although an unpretentious little work, written by an ordinary "deep-sea" hand during his spare moments at sea, I trust it may also commend itself to other and older sea-going engineers as being not altogether devoid of merit.

C. W. R.

London, 1894.

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PRACTICAL ADVICE FOR MARINE ENGINEERS

CHAPTER I

THE ENGINEER

Introduction—His Social Position—First Joining a Steamer—Duties of the Engineer—Chief Engineer—Official Log-Book—Coaling—Second Engineer—Reporting Defects—Receiving Stores—Engaging Firemen—Entering Port—Third Engineer—Junior Engineers—Learning to Grease the Engines.

Introduction.—It is to be presumed that every engineer who is worthy of the name will endeavour to make himself master of the principles which rule the working of the engines, but the knowledge must be something more than a mere acquaintance with the theory of these principles. While not disparaging the value of theory in the slightest degree, it must be admitted that practice often proves theory to be at fault, and that practical experience alone is worth far more than a lot of theory without any experience. It is not sufficient to know that, according to rule, if a certain force were applied to some particular part of machinery, it would produce certain results; the more important consideration is, will it in practice act in the manner anticipated? This can very often be ascertained only by actual experiment, for an opposing force, which would materially modify the expected result, may have been inadvertently overlooked. Indeed, it requires considerable discrimination and experience on the part of an engineer to know when to refrain from using certain *formulæ* which might at first have been thought applicable to the question under consideration. Theory is, after all,—well, only theory, whereas actual results are stubborn facts which no amount of theory can gainsay. Facts remain the same but opinions differ, and we may all draw our own inferences from the facts we notice in our various experiences. Theory and practice should always agree, but the fact remains that they do not, and, when practice proves any theory to be incorrect, a new theory has to be formed in accordance with the discovery. If, therefore, before accepting any theory as correct, it were made a rule to test its veracity whenever possible, a feeling of confidence would be established, and pleasure would be experienced where previously nothing but fear was felt through ignorance and uncertainty.

Having then become perfectly familiar with the laws governing the forces which are brought into play about the engines and boilers, it becomes necessary to study how these forces may be utilised in the most economical manner, and how constrained to do their work so as to yield the very best results.

High pressure steam and triple-expansion engines, with all their necessary adjuncts, have practically superseded compound engines wrought at a comparatively low pressure; and the former type of engine is now being replaced by turbines driven at a high velocity, as a natural result of the limitations of speed which are imposed on reciprocating engines, which, together with the materials and appliances at disposal, present serious difficulties in the way of constructing such engines to develop the enormous power frequently required. Sea-going engineers have, therefore, a great deal more to look after than they had but a short time ago, and necessarily incur a greater responsibility; but, by making a study of his work, an engineer will gradually acquire an assured feeling of competency to cope with any difficulty which may arise, and every throb of the engines will be correctly interpreted, instead of being the frequent cause of vague terror or unnecessary apprehension.

His Social Position.—By how many of the general public is the social status of the marine engineer realised? By a very small percentage indeed of the community are his duties really understood, and many of the uninitiated consider (when they do happen to give the matter a thought, which may not be very often) that he is simply an unskilled workman, a mere engine-driver whose most salient characteristic is his greasy and dirty condition; one who has had some experience in looking after machinery and oiling it when required; and, possibly, whose duties are finished soon after his ship has arrived in port, his services not being again required until the ship is nearly ready for sailing! What a difference there is between the reality and such an idea, for the engineer requires to be an intelligent, well-educated man before he can become a worthy member of his profession, which is one of the most important of the present scientific age.

The modern marine engine is the gradual outcome of numerous observations made by men of experience, and several of the improvements connected with marine engineering are due, not to the theorist who stays at home, but to the man who is immediately associated with the practical element of the profession, who daily watches the engines as they throb along, noting the defects and weak points in their design under the different conditions of weather, etc., being thereby enabled to judge how they may best be remedied. To this class of men belongs the credit of having worked out many of the scientist's ideas, putting them into practical shape, and adding improvement to improvement until the marine engine has attained its present efficiency. What wonder then that the social position of the marine engineer is now gradually becoming better recognised, and his importance more fully established! Needless to add that it behoves all sea-going engineers to uphold the dignity of the profession to which they belong, and by so doing they will help to improve their position in society and merit the respect of all with whom they may have to deal.

First Joining a Steamer.—It often happens that, on being sent to join a fresh steamer, one finds that all the work below has been finished, and everything closed up again in readiness to commence another voyage. If this be the case, such a detailed examination of the engines and boilers as one would desire to make is rendered impracticable; but no time should be lost in tracing the pipe connections and making one's self thoroughly acquainted with the various cocks and valves and the purpose for which they are placed there. The arrangement of bilge connections deserves special study until one has become perfectly familiar with it; and the first time that the boilers can be opened up they will require a particular and minute examination as to the condition of the plates, if pitted at all and where attacked most, their probable thickness, and if worn thin at any particular place, also the state of the combustion-chambers, tube ends, stays, etc. The condition of the cylinders, valves, shaft bearings, pumps, and all working surfaces should be ascertained on the first opportunity for doing so presenting itself. The bunkers too should not be overlooked, and, whenever empty, the condition of the plates, frames, stringers, and beams noticed, for they will corrode away very rapidly if not attended to properly, especially if a practice be made of putting in coal when it is in a damp condition.

In short, everything in the engineers' department should be most carefully looked over, and any deterioration that may occur from time to time should be carefully remarked, and all possible precautions taken to prevent its continuance.

Duties of the Engineer.—The scene in the engine-room of a steamer built, say, twenty years ago, would have a very different appearance to that presented in the engine-room of one of our larger modern passenger steamers, containing its powerful turbines or triple expansion-engines, its electric lighting plant, its distilling apparatus, its centrifugal fans for ventilating the ship and forcing the draught in the furnaces, its refrigerating aud hydraulic machinery, together with the complicated arrangement of piping and other accessories pertaining to the numerous inventions for contributing to the comfort of passengers, or economy of fuel.

Were it possible to effect a saving in the consumption of coal or stores by the use of various economic devices to the extent claimed by their inventors, the engines might almost be run at a profit and not require to be oiled at all! Such a happy state of affairs is, of course, impossible, though the consumption per indicated horse-power has been greatly reduced within the last few years. When endeavouring to arrive at a rough estimate of the economical performance of the machinery, it must be borne in mind that the engineer himself resolves into x, the unknown factor in the problem, whose value, unfortunately, does not remain constant but varies in each individual case; and, in order that these various inventions may get proper justice, it is absolutely necessary that they be treated in a proper manner and thoroughly understood by the men who are appointed to look after them. Then again, it is no use having all these appliances for effecting economy if the coal is to be wasted by unskilful firing, and it must be remembered that it requires considerable skill to burn the fuel in such a manner as to produce the best results from its combustion. In order that there may be no retrograde tendency, a marine engineer must look to the improvement of himself as well as his engines; he must be something more than a mere engine-driver, and, if he wishes to keep pace with the times, he must be a highly-trained expert, whose knowledge can only be obtained by close application to work and careful study. It is quite possible to be all this without any tendency to "snobbishness"; and, while preserving a certain amount of *amour* *propre*, an engineer should not be too big for his job, but, if thought necessary, should lend a hand to put in a fire-bar, or help to clear a choked rose-box, etc. Many an engineer cherishes the erroneous idea that such actions on his part would be accompanied by a corresponding loss of dignity and diminution of authority over those placed under his supervision.

A man can only gain the respect of those about him by first respecting himself, and, if he faithfully does his work and carries out the instructions of those placed in authority over him, his worth—if he has any—will soon be recognised, and in due time he will be promoted to a higher position if he merits it. There is scarcely anything so unbecoming as to hear a young engineer continually giving vent to his feelings by such expressions as—" It is not *my* work to do this "; " Why doesn't the second do that himself? He's not doing much "; " One of the firemen might have been sent to do this job," etc. Junior engineers are not sent to a ship to do just as they please: they may have their own opinions, and good ones too perhaps, but it is their duty to do as they are told without murmuring, and in the ordinary course they may eventually attain a position in which they can carry out their own ideas. Authority *must* be maintained in the engine-room, and, if each engineer conscientiously carries out the orders given to him by those who are placed over him, it will preserve harmony instead of leading to continual discord and strife. In this way the third and junior engineers will help the second by enabling him to feel that he can always depend on his men, without continually having to run after them to see if they are doing as they were told; and in like manner the second will relieve the chief of much anxiety by giving due attention to his duties, for the chief engineer will then feel that he has a worthy right-hand man who will endeavour to carry out his suggestions and wishes, and see that order and regularity are maintained in all matters relating to the engine-room and its staff.

"Different ships, different long splices," and in each engine-room a different arrangement of the work may be found according to the particular ideas of those placed in charge of the machinery for the time, there being no very clearly defined or absolute rule regarding the several duties of the engineers in their different capacities. Nevertheless there seems to be a certain amount of uniformity, and the duties which fall to the lot of each engineer seem to run in very similar grooves in the majority of cases.

Chief Engineer.—The chief engineer is in all cases held responsible for the working of all the machinery on board his ship, whether on deck or in the engine-room, and this should be clearly understood and acted upon.

When three engineers are carried, which is very seldom the case in a coasting or cross-channel steamer with a short run, the chief will not require to keep watch, the second and third keeping watch-and-watch for the short time that the vessel is under way; but, if there be only two engineers, the chief will, of course, have to keep watch, and ought also to do his share of work when overhauling the machinery.

In boats of the usual "tramp" class, carrying only three engineers, the chief will also require to keep his own, or eight to twelve, watch in the engine-room when at sea.

As most ocean-going steamers of any size now carry at least four engineers, the chief engineer is not in such cases called upon to keep watch, and he has therefore more time to devote to writing up the official log-book, taking and working out indicator cards, etc.

The official log-book should be written up daily from the rough engine-room log-book or slate—which is written up regularly at eight bells by the engineer going off watch—inserting every particular connected with the working of the machinery and boilers, as well as every incident worthy of note. An abstract of this official log is usually made up, mentioning the various averages of the engines' speed between the different ports, percentage of slip, total consumption of coals and stores for the voyage, quantity remaining, etc. etc., and this is sent in to the superintending engineer, or company's agents, at stated intervals, or at the termination of the voyage, as may be arranged, together with the machinery condition report. Prior to the ship's arrival at headquarters, all existing defects about the boilers and machinery, which cannot be repaired at sea, should be carefully described in that report, and all the requirements for remedying them inserted in the same.

When the ship has arrived at a coaling port, the chief engineer should adopt every measure in his power to accelerate the receipt of the coal, previously assuring himself of the quantity remaining on board, and, as far as practicable, check the weight of coal received before granting a receipt for it, which may be done by weighing a portion and forming an average where circumstances do not allow of the whole quantity being weighed. In such ports as Naples, Malta, Port Said, etc., where the coal is stacked up pretty evenly in barges, a better idea of the amount received can be formed by measurement than by tallying the number of baskets, for they will sometimes vary in weight to a considerable extent, while rough averages are often very deceptive. Some coal agents are perfectly willing to accept receipts made out according to the bunker space, as measured before and after coaling, but in such cases the trimmers have to be very carefully watched while they stow the coal, or they may leave some big holes unfilled which will seriously mislead as to the amount supposed to have been taken on board.

According to present-day etiquette the captain is regarded as the head of the ship's company, and he alone. It would be absurd, therefore, for any chief engineer to entertain the idea that his position is, or ought to be, superior to that of the captain. Each is at the head of his own special department, and merits respect accordingly. The one should defer to the wishes of the other as far as possible, so long as they are reasonable; but, while the chief engineer should treat the captain with all the courtesy which his position demands, he should firmly oppose all undue interference on the part of the captain with his own particular department. Larger and larger ships are continually being launched, having little or no sail power, but a mass of complicated machinery, and the chief engineer of such a ship occupies a very responsible and important position. In the future it is quite possible that *he* may be the man described as being "in command"; but meantime it behoves every member of a ship's company to content himself, and honourably fulfil the various duties which his own rank demands, without seeking to detract from the honour due to those who may occupy some higher position.

One occasionally meets with a chief engineer who hardly ever speaks to his juniors except regarding their work, with which he never seems satisfied. Apparently the idea is that, were he to unbend from his lofty position and condescend to make himself a little agreeable to those placed under him, he would lose his authority over them; but this is altogether a wrong sentiment, for a man may make himself pleasant to another without being too familiar, and the respect for such a man would increase, not diminish.

Second Engineer.—Though the chief engineer is at the head of the engine-room department, his position is often of rather an honorary nature, the real onus of the responsibility falling on the shoulders of the hard-working second, who, besides keeping his own four to eight watch, and perhaps repairing the after winches when at sea, is expected to account for all the stores that are used, give out the work to the different members of the engine-room crew, choose the firemen and preserve discipline amongst them, watch the stowing when coaling, superintend the cleaning of the boilers and see them properly closed up, see that the engines, engine-room, and stokehold are kept clean, besides doing his own work on the top platform, overhauling the pistons, valves, etc., when in port. Then, if anything goes wrong, of course the second engineer comes in for most of the blame. His position in the ship is often a most thankless one, for on the one hand he may have the chief continually "nagging" at him—"When are you going to do this?"

"Why don't you do that the other way?" etc.; and on the other hand he may, when endeavouring to carry out the chief's wishes, cause discontent and grumbling amongst the other engineers, who think they are being imposed upon when they are told to do certain jobs. The work must be done somehow, the disagreeable as well as the pleasant, and somebody has to do the former as well as the latter. There may be an occasional second engineer, however, who, cherishing some petty spite, will show the smallness of his mind by taking advantage of his authority to order one of his subordinates to do very disagreeable work which really does not require to be done at the time. Whatever position a man may hold on board ship, he should never order another man to do anything not absolutely necessary, or which he himself, if in a similar position, would have just reason for objecting to do.

When the chief engineer does not keep his own watch, he cannot be expected to find out all the various little defects about the engines which would be observed by one keeping watch, and, when he comes down below for his daily survey in the second engineer's watch, the second should report every irregularity and everything worthy of note, so that it can be decided what work has to be done when the next port is reached.

The second, if he be fit for his job, should not require to be dictated to by the chief engineer, but should anticipate his wishes as much as possible with reference to the repairs to be done to the machinery; and, prior to arriving at headquarters, he should make out a list of the work that he considers necessary to be done and submit it for the chief's approval, so that it can be decided if any extra hands will require to be taken on, and, if so, how many.

A list of the remaining stores, such as oil, paint, turpentine, lamp-wick, packing, waste, soap, bathbrick, etc., should also be made out, together with the quantity required for the ensuing voyage, to enable the chief to write out his indent, and send it ashore with his other papers to the superintending engineer on the ship's arrival.

When the new stores come down to the ship, before signing for them they should be checked over to see that the articles sent are those indented for, and, if not, they should, of course, be sent back unless the reason for the difference be satisfactorily explained,

When choosing a new staff of men, a second engineer is usually quite unable to discriminate between the good, bad, and indifferent, for the men may be quite unknown to him, and the only guides that he has to go by are the discharges, which are frequently little better than frauds, as every one who has had any experience in selecting men knows to his sorrow, for the incompetency of the chosen few may only be found out by painful experience after sailing. Under the old system there was nothing to prevent a man producing, as his own, a discharge belonging to some other man; and, in the event of gaining a bad discharge, all he had to do was to destroy it and fall back on some previously obtained good discharges. With the present arrangement of continuous discharges, however, the risk of being imposed upon is considerably reduced, although the danger is not altogether eliminated.

If the firemen cannot be retained when in port, it will necessitate taking on a few casual hands for cleaning up and rendering assistance at the overhauling of the engines. These men will probably be strange to the ship, and a lot of the second engineer's time will be taken up in instructing them how to do this, where to put that, etc., and half a dozen such men are sometimes not worth one handy fireman who has been accustomed to the work in that particular ship, and knows exactly what is wanted. It is questionable economy to discharge the firemen at the end of the voyage, unless the ship is going to be laid up for a considerable time, but shipowners have not always realised this.

When entering or leaving port, and in such places as the Suez Canal, it is always advisable to have another engineer in the engine-room beside the one on watch, to stand-by and render any assistance required; and then in case of the ship going ashore, or any other mishap occurring, there will always be corroborative evidence regarding the working of the engines. Then again, one engineer might inadvertently put the engines astern instead of ahead, but the mistake would probably be noticed by the other and rectified immediately. During the daytime the second engineer will stand-by in either the third or fourth engineer's watch, but after eight o'clock at night he ought to be free to obtain his well-earned rest, and the chief should then render any assistance required when working the engines. In the second's watch the third engineer may be called upon to stand-by up to six o'clock, and the fourth engineer any time after that.

Third Engineer.—In a large steamer carrying only four engineers, the chief will not do much as far as the actual work is concerned, so that there are really only three engineers available for carrying on the work, and, besides keeping his own twelve to four watch, the third engineer will require to do his own share of the deck work when at sea.

There are several things which go to make the life of the third not altogether a happy one. In the first place, it is his unenviable duty to get up in the middle of the night in order to keep the middle watch. Having spent a tiresome time in attending, perhaps, to some pump that has been giving trouble, or in "nursing" a hot bearing, he will come off watch at four o'clock, and, after a refreshing wash, will turn in. He may have just fallen asleep when, possibly, he is wakened by the noise made by the deck hands while washing down. This disturbance having subsided a little, he may be dozing off again when he is again roused by the chattering and noise made by the men getting their water from "chips"; for frequently the fresh-water pump is not very far distant from the cabin of the third and fourth engineers, and, as it is seldom kept in a very excellent state of repair, it is not altogether a silent-working piece of machinery. At last he may be able to snatch an hour or two's sleep before breakfast. After breakfast perhaps he will have to turn-to and overhaul or repack the winches at the main hatch. Time is spent running for tools and getting everything ready, and very little work can be done before twelve o'clock, when he has to go below again and keep the hottest watch during the day. At last four o'clock comes round, and he will be able to get into some clean clothes and feel free for a few hours—unless the ship be arriving at some port, when his presence in the engine-room may again be required to stand-by and render the second any assistance that he may require while working the engines.

Amongst other things, the work of the third engineer in port will comprise the overhauling and adjustment of the crank and crosshead bearings, the eccentrics and valve gear, the main bearing, thrust and tunnel blocks; and, when the propeller shaft has to be examined, he will usually require to remain in the tunnel in order to draw in the shaft, while the second engineer is outside taking off the propeller nut, seeing the propeller slung, etc.

Junior Engineers.—One of the first duties of a young engineer going to sea for the first time is to learn how to grease the engines properly, even though greasers be carried. No one should be left in entire charge of a watch until he can do this. On the first attempt to oil the cranks and crossheads he will probably put more oil in the crank-pits than in the cups, so that it is advisable to practise, by going round the engine with an empty oil-feeder, until one has become familiar with the manner of holding the feeder, giving it the required motion from the wrist, rather than from the elbow, as is the usual inclination to do at first. When able to properly grease an engine without any undue waste of oil, an engineer is competent to instruct and direct any new greaser who may be strange at the job or unfamiliar with the engines.

In the smaller class of boats carrying only two engineers, a donkey-man, and three or four firemen, the engineers are quite able to do all their own greasing unassisted; but in ships having engines of, say, 1000 I.H.P., and carrying no greasers, the engineer on watch has plenty to do even in fine weather, and in bad weather, with perhaps a heavy beam sea running, he must have all his wits about him while holding on to the hand-rail with one hand and using the feeder with the other, running round to the back of the engines to look after the pumps, into the stokehold to look at the water in the boilers and regulate the feed, etc. Whereas if regular greasers were employed less oil would be used, and the engineer would be able to devote more of his time to the numerous things demanding his attention.

In large ships, with engines of 2000 I.H.P. or so, it becomes absolutely necessary to carry greasers; not because it is lowering to the dignity of an engineer to go about with an oil-can, but because his superior knowledge is required to be exercised in the management of many important things both in the engine-room and stokehold. For instance, the brushes of the dynamo may start sparking, and while resetting them the Weir's feed-pumps may commence to kick, and the engineer has to run up the engine-room ladder and readjust the feed-heater; then the evaporator may require blowing down next, or the refrigerating engine may require some attention, or else some part of the machinery may start to grunt and he may be called away to look after that.

There is one thing which every engineer in charge of a watch should be able to do, and that is to handle the main engines with perfect freedom; and it is desirable that the second engineer should instruct, on this point, any junior engineer who may have just come to sea, and, when coming into or leaving port, should let him take charge of the levers and tell him what to do, until he can get into the way of working them. Even when well out at sea, the man on watch does not know the moment that the telegraph may ring and the engines require to be stopped and reversed, and that smartly, and, if unused to working the engines, he may become flurried on such an occasion, lose his head and forget what to do first, and serious results may follow.

If, during his watch, a bearing should get hot, or anything else happen about which he does not feel very sure how to act, a junior should send up at once for the chief or second engineer, so as to relieve himself of the responsibility and get their greater experience to bear on the question.

When only four engineers are carried, the fourth engineer, besides keeping the eight to twelve watch at sea, usually comes in for a large share of the deck work, being appointed when necessary to overhaul the windlass, fore winches, donkey-boiler mountings, and feed-donkey.

The more dirty work in the stokehold also falls to his lot when in port, such as grinding up the safety-, steam stop-, and feed check-valves, attending to some other of the boiler fittings that may require repair, or his services may even be required in tallying coal. In the engine-room he usually gets the pumps to overhaul and repack, the pump links to strip, and perhaps the piston-rod and valve-spindle stuffing-boxes to repack.

If a fifth engineer be carried, he will, of course, do all the deck work, and thus, in the ordinary course of events, the second, third, and fourth engineers will merely require to keep watch when at sea. If hydraulic machinery be fitted in the ship, the fifth will be available for overhauling the hydraulic engine, packing the accumulator piston or any of the stuffing-boxes of the rams, etc. He may also go round periodically to ease and try the main steam stop-valves, and water-gauge cocks, etc., put in a new gauge glass, or do anything else as the second engineer may direct.

When a refrigerator is fitted, there is usually a sixth engineer to help with that. In boats having engines of over 4000 I.H.P. or so, a boiler-maker is frequently carried; and in these larger boats it is usual to have two men in charge of each watch, the boiler-maker keeping watch with the second engineer, the sixth with the third engineer, and the fifth with the fourth engineer.

CHAPTER II

IN THE STOKEHOLD

The Main Boilers—Corrugated Furnaces—Forced Draught—Collapsed Furnaces—Cracked Furnaces—Corrosion, Pitting, etc.—Zinc in the Boiler—Leakage of Seams at Bottom of Boiler—Ballast Tank under Boiler—Broken Combustion-Chamber Stays—Scaling the Boiler—Closing up the Boiler—Jointing Manhole Doors—Filling the Boiler—Laying the Fires—Lighting the Fires—Raising Steam—Weir's Hydrokineter—Combustion, Firing, etc.—Cleaning Fires—Sweeping Tubes—Boiler Lagging—Brining—Leaky Tubes—Stopping a Split Tube at Sea—Putting in a Furnace-Bar—Bridges—Water-Gauges—Putting in a Gauge Glass—Regulating the Feed—Broken Check-Valve—Safety-Valves—Opening up the Boiler—Precautions before Entering the Boiler—Coal in the Bunkers.

The Main Boilers. — Steam is merely a convenient medium by which heat, as a prime mover, is transmitted to the engines and constrained to do useful work. The boilers, being the generators of this medium, naturally claim first consideration, and to them attention must be turned in order to discover the principal source of waste.

It is well known that boilers which are so constructed as to have a large margin of surplus power last longer, are more easily kept in good order, and give less trouble than those which are usually kept working up to their full power. This is, however, a matter which those who are placed in charge of a set of engines and boilers cannot alter. One must, therefore, direct attention to those things which are under immediate control, and, in order to obtain the most economical results, an endeavour must be made to obtain the greatest number of thermal units out of the fuel, to heat the water with the least loss of any of these units, and, having converted the water into steam, to maintain its temperature until it has completed its work.

While one improvement in connection with the marine engine has followed another with rapid strides, the general design of the marine boiler has remained unaltered for years, and even now is very far from being perfect, for the boiler of the present day does not evaporate anything like the quantity of water that it should for a given amount of fuel, and its general form being unsuited for promoting a regular circulation of the water it contains, the plates are necessarily subjected to very severe strains through the unequal expansion caused by local variations of temperature.

Water-tube boilers have not been an unqualified success in the mercantile marine service, and the only real advance that has been made in boiler construction, for several years, has been in the extensive, and now almost exclusive, use of steel having a comparatively high tensile strength. This, of course, gives a far lighter boiler for the same power than if made of iron, the plates not requiring to be so heavy; and the furnace plates being thinner, there is consequently less heat wasted in its transmission through them from the fire on the one side to the water on the other. At first there was a deal of uncertainty felt, if not always expressed, regarding the use of steel for anything but the shell, which did not require to be flanged; but now that steel can be obtained of a more homogeneous character than formerly, and can therefore be more relied upon, this consideration, along with the experience gained by past failures through fault of treatment, has caused it to almost entirely disappear. The use of hydraulic flanging presses contributes not a little towards establishing a feeling of confidence in steel, for there is no doubt that a steel plate when flanged by hand is rendered "short," and liable to crack ultimately, by the repeated heating and hammering to which it is subjected during the process, even though it be afterwards annealed.

It has been found advisable to limit the thickness of furnace plates to about $\frac{3}{4}$ inch; but this is greater than is desirable, for the thicker they are the greater their liability to sag by becoming overheated on the fire side, the difference between the temperate on the fire side and that on the water side being, with thick plates, something enormous. The late Dr. Kirk found by experiment that on boiling water at atmospheric pressure over a clean plate 1 inch thick, the temperature on the fire side exceeded that on the water side by 294° Fahr., while with a $\frac{1}{2}$ inch plate the difference was only 88° Fahr.

In order to avoid the necessity of either increasing the thickness of the plates, making the furnaces of an inconveniently small diameter, or fitting them with stiffening rings, corrugated steel furnaces were introduced by the late Mr. Samson Fox, in 1877, to meet the demand for greater strength to withstand the increased boiler pressure, and they have now become almost a distinctive feature of the modern type of marine boiler.

With a view to overcoming certain objections to the original form of corrugated furnace, others have since been designed, amongst which are the Morison Suspension (Fig. 1) and Deighton corrugated types, the Purves ribbed and grooved type, and Brown's cambered type, which is very similar to that of Morison.

Anticipations as to the additional advantages of the suspension section over those of the original corrugated furnace have been fully realised, and, since 1890, when the Leeds Forge Company commenced the manufacture of Morison's furnace, it has been one of the most

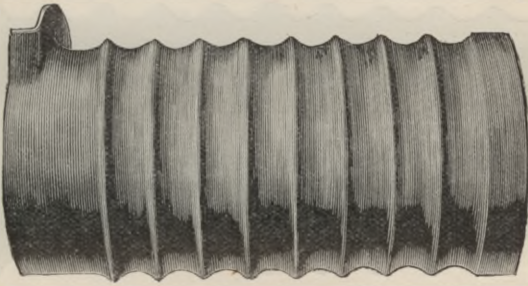

FIG. 1.—Morison's Suspension Furnace.

favoured by engineers, owing to its superior ability to retain its original circular form when at work. This is probably due to the uniform stiffening effect of the ridges, which gives a little less elasticity, and therefore corrects to some extent any disposition to sag under severe conditions of work.

The latest development of this class of furnace is that known as the "Leeds Forge Company's Suspension Bulb Furnace" (Fig. 2), which not only embodies the suspension principle, but, by a special process of manufacture, it has a greater uniformity of section, and a girder or supporting corrugation which is deeper, and which, by a particular disposition of the material, gives greater strength than has ever before been obtained.

Forced Draught.—Amongst other recent improvements in working marine boilers must be mentioned the system of using forced draught, which has now been quite extensively adopted in ships belonging to the merchant service. It was thought at first

FIG. 2.—Leeds Forge Company's Suspension Bulb Furnace.

that the only benefit to be derived from forcing the draught in the furnaces would be in the reduction in the weight of the boilers, because they would not require to be so capacious in order to do the same work as those working under natural draught, and this would also admit of reducing the size of the stokehold, and leaving more space in the ship available for cargo. It is now found that there is, besides, an actual economy in fuel under this system; if, however, the capacity of the boilers be unduly reduced, owing to the higher rate of combustion, the additional wear and tear will seriously affect the longevity of the boilers, and trouble may be experienced by the furnace crowns collapsing or cracking. Under these circumstances the economy in the fuel may not compensate for the increase in the cost of maintenance. This has been fully recognised by some superintending engineers, who specify for boilers of nearly the same size for forced draught as would be required were they to be worked under natural conditions.

Forced draught is especially appreciated in the tropics, where a steady speed of engines may often be maintained in vessels in which this would otherwise be impossible, owing to the heat of the atmosphere, and, possibly, inferior coal.

Some idea of the economy of forced draught may be gathered from the performances of the *Vadala* and *Virawa*, two steamers built by Messrs. W. Denny & Brothers, Dumbarton, for the British India Steam Navigation Company. These steamers were alike in every particular of hull and machinery, with the exception of the boilers, the *Vadala* having two double-ended natural draught boilers, with eight furnaces 3 feet 7 inches internal diameter, while the *Virawa* had two single-ended boilers with Howden's forced draught, having four furnaces 3 feet 6 inches internal diameter. During the first two years that these steamers were working in the eastern seas, they were carefully tried by the company in order to ascertain the difference in consumption and otherwise. Every precaution was taken to arrive at a correct comparison, by changing the engineers from the one ship to the other, etc., to eliminate any chance of error from better management in one ship than in the other. The results showed that, besides other advantages of forced draught, the *Virawa* performed the same work as the *Vadala* on 15 per cent. less fuel. The coal used was to a large extent Bengal coal. This comparison, it will be noticed, is giving the natural draught every advantage in large boiler power, as the *Vadala* had eight 3 feet 7 inches furnaces against the *Virawa's* four 3 feet 6 inches. In addition to the saving in fuel, the *Virawa* has also shown the maintenance of a considerably higher average speed. Probably in no case has there been so much care taken to arrive at a fair comparison as in these trials, so that they may be accepted as in every way correct and in no way prejudiced by personal interest.

Collapsed Furnaces. — The collapse of furnace crowns is due to the overheating of the metal, which may be caused by shortness of water, a deposit of scale or salt, the presence of oil brought into the boiler with the feed-water, careless patching, or the intensity of the draught.

When the deformation is comparatively slight, a collapsed furnace can usually be restored to its original circularity by pressing it outwards where required by means of a jack. For this purpose a cast-iron block may be made to fit into one or two of the corrugations for the head of the jack to act upon, and the jack placed in position on a block of hard wood cut out to the requisite form on the under side. If the bearing surface of the latter block be insufficient to prevent the distortion of the furnace bottom, it will be necessary to shore or pack up the furnace from the inside of the boiler. The plate should be treated as evenly as possible over the whole of the damaged part, thrusting it outwards a little at a time, and frequently altering the position of the jack. It is undesirable that the plate should be heated before the operation more than would be sufficient to take the chill off it, owing to the impracticability of annealing the furnace afterwards.

Having brought the furnace to the desired form, gauges should be made and fitted as required to enable it to be seen at any future time whether the furnace retains it shape. Furnace crowns which have been set up are liable to give trouble by coming down again after being at work, and the gauges should be frequently applied, as opportunity occurs, in order to see if there be any tendency in this respect.

Should a furnace crown be so seriously damaged by collapsing as to preclude the possibility of jacking it up, the furnace will require to be taken out and a new one put in; and, in order to admit of their withdrawal from the boiler and to facilitate their renewal, furnaces are now usually made with coned back ends, as shown in Fig. 2.

Cracked Furnaces.—Furnace cracks are usually attributable to an accumulation of scale, or to the plate becoming suddenly chilled. Corrugated furnaces are specially subject to these defects, as the stresses produced by their expansion and contraction are frequently localised in the hollows or ridges.

A very common way of repair is by fitting a series of small interlocking screwed plugs along the crack, the holes for the terminal plugs being bored clear of the crack, in the solid metal. This method is not, however, satisfactory if the crack be at all extensive, or situated where the plate is subjected to the direct heat from the fire, and serious accidents have occurred from the plugs being blown out, owing to their corrosion or the working of the plate. Moreover, it does not reduce the weakness of the plate caused by the defect, and it is far preferable to rivet a thin patch over the crack, having previously carefully fitted it in place.

Corrosion, Pitting, etc.—If two dissimilar metals, or even two pieces of the same metal if it be not of a homogeneous nature, be placed in a liquid and in metallic contact, an electric current will be set up at the expense of the metal forming the positive pole of the couple, which will gradually waste away. A familiar example of this may often be noticed at the bottom of iron railings, where they have been set into the stone-work forming the base by pouring lead round the hole. The iron, having been subjected to continual wettings by rain, will be seen to have corroded away where it was in contact with the lead. To this cause is the pitting and corrosion of boilers largely attributed, but often, perhaps, to a really unwarrantable extent. Zinc slabs are frequently put into a boiler, and the mere fact that they waste away is often considered ample proof that the boiler plates have escaped the attacks of corrosion in a proportional degree. Undoubtedly their presence does materially assist in reducing the liability of the boiler plates to be attacked, but not to the extent very commonly supposed, for it must be remembered that their presence produces a voltaic current which would otherwise be absent. Anyhow, it does little good to suspend a few zinc slabs by wire from the stays. When they are used they should be firmly secured by studs and nuts, in strict metallic contact with the furnace and combustion-chamber plates, in the proportion of about 6 lb. per square foot of grate surface. When the slabs become too much worn away to fix on the studs, they can be placed along the bottom of the boiler.

Internal corrosion is principally due to the chemical action of the acids contained in the water in contact with the plates, or to oxidisation produced by the presence of air in the feed-water, and may be to a great extent prevented by the use of suitable feed-heaters and filters. Should the mechanical action of the plates cause the continuity of their surface to be disturbed, the material is more susceptible to the attacks of the corrosive elements in the water, and grooving is usually the result. When the corrosion is fairly uniform, and the surface of the plates presents no marked irregularity, their condition is often difficult to detect, and may escape observation, as the appearance of the rivet heads and the edges of the plates may be no guide in estimating the actual thickness of the plates.

The wasting of a plate may often be detected by testing with a hammer; but this is not infallible, for, owing to the position or comformity of the part hammered, the usual indications of thinness may not be presented. When testing in this manner, a finger should be placed on either side of the part being struck, in order to feel the extent of the vibrations of the plate during the operation. Where the plate is thin, the sound produced by the blow will be duller, and the plate will feel more "dead" than where thicker; but by experience alone can these peculiarities be recognised. Any part suspected of undue thinness should be drilled, and the thickness of the plate ascertained by actual measurement: the hole can afterwards be tapped and fitted with a screwed plug riveted over at the ends.

Wasting of the combustion-chamber plates on the fire side may be caused by leaky seams or stays. The former may be remedied by caulking, or by taking out any defective rivets, rimering out the holes and reriveting the seam: and the latter by caulking round the stays, having previously removed the nuts from the ends; or, should the threads in the plate be faulty, by putting in stays of a larger diameter.

Corrosion sometimes declares itself in the form of pitting on the water side of the furnaces about the line of fire. This may be caused to some extent by the fretting of the material, due to the unequal expansion of the plates where they are exposed to the intense heat of the fire, while immediately below they are cooled by the air rushing up through the ash-pits. Plain furnaces are more liable to give trouble in this way than those of corrugated section.

Corrosion on the outside of the boiler may be caused by the vapour arising from the bilges, by wet ashes being placed in contact with the plates, or by leaky seams, mountings, manhole joints, etc. The bottom of the boiler and the furnace front-plate should be kept as dry as possible, scaling them when necessary and afterwards giving them a good coating of boiled oil or oxide paint.

The unequal expansion, due to the great difference of temperature to which high-pressure boilers are subjected whilst raising steam, is the chief cause of leakage at the landings and rivets in the bottom of the shell. The bottom of the boiler may be comparatively cool while a few feet above the temperature is much greater, the variation in some cases extending over a range of 250°, and the consequent unequal expansion of the shell plates often throws a greater stress on the rivets in the lower landings than they can successfully withstand, hence the joints yield and leakage ensues. The obvious remedy is to improve the circulation of the water in the boiler by artificial means; but this can seldom be effected by the engineer in whose charge the boiler is placed, unless special fittings be provided. Without fully understanding the cause of the trouble, many engineers continually pare the edge of the plate and "horse" it up in the vain endeavour to stop the leakage, which is in this way often aggravated. As the confined space under the boiler renders it impossible to efficiently rerivet the seam with larger rivets, it is in most cases best to leave the seam alone, and the leakage will probably "take up" in time; it should, however, be kept under observation meantime, and the condition of the plates and rivets frequently noted.

If there be a ballast tank under the boilers, it will be found to corrode away very rapidly, the top of it should, therefore, be protected by a good thick layer of cement. It has been found beneficial to promote a circulation of air through such a tank when not in use, so as to keep it as dry as possible: this is effected by fitting it with ventilating shafts leading into the uptake, and others from the deck to act as downcomers.

Broken Combustion-Chamber Stays.—The water space stays should be frequently examined and sounded with a hammer, especially those in the upper rows between the combustion-chamber sides and the shell plates. The lateral movement of these stays, due to the expansion and contraction of the combustion-chamber, often causes them to break off close to the shell. It is difficult to ascertain, by ordinary means, if this has occurred, but, if a lamp be held behind each stay as it is examined, the light may be seen between the fractured edges of several of the broken stays: a suitable hydraulic test of the boiler is, however, frequently the only means of revealing their condition.

Steel stays have been found more liable to crack in this manner than those made of good wrought iron, and the latter are, therefore, preferable. It may be mentioned that the Board of Trade regulations regarding passenger vessels do not now require iron combustion-chamber stays to have a greater sectional area than would be necessary if they were made of steel, provided the material is duly tested and found to have a tensile strength of at least $21\frac{1}{2}$ tons per square inch, with an extension of 25 per cent. on a length of 10 inches.

In order to give these stays greater flexibility, some makers turn off the threads from that portion which is between the plates through which they are screwed.

Scaling the Boiler.—Although it is not desirable to leave the internal surfaces of the boiler wholly unprotected by scale from the action of any corrosive agent that may be present in the water, an attempt should be made to prevent the thickness of scale on the heating surfaces from exceeding that necessary for this purpose; and, unless fresh water be used for feed, the boilers should be scaled as opportunity for doing so occurs. The furnaces, being the parts subjected to the greatest heat, demand particular attention in this respect, for, if scale be allowed to accumulate on the crowns, their collapse is the inevitable result. If, as with some forced draught jobs, the rate of combustion be considerable, the danger is accentuated, and a special endeavour should then be made to keep the furnace plates free from a deposit of any kind.

The tubes are generally the only parts of the boiler very difficult to scale, owing to their inaccessibility; but they should be kept as clean as possible, more particularly round the necks, where, if scale be allowed to gather, the unequal expansion may cause the tube-plates to fracture. Scale is occasionally cracked off the tubes by placing heaters in them, but this usually starts the tubes in the tube-plates, causing them to leak afterwards, and they then have to be re-expanded. A heavy scale will sometimes break off in large flakes if just started, and this may be effected by placing between the tubes a long square bar of the required thickness, and turning it with a spanner. If allowed to get very bad, all attempts to remove the deposit may fail, and the tubes will require to be cut out and renewed; but such a contingency is not likely to occur in a modern vessel, except perhaps in the case of a donkey-boiler fed entirely from the sea.

It is very exceptional to find brass tubes fitted in a boiler, but they are much easier to keep clean than those made of iron or steel, for the scale does not appear to stick to the metal with such persistency. They have the additional advantage of being more efficient and last longer: the first cost seems to be the chief objection to their more general use, although they will always fetch a good price as old metal.

Scale should not be permitted to accumulate to any great extent on any seams, whether constituting heating surface or otherwise, but should be periodically removed to admit of a thorough examination of the plates and rivets below. Although in many cases the defective condition of the underlying plate causes a significant discoloration of the scale, it cannot be relied upon to do so.

Closing up the Boiler.—Having scaled the boiler, it should be thoroughly washed out with the aid of a hose, and all loose dirt removed. Before closing it up, a final examination should be made inside to see that no oily waste or anything else has been left on the top of the combustion-chambers or furnaces which would render the plates liable to burn if allowed to remain. It should also be seen that the passages to the stop-valves, etc., are clear: bags or cloths are often inserted in the necks of leaky stop-valves by the men working in the boiler, and these may be unnoticed or forgotten. Everything being clean and clear inside the boiler, the bottom manhole doors can be jointed, and the drain plugs, if any, put in.

Great care should be observed when jointing manhole or mudhole doors, as negligence in this respect is the frequent cause of a joint being blown out after steam is raised, and in many cases results in fatality or serious personal injury. It should be seen that each door is in a central position relative to the hole it fills, with an equal amount of clearance all round. It is scarcely necessary to mention that this clearance should not, if possible, exceed that just sufficient to enable the door to be easily placed in position, for the more extensive it is, the greater will be the danger of the jointing material being blown out. If the clearance be excessive, the door should be renewed, or a ring shrunk round the spigot to make it a more perfect fit. The condition and extent of the jointing surfaces should be taken into consideration when deciding upon the amount of clearance permissible, but, if satisfactory, the clearance should not be more than about $\frac{1}{8}$ inch all round, and less than this is, of course, desirable.

The joints should be as thin as possible, so as to present a minimum surface to the pressure of steam, which, acting on the edge of the joint, tends to force it out of position; and, if the jointing surfaces be very irregular, they should be faced up rather than an attempt made to effect steam-tightness with thick jointing material. The use of thick packing for these joints is a fruitful source of danger, and should not be permitted; rubber is also unsuitable, as it rapidly deteriorates with the heat. When ordering the joints it is best to send a template, so that they may be made in continuous rings of the exact size required.

Filling the Boiler.—Instead of running up the boilers from the sea, it is the usual practice to fill them with fresh water from the shore, through a hose-pipe led into the top manhole, whenever such a supply can be obtained. When this is done, before jointing the manhole door, the height of the water-level above the combustion-chamber tops should be measured; by deducting from this amount the height of the water in the gauge glass, it will be found what quantity of water is above the combustion-chambers when the water is just showing in the bottom of the glass, and a note of this may be very useful on future occasions for establishing a feeling of safety. The ship would, of course, require to be in her usual sea trim while doing this, or, if not, due allowance would have to be made for any difference. It may here be remarked that the water-level in the boiler may be 4 or 5 inches higher when steam is up, owing to the expansion of the water, together with that of the furnaces, combustion-chambers, etc., when heated.

The amount of water required to fill the boilers should be noted on the first opportunity for doing so presenting itself, either when it is supplied through a meter, or taken from a tank of known capacity. The utility of this will be apparent from the following account of a case in which the chief and second engineers showed great lack of care and intelligence, for which they were discharged:—After the arrival of a certain vessel in port, it was decided to change the water in the boilers, of which there were two, each having two furnaces; they were therefore emptied and allowed to cool down. Fresh water from the shore was then supplied through a hose-pipe led into the upper manhole of the port boiler, the door being removed for this purpose, while water was drawn from this boiler by the donkey-pump and discharged through the donkey-check into the starboard boiler. Each boiler was provided with the usual arrangement of water-gauge fittings, consisting of the gauge itself and three test cocks attached to a hollow column which was connected to the steam and water spaces by suitable pipes and cocks. It was said that the drain cock of the water-gauge on the starboard boiler was kept open in order to allow the air to escape as the water was pumped in, all other outlets from the boiler being closed. When the desired amount of water was shown in each glass, the supply was shut off, the manhole door jointed, the fires set away and steam raised. A few hours afterwards the furnace crowns of the starboard boiler collapsed, and the combustion-chambers were seriously damaged by overheating.

A subsequent examination of this boiler showed that the water-level had been about eight inches below the furnace crowns. The water-gauge fittings were in a very defective condition, the connections being choked, more or less, with a muddy deposit; while the gauge cocks on the column, which were asbestos-packed and had $\frac{1}{4}$-inch square holes through them, were partially blind, owing to the plugs not being entered far enough into the shells, the extent of the opening in the upper and lower cocks being $\frac{1}{16}$ inch and $\frac{1}{8}$ inch respectively.

Presumably the steam connection to the gauge column had been choked at the time of filling the boiler, and, as the water-level rose above the hole in the furnace front-plate communicating with the gauge column, the air enclosed in the boiler was compressed, and a pressure was exerted on the water, which was forced up to the gauge above the level in the boiler and so misled the engineers. It only remains to add that the waterman's book showed that 20 tons of water had, on this occasion, been delivered through the meter, whereas the capacity of the boilers under working conditions was 30 tons.

Laying the Fires.—If the coal provided be very small, as is often the case when obtained abroad, there may be a difficulty in laying the fires unless something be placed upon the bars to prevent the coal from falling through. Pieces of fire-brick are sometimes broken up and scattered over the bars, but cargo-mats also answer very well for this purpose, for, after the fires are well alight, the coal will usually cake together, the bars will require no other covering, and no further trouble will be experienced.

Lighting the Fires.—From eight to twelve hours before steam is required the fires may be kindled, which can readily be done with a hand-lamp and a little oily waste, the ash-pit dampers being off and the funnel damper open. After the coal is well ablaze, the funnel damper should be nearly closed, and the boilers allowed to heat up gradually, without forcing the fires.

When there are no hydrokineters or other means of circulating the water while raising steam, the centre fires should be lit first, so as to warm up the dead water at the bottom of the boiler as much as possible, the wing fires being kindled three or four hours afterwards.

Raising Steam.—When special appliances are provided for promoting a circulation of the water in the boiler, steam may be raised more rapidly, and without injury to the boiler. One of the most efficient fittings for effecting this is Weir's hydrokineter, a section of which is shown in Fig. 3, from which the general construction of the apparatus will be readily understood. The flange of the first or steam nozzle is fixed on the inside of the boiler shell, and set in the direction the circulating current is to take. On this nozzle are fixed two outer or induction nozzles, and the back end of the one and the outer ring of the other are perforated to admit water between. Steam from the winch boiler is admitted by the non-return stop-valve to the steam nozzle, and, getting condensed, throws a jet of water through the second nozzle. The volume of water is increased in passing through the outer nozzle. It then enters the bottom of the boiler and induces a current, as shown by the arrows in the figure. The purpose the two outer nozzles serve is more effectually to direct the force of the jet in the direction circulation is desired. When a steam jet is blown in openly, as the water gets heated to a certain temperature, the steam, on leaving the nozzle,

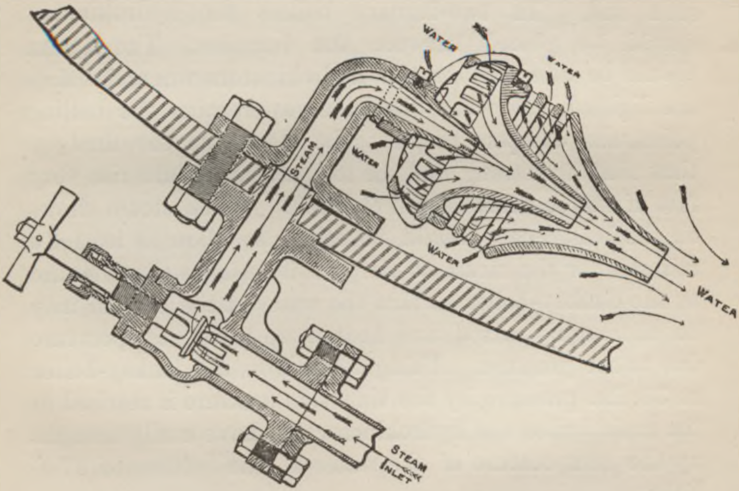

FIG. 3.—Weir's Hydrokineter.

expands and impairs the force of the jet. With the three-nozzle arrangement this is obviated. The water being directed on the steam jet, part of the steam is condensed between the first and second nozzles until the temperature of the water reaches about 270° Fahr. The outer nozzle then comes into play, keeping the steam from expanding, and directing the jet straight into the water at the bottom of the boiler, until the pressure reaches that of the steam jet. The check-valve now closes and so prevents the water being forced back into the auxiliary boiler.

In single-ended boilers the hydrokineter is placed on the centre, at equal distances from the ends. With double-ended boilers, two hydrokineters are used, and these are placed one-fourth the length of the boiler from each end. In two-furnace boilers the hydrokineter should be placed between the furnaces. The steam should be admitted to the hydrokineters when the fires are lighted, but, when the water approaches the boiling point, the dampers ought to be closed, as the fires by that time are strong, and the temperature would rise very fast if not in some degree checked. When steam shows on the boiler, care should be taken to allow at least 30 minutes for the steam to rise till it reaches the pressure in the donkey-boiler, so that the water at the bottom may be thoroughly mixed, and heated up to the temperature due to the pressure. Using steam from the donkey-boiler at 30 lbs. pressure, by the time this pressure is reached in the main boiler, the hydrokineter will have easily brought up the temperature of the water at the bottom to 270° Fahr.

In very large steamers where there is a number of boilers, steam should first be raised in one of the main boilers, the water being circulated by steam from the donkey-boiler. The fires of the remaining boilers should then be lighted, and the steam from the first main boiler used to circulate the water in the others. In this case the intensity of the steam jets can be increased, so that steam may be raised more rapidly.

Instead of hydrokineters, many vessels now have an arrangement whereby the donkey-pump can draw the water from the bottom of the boilers and discharge it through the check-valves or overboard, as desired. By this means a regular circulation of water may be maintained in the boilers when raising steam, the boilers can be emptied without running any of the water into the bilges, or, should one boiler only require to be emptied, the water might be stored in the other boilers and afterwards put back again. When circulating the water in a number of boilers simultaneously by this system, it is necessary that the same attention should be given to the regulation of the feed in the boilers when raising steam as when at sea.

As steam appears, the main steam stop-valves should be eased, not only to equalise the pressure in the boilers, but to allow the steam pipes to heat up gradually; and needless to add that the drain cocks should at the same time be opened as required, to free the range of piping from the water formed by the condensation of the steam therein.

It is very important that one should go round to all the manhole and mudhole doors that may have been rejointed, as the boilers heat up, and tighten the nuts as they become slack on the studs, owing to the compression of the jointing material as it softens with the heat.

Combustion, Firing, etc.—By the combustion of fuel is meant the chemical union of its various constituents, carbon, hydrogen, etc., with the oxygen of the air, producing heat, which is a manifestation of kinetic energy. As an example of the two extremes of combustion may be taken the rusting away of a piece of iron, and the explosion of gun-cotton. In the former instance the combustion is so gradual that any heat developed during the process is insensible, being carried away as soon as generated by the surrounding air. In the latter case the chemical union is completed in the fraction of a section, resulting in the most powerful energy.

Heat being the latent power stored up in the fuel and liberated during the process of combustion, it is a natural sequence that heat which is lost is so much power wasted. As heat which ought to be utilised may be lost in several different ways, it will be advisable to arrange these under different headings, and consider them separately, and also the means which may be adopted to minimise the waste as much as possible.

Heat is lost—

1. By admitting insufficient air into the furnaces.
2. By heating superfluous air.
3. By heating the ash.
4. In its transmission through the plates.
5. By radiation.
6. By blowing off.

1. Part for part the hydrogen of the fuel produces the greatest number of thermal units by its combination with the oxygen of the air, but, as there is only a small percentage of this gas in ordinary coal, it does not play such an important part as the carbon when considering the total heat of combustion. A small portion of the hydrogen combines with oxygen and forms water, and heat is lost in heating this water, but, as it is such a small quantity, it is not regarded as worthy of consideration.

The carbon of the fuel combines with the oxygen of the atmosphere and produces carbonic oxide (CO), or with twice that amount of oxygen to form carbonic acid gas (CO_2). Whereas the heat developed by burning to CO is only about 4400 thermal units per pound of carbon, by burning to CO_2 as much as 14,500 are produced, being about $3\frac{1}{3}$ times as much. This will enable one to form some idea of the enormous amount of energy wasted by admitting too little air into the furnace. When the coal is first thrown upon the furnace bars, CO is formed, but as it travels along it will probably meet with sufficient air coming up between the bars to supply enough oxygen to produce CO_2 before it gets any farther.

Bituminous coal contains a large amount of hydro-carbons, which are given off *immediately* the fuel is introduced into the furnace, so that air must be admitted above the fuel directly it is put in, in order to burn the hydro-carbons. For this purpose air-holes are usually made in the furnace doors, but the air is only required for three or four minutes after the fuel is put in, whereas this arrangement allows a continuous draught in the furnace. Registers with a sliding grid are sometimes fitted to the doors: this is a good plan if they receive the necessary attention, but the men get careless, or do not appreciate their use, so that they are not really of very much benefit. Air-holes, too, are sometimes left in the bridges, so as to allow air to pass up from the ash-pits and meet the carbonic oxide as it passes, thus completing the combustion in the "combustion"-chambers; but, unless attended to often, these air-holes will soon get choked up with clinkers and soot, and become useless.

The furnaces providing the most effective heating surface in the boiler, endeavour should be made to get the combustion in them as perfect as possible, for the comparative efficiency of the tubes and vertical heating surface of the combustion-chamber plates is very small. Great attention should therefore be paid to the fires, not allowing them to get too heavy, and so prevent the air from passing up to them between the bars, which latter should not be placed too closely together. Combustion is, of course, always perfect in any case, but the expression perfect combustion is understood to mean combustion in the manner calculated to produce the most heat, which, it must be remembered, is accomplished by burning the carbon direct so as to form CO_2, not first to CO and afterwards supplying sufficient oxygen to form CO_2, though this is far better than merely burning to CO, and a pound of carbon will in this way liberate about 10,000 thermal units.

A flame will sometimes appear at the top of the funnel, and this is simply caused by an insufficiency of air in the furnaces, the gases passing up the funnel unconsumed until they reach the top, where they meet with enough air to complete their combustion, when they burst into flame. By admitting more air to the fires (which are probably too heavy), either by pricking them or opening the furnace doors, the flame will disappear. Thick black smoke, too, is nothing more than so much carbon passing away unconsumed. By careful stoking, the formation of black smoke may be greatly reduced, if not actually prevented, although it must be remembered that the fact that there is no smoke coming out of the funnel is no proof that there is perfect combustion in the furnaces, for carbonic oxide, which is invisible, may be escaping all the time, and the greatest economy may often be effected when there is a slight amount of smoke.

The fireman who properly attends to his fire keeps it pretty equally distributed over the fire-bars, immediately covering any space that may be left bare; but, when a fresh supply of fuel is required, instead of throwing it in as far as possible over the burning surface, he piles it up near the furnace door. This pile of fuel, being acted upon by the heat, soon gives out its volatile products, and these, passing over the intensely hot surface of the partially consumed fuel, are raised to the temperature necessary for combining with the oxygen of the air. As the coal burns, it is raked back over the bars before a fresh charge is supplied. This system of firing is productive of the greatest economy, although not the most rapid evaporation, and, as the way in which steam is most readily maintained naturally commends itself to the fireman, he usually distributes the coal all over the grate at each charge. Should the coal cake much it will, however, necessitate firing more or less in the latter way, and it is then almost impossible to prevent the formation of smoke, unless the charges be moderate and supplied at regular and frequent intervals.

2. However much air may be admitted to the fires, the various constituents of the fuel will only combine with a fixed proportion of oxygen in producing the gases resulting from their combustion, hence it will be seen that a quantity of heat may be wasted by heating any superfluous air. This should be guarded against by keeping the bars uniformly covered with coal, leaving no bare places, the coal being broken up into lumps of as nearly one size as possible, in order to prevent the air from passing up in one place more than another. With the engines going at an easy speed,

and with good coal, the damper should seldom require to be kept fully open if the boilers have anything like sufficient grate surface. The furnace door should not be opened oftener or kept open for a longer period than is necessary, as waste will occur in heating the cold air thus admitted, not to mention the possible injury to the furnace, etc.

Theoretically, one pound of coal requires about 150 cubic feet of air to effect its combustion, but in practice it will be found to be about double this quantity.

3. When the fires are cleaned and the clinkers taken out, all the heat expended in heating them is completely lost; the fireman should not, therefore, when cleaning a fire, be allowed to draw it out entirely, and have to re-coal the bars, setting the new fire away with one or two shovelfuls of live coals taken from the next furnace, for by so doing the furnace is cooled down, and a considerable time will elapse before the "green" fire will burn up again. The live coals should first be raked to one side of the furnace and the clinkers removed from the side laid bare, then they should be raked back again and the other side freed from clinker. Having cleaned both sides in this way, there will be sufficient live coal left in the furnace to kindle the fresh coal, and the cleaned fire will soon burn up, without having unduly cooled the furnace during the process of cleaning.

When pricking the fires, the firemen are often apt to shake them about far too much, and cause an unnecessary amount of waste by allowing the coal to fall between the bars. This should be collected, together with the ashes out of the ash-pits, and burned over again.

Coal varies so much in its character that each variety requires its own special treatment, and no very absolute rule can be observed regarding firing generally, but an attempt should be made to carry out, as far as possible, the foregoing suggestions.

4. The resistance of a homogeneous plate to the internal conduction of heat through it is directly proportional to the thickness of the plate, and inversely proportional to the difference between the temperature of the two surfaces. Hence the thicker the plate, the greater will be the loss of heat in passing through it. This is forcibly illustrated in the case of a thick patch on a furnace, for some of the heat, instead of passing through the plates at this part, is utilised in burning the patch. Further, the transference of heat from the boiler plates to the water will be retarded by a deposit of scale, which is a very bad conductor of heat, hence loss will occur in proportion to the thickness of scale allowed to accumulate on the heating surfaces. To put it differently, the scale acts on the furnace in the same way as the lagging on the boiler shell, keeping the outer surface of the plate warm, and the difference between the temperature of the inner and outer surfaces being reduced, the resistance to the transmission of heat through the plate is increased.

The heating surfaces should be kept as clean as possible on the fire side also, for soot is a very good non-conductor of heat, and will considerably diminish the efficiency of the surface on which it it allowed to collect. For this reason the furnace and combustion-chambers should be scraped clean in port, and the tubes swept at sea whenever soot collects in them to any extent. A practice should be made of sweeping the tubes periodically, without waiting until the boilers are "stiff" to steam. Five or six days is usually quite long enough to let them run before cleaning them; and, while they are being swept, the engines should be eased down, if necessary, until the firemen have regained their hold of the steam. With some forced draught jobs, if, when burning down a fire preparatory to cleaning it, the air supply be partially shut off from the other furnaces, the increased draught thus obtained in the tubes communicating with the remaining furnace is sufficient to clear them of soot, and this, falling to the bottom of the smokebox, can then be removed by means of the doors provided for the purpose.

5. The loss of heat by radiation from the shell of the boiler is partially prevented by covering it with some non-conducting material, which should also be incombustible. There are many preparations for this purpose, some of the most efficient being asbestos fibre, silicate cotton, and fossil meal.

Without full particulars of the ventilating arrangements, etc., records of temperatures taken in a stokehold may be misleading, but the following figures are of interest, and give a slight idea of the efficacy of Bell's asbestos covering, which in this instance was unsheathed:—

The boat in which the temperatures were taken had two single-ended boilers working at a pressure of 70 lbs., each boiler being 13 feet 8 inches mean diameter by 10 feet 3 inches long, and containing three furnaces 3 feet 4 inches diameter. The thickness of covering was about 2½ inches, and the temperatures were taken from the port boiler.

Temperature of stokehold 125° Fahr. (in the Red Sea).

	Temp. of Covering.	Temp. 12 ins. from Covering.
Back of boiler, . .	134°	132°
Top „ . .	155°	152°
Starboard side of boiler, .	126°	118°
Port „ „ .	148°	138°
Mean, .	140°·75	135°

It is very desirable to lag the bottom of the boiler, as well as the other parts of the shell, and, if this be done, it will assist in keeping the seams tight; but, unless the covering be of a description that can be readily taken off and replaced, it is perhaps better to leave the plates bare at this part, so that the landings may be under constant observation.

Whatever description of lagging is used, it is advisable to sheathe it with sheet iron or lead, or at any rate on the top of the boiler, where it is most liable to be damaged unless efficiently protected.

6. When blowing off is resorted to in order to reduce the density of the water in the boiler, the whole of the heat expended in heating the water blown out is irretrievably lost; but brining the main boilers of a modern steamer is of rare occurrence, thanks to recent appliances. The deposition of scale in high-pressure boilers is, owing to the higher temperature, very much more rapid than in those working at a lower pressure; moreover, for a given size of boiler, a greater weight of water is evaporated, it is therefore desirable to put as little salt water as possible into these boilers, after a

thin protective scale has first been obtained on the surface of the plates. In view of this, evaporators have been introduced; but, when these fittings are not supplied, fresh water for the extra feed is frequently carried in the double bottom of the vessel, or in special reserve tanks.

Leaky Tubes.—The leakage of tubes is generally caused by an accumulation of scale round the necks, or by the back ends burning away. This may usually be remedied by re-expanding the tubes and beading them over at the back end, having previously removed the scale in the former case, and in the latter, driven the defective tubes farther through the tube-plates from the front end.

Should a tube split when at sea, it may be quickly and effectually closed up by means of one of the patent stoppers now frequently carried. Fig. 4 represents one of Beldam's tube-stoppers. To apply this instrument to a tube that has burst, enter the disc E, which is permanently secured to the rod C, from the front or smokebox end, and drive it through the tube. This disc E, by its formation, will clear its way through the tube, allowing the other parts to follow freely. Having placed the stopper in the tube as shown in the upper figure, screw up the nut D. There is a disc (not shown in the illustration) of suitable metal in each of the spaces marked R, R, and these are forced up the cones B, B, as they are drawn together, and, when screwed up tightly, the discs will fill the conical spaces, and the tube will be made perfectly steam-tight and reliable.

When such an appliance is not available a stout rod may be employed, each end being screwed and

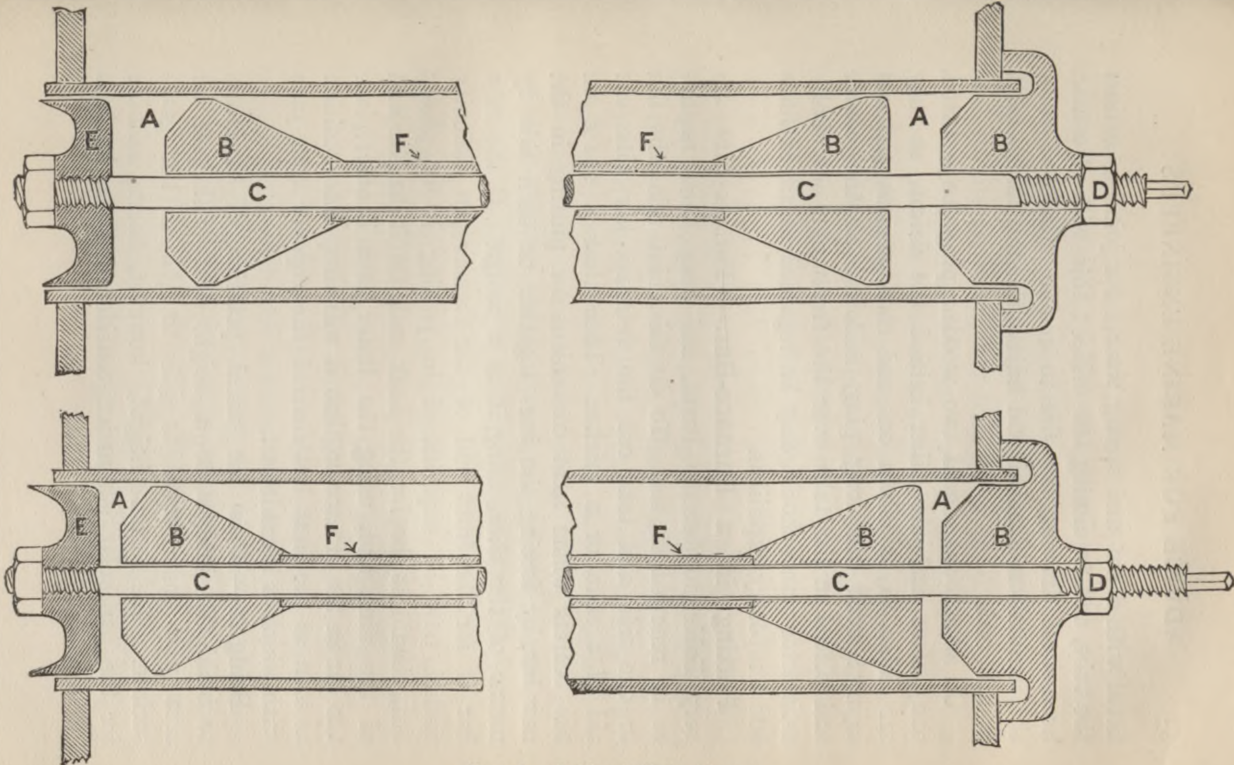

FIG. 4.—Beldam's Tube-Stopper.

fitted with a nut and strong washer for jointing against the tube, and so closing the orifice; this will, of course, necessitate drawing the fire to enable a man to enter the combustion-chamber and adjust the nut and washer at that end.

On no account should two wooden plugs be inserted, one before and the other behind the defect, as they are liable to be blown out and cause serious personal injury: even one long plug, hollowed at the centre and placed in the tube over the fracture, is not wholly satisfactory, and should only be regarded as an extreme and temporary expedient.

Putting in a Furnace-Bar.—Furnace-bars are very liable to become burnt, and may then require to be renewed at sea. To do this, first rake the fire to one side and take out the defective bar with the aid of a rake or a pricker. Then clear a space on the bearers where most convenient for putting in the new bar, by forcing the bars together on each side by means of the slice, using it as a wedge. If the new bar be for the front end of the furnace, no difficulty should now be experienced in putting it in place; but, should it be for the back end, tie it to the end of the slice, and, using the latter as a handle, place the bar in the furnace so that it will drop into position as soon as the heat has charred the rope or spun-yarn with which it is made fast.

Bridges.—It is the usual practice of engineers to build the bridges to a height that will give an area past them equal to $\frac{1}{7}$th to $\frac{1}{8}$th of the grate surface. The exact height, however, most suitable for the particular job under consideration can be best determined by actual experiment. An extra row of bricks at the top or a slight modification in the form of the bridge, will sometimes make an astonishing diminution in the daily coal comsumption, and the boilers steam quite as freely; but trial alone can decide this.

Water-Gauges.—When coming on watch, it is well to make a habit of always testing the working of the gauge cocks, and ascertaining if the correct water-level be shown in the glass, and this will insure the cocks being kept in working order, for they are very liable to become set fast unless attended to. It is most important that every one in charge of a boiler should thoroughly understand how to do this, and serious accidents constantly result from an ignorance of this very simple matter. Referring to Fig. 5, which represents the usual hollow type of column with gauge glass and cocks attached, and its pipe connections to the steam and water spaces of the boiler, if the cock B be shut and the drain cock C opened, and a clear blow through be obtained, it merely proves that the passage at A is clear. In like manner, if A be shut, B left open, and the drain opened, it simply proves whether B is clear. The pipe G or cock F might be partly or wholly choked, still a blow through would be obtained through the pipe E; or *vice versâ*, if the top pipe were choked, a blow through would be obtained through the bottom. So that either of the pipes might be choked, still its condition would not be indicated by simply manipulating the gauge cocks. Now, if the cock A be shut *and* the cock D, and on opening the drain cock a clear blow through follows, it will prove, beyond doubt, that both the cocks B

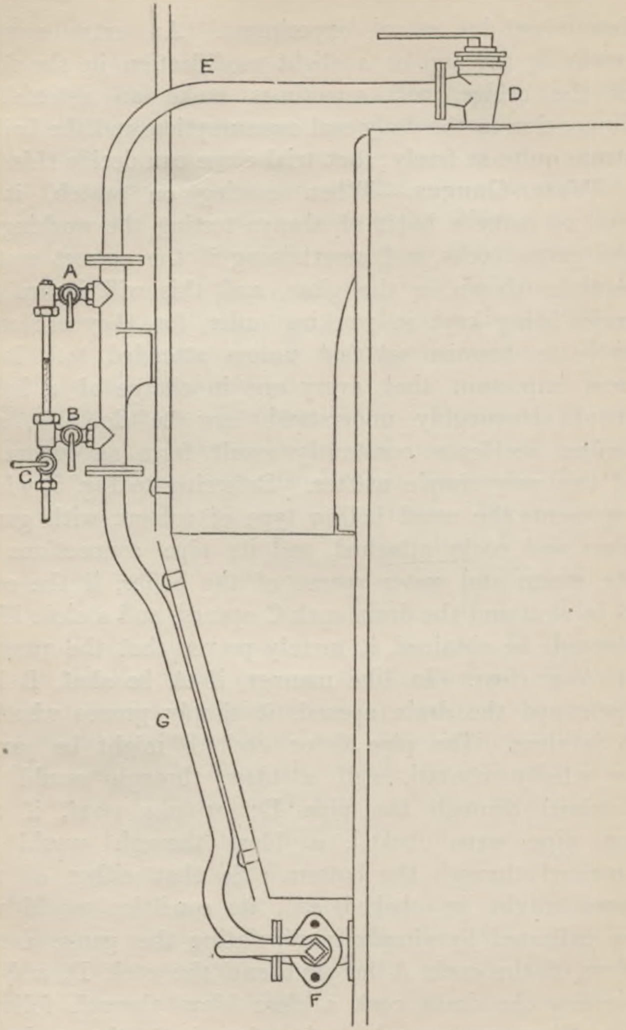

Fig. 5.—Arrangement of Connections for Water-Gauge.

and F and the pipe. G are all clear. The same with the other cocks, if B and F be both shut off, it can readily be seen if there be a free passage past D and E by opening the drain.

Were the column made according to the design shown in Fig. 6, with a couple of webs left in the casting to prevent a free passage through it from top to bottom, matters would be greatly simplified, and the necessity of closing the cocks on the boiler obviated; for if, when closing B and opening the drain, steam blew through, it would not only prove the passage at A to be clear, but also the steam connection to the boiler. The same also with the bottom connections, if A were closed, a blow through at the drain would prove that they were all clear. With this arrangement it is most important to note that, *if the gauge glass should be broken, the test cocks on the stand-pipe are unreliable,* and on this account they should not be fitted to such a standard, but directly on the shell of the boiler.

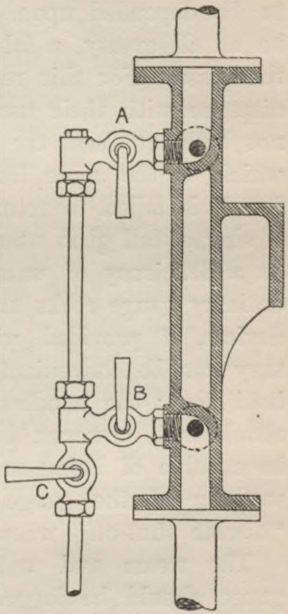

FIG. 6.—Pillar for Gauge Cocks.

Some gauge cocks have a small automatic ball or valve inside, which is held in equilibrium and is afloat, as it were, as long as the gauge glass remains intact, but, on the glass breaking and so relieving the pressure on the one side, the pressure on the inside forces the valve back on its seat, and thus closes the passage through the cock. These fittings are very convenient, and may save many a scalding; but, in the case of some designs, their action is not always to be depended upon, and, if the water in the boiler be at all greasy, a false indication may be shown in the glass. For this reason many engineers prefer to dispense with their use and remove the valves, or, if not both, at least the one fitted to the steam cock, which is the more likely to be a source of danger, for, if it failed to return to its normal position after closing, a full glass would appear although there might be a deficiency of water in the boiler. In any case, ordinary gauge cocks are preferable to these automatic devices, if provided with handles and gear whereby they can be conveniently manipulated from the stoke-hold floor; the handles of the steam and water cocks should not, however, be coupled together, but should be capable of being moved independently, so that the working of the gauge can be readily tested by the "double shut-off" when required.

The steam and water connections to the water-gauge should be lagged, so that their contents may be kept as nearly as possible at the temperature of the boiler. When the pipes are long and of small diameter, the steam and water they contain are rapidly cooled, and the usual level of the water in the gauge may be 4 or 5 inches below that in the boiler. On shutting the drain after blowing through the gauge, and expelling the comparatively cold water, the water will rise in the glass to the level of the water in the boiler, but it will gradually subside to its former position as the water in the pipe cools and therefore contracts.

The handles of the gauge cocks are liable to become bent or twisted, and it should be seen that the ports in the plugs are fully open when the handles are in their working position. This can be done by taking out each cleaning plug and feeling round the sides of the orifice with a scriber; should the cock be partially blind, the plug can then be marked, taken out, and remedied as required. The relative position of the handle and port through the plug may also be verified when steam is up, by blowing through the cock and moving the handle until the cock is just closed, and then turning it to the other side till again just closed: the working position of the handle should be equidistant from each of these positions.

It is a good plan, when repacking a glass, to temporarily place a small round piece of wood or cork on the upper end and tighten the cap-plug on to it, so as to keep the glass in position during the operation. If precautions be not taken, there is a danger of unknowingly lifting the glass when tightening the upper gland, leaving an aperture at the bottom through which the packing material might be forced when adjusting the lower gland, thus closing, or partially closing, the water orifice. The contingency is obviated when the lower cock is made, as it should be, with a recess to receive the end of the glass; or by packing with such appliances as woodite ferrules, which secure tightness by the pressure of steam acting at the back, and by their use there is no risk of breaking the glass through screwing up the glands too tightly.

When fitting a gauge glass in its place, it is specially important that it should not be placed so high as to prevent a clearing rod being inserted in the passage through the steam cock. This defect, especially if it occur in a water-gauge fitted to a boiler subject to priming, permits a rapid accumulation of scum around the top of the glass, and results in the choking of the orifice from the steam cock to the gauge glass.

If a gauge glass be too long, by scratching round the inside with the point of a small round file, using the edge of the glass as a fulcrum, short segments may be readily and cleanly broken off until the glass is of the required length.

Regulating the Feed.—The feed check-valves on the boilers are very often allowed to have too much lift, causing them to clatter and wear away quite unnecessarily. This is, however, inevitable when, as is frequently the case, the diameter of the valve is not much, if any, greater than that required for the supply pipe connected to it. The valve ought to be of such ample size that the necessary opening is obtained by giving the regulating screw only one or two turns from its position when the valve is closed.

On one occasion, in a vessel having two boilers, the port boiler commenced to take far too much feed-water, although the check-valve spindle was shut down hard, and this at the expense of the starboard boiler, which refused to take its requisite amount of feed-water, although its check-valve was fully open. On arriving in port the following day, blowing down the port boiler, and taking the cover off the check-valve chest, it was found that the three guide-feathers had been broken off the valve, which had actually turned upside down and was lying on its seat face upwards. This was undoubtedly caused by giving the valve too much lift, thus allowing it to cant.

In such cases as the one just described, the feed supply to the boiler with the broken check-valve can be regulated by judicious firing, and manipulating the steam stop-valve in the same way as a check-valve. For instance, should the boiler be taking too much feed, if the stop-valve be partially closed, it will allow the pressure to rise in that boiler, and the feed-water will flow to the other boiler where the pressure is not so great, and *vice versâ*. If, however, the arrangements admit, the surplus water can be drawn from the boiler with the defective valve by means of the donkey-pump, and discharged to the other boiler, keeping both stop-valves fully open as usual.

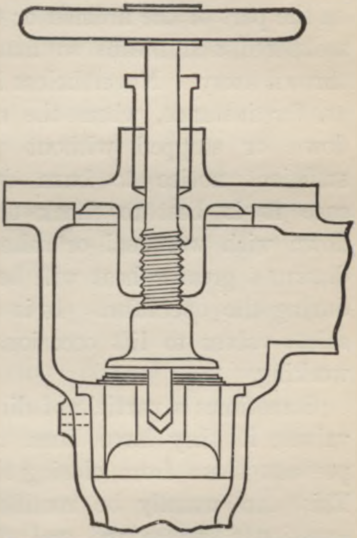

FIG. 7.—Feed Check with Kinghorn's Multiplex Valve.

Kinghorn multiple disc valves are largly used in the feed systems, for which they are eminently adapted. Being light, they do not destroy the seating so much as cast valves, and they are, moreover, noiseless in their action and very durable. Fig. 7 shows the application of these valves as a boiler check.

Safety-Valves.—Steam blowing off furiously at the safety-valves is usually a sign of incapacity or inattention on the part of the fireman or the engineer on watch in the stokehold, and means so much water and fuel literally thrown away. Nevertheless it cannot always be avoided, as, for instance, when the engines have to be slowed down or stopped without previously having received sufficient notice to burn down the fires. In such a case it is best to check the fires by damping them down with wet coal or ashes, for, if they be partially drawn, a greater heat will be thrown out from the fuel during the operation. It is also advisable to allow the safety-valves to lift occasionally in order to test their working.

Sometimes a particle of dirt will get under the safety-valves, if they have been allowed to lift, which will prevent them from closing tightly on their seats again. This can usually be rectified by giving the valve in question a turn round, and this should be done as soon as it is noticed that the valve is leaking, for, if allowed to continue, the escaping steam will probably wear away the seat and spoil the bearing of the valve, which will never be tight until ground up again.

The easing gear will very soon set fast at the joints, screws, etc., unless lubricated and tried now and again, and, as it is seldom used, it is consequently often neglected; but one never knows when an occasion might arise on which it would be required, and it should therefore not be overlooked or left disconnected.

Stop-Valves.—The same with the main stop-valves on the boilers, unless special attention be given to them, the spindles will very soon become stiff to work. At least once a week the spindles should be cleaned, the gear oiled, eased, and run back again. This will keep them in good working order, and then in case of emergency no trouble will be found in shutting off any of the valves.

Banking Fires.—When banking the fires they should be drawn forward, and damped down with wet coal at the *front* of the furnaces, and not at the back by the bridges. This will help to keep the temperature of the furnaces more uniform, and heat the air as soon as it enters, thus reducing the liability of the seams to leak. Having banked the fires, the funnel and ash-pit dampers should be closed.

Blowing Down.—Having arrived in port, the fires should not be drawn, but allowed to die out, and the boilers should not be blown down, but allowed to cool gradually, so that they may not be subjected to the evil effects caused by the sudden contraction of the plates. After the pressure has died away, the water can be run out into the bilges and then pumped overboard by the donkey, or pumped direct from the boilers if the arrangements are such as will admit of this being done. This is all very well as a maxim, but it is not in every boat that it can be carried out, for in most cases there is no time to lose, the fires require to be drawn, and the boilers blown down, or pumped out shortly after arrival, so that they may be cool enough on the following day for the men to go inside and start to clean. However, if it be not intended to open up the boilers, the fires should be allowed to die out as recommended.

Opening up the Boiler.—Before breaking the joint of a manhole or mudhole door, it is most important to ascertain that there is no pressure in the boiler by other means than a reference to the pressure gauge, which may not be reliable at a low pressure. This may be effected by easing the safety-valves, opening one of the test cocks, the salinometer cock or the drain cock on the pressure-gauge pipe, one at least of which should, however, be left open as soon as the boiler has been blown down or otherwise emptied of water.

It is not generally realised that there may be any serious danger should similar precautions not be taken to destroy any vacuum that may have been formed by the condensation of steam left in the boiler, and two remarkable instances to illustrate this are worthy of more than a mere passing notice:—On the arrival of a certain vessel in port, the two double-ended main boilers with which she was fitted were blown down, and, although the chief engineer gave orders for one of the gauge cocks to be left open, it was subsequently found that his instructions in this respect had not been carried out. The following morning the third engineer, assisted by one of the fireman, proceeded to remove the door from the upper manhole in the after end-plate of the port boiler, there being a platform across the smokebox, almost in line with the lower edge of the manhole. One of the nuts and a crossbar had been taken off, and the fireman was then sent to prepare to remove the door from the other boiler. Shortly afterwards there was a loud noise, described by the second engineer, who was in the engine room at the time, as being like coals falling in the bunkers; and, on going to the stokehold, it was noticed that the door of the port boiler was off and vapour was issuing from the manhole, but neither the third engineer nor the door could be seen, and the boiler was too hot to enter. The lower manhole doors were then removed, and blood was seen running down the furnace sides at the *forward* end of the boiler. When the boiler was sufficiently cool it was entered, and the dead body of the third engineer was discovered lying across two of the longitudinal stays, close to the forward end and immediately opposite the manhole, his skull being fractured and clothing torn. The door was lying on the tubes below the body, a piece of rope being attached to one of the studs, both of which were bent; a spanner was also found on the combustion-chamber girders, and a lamp, a hammer, a chisel and a brush at the bottom of the boiler.

Having regard to all the circumstances of the case, it seems probable that the third engineer met his death in the following manner:—He removed the nuts and crossbars from the door without starting it, having first tied a piece of rope to one of the studs, and made it fast to the water-gauge standard. Lying or stooping over the platform in front of the manhole, he then took hold of one of the studs, or rope, with one hand, and tapped the door with the spanner held in the other, when the door suddenly started and was driven inwards with great force by the external pressure of the atmosphere. The rope, which was very poor stuff, broke, whereupon the man involuntarily tightening his grip on the stud, or piece of rope, was drawn into the boiler, and, the stays guiding his course, he was hurled with sufficient violence against the forward end-plate to fracture his skull—or possibly his head struck the edge of the plate when entering the manhole. He was not a big man, and is said to have weighed about 10 stone, the manhole measured 16¼ inches by 12¼ inches, the door weighed 85 lbs., and the length of the boiler was about 16 ft.

In another vessel a Chinese fireman was about to remove the door from one of the boiler manholes, which was situated a few inches above the stokehold floor, in the end-plate, and, squatting down in front of the door, he took off the nuts and crossbars. He then started the door, which was suddenly forced inwards and struck the other end of the boiler with a loud noise. At the same time the unfortunate man was drawn towards the boiler by the rush of air, and, his stomach practically filling the manhole, he was held in this position, suffering great agony, until the engineer, hearing his cries, destroyed the vacuum in the boiler by opening the gauge cocks and admitting air. Although the man complained of internal injuries, he had sufficiently recovered to resume work in a few days.

Precautions before entering the Boiler.—After all the manhole and mudhole doors have been removed, it is desirable to wait till the boiler is well ventilated before entering it. Care should also be taken to see that the stop-valve and blow-off cock or valve are closed, and any other mountings which, if left open, might inadvertently be the means of forming communication with the donkey or any other boiler that might be under steam at the time.

Coal in the Bunkers. — It is well to make one's self familiar with the appearance which different quantities of coal would have in the bunkers, so that it may be possible to tell, approximately, at a glance how much coal remains, and thus check the daily consumption as given per watch. Thus, the space between each beam will hold so much, up to this stringer represents so much, that pocket will contain so many tons, and so on. The side of the bunkers may also be marked off in feet, from the bottom upwards, to show the depth of coal after it has been levelled down, when the quantity is being taken by measurement.

CHAPTER III

THE DONKEY-BOILER

Treatment of Boiler—Zinc in the Boiler—Formation of Scale—Brining—Cleaning—Sources of Danger—Grooving, etc.—Overheating—Shortness of Water—Priming—Working Cargo.

THE treatment best suited for the main boilers is equally applicable to the management of the donkey-boiler, with the exception, perhaps, of one detail—*i.e.* placing zinc plates in the boiler to prevent corrosion. If the boiler be required to produce steam to be condensed for drinking purposes, the quality of the water may be impaired, if not actually poisoned, by the presence of zinc. Anyhow, if the ship be on a run where it is likely to use the boiler much for this purpose, it will be the more judicious plan not to place any zinc in it.

Less scale will be formed inside the boiler if, when being fed from the sea, the density of the water be kept high—that is, within a reasonable limit. The reason for this it is not difficult to see, and may be briefly explained:—Salt water contains about three per cent. of solid matter, consisting of different kinds of lime and sodium or salt. The lime, being insoluble, excepting when at a low temperature, is held in suspension, and, on boiling the water, it is deposited on to the heating surfaces of the boiler, where the action of the heat causes it to form a hard scale. The salt, on the other hand, is soluble, and is therefore not deposited on the plates, but remains in solution, the water becoming salter and salter as the evaporation continues. Now, when blowing down is resorted to, part of this very salt water is blown out and its place made up by pumping more sea water, which is not so dense, into the boiler. This, while reducing the density in the boiler, is bringing in more water containing fresh material for forming scale; and, as the lime which was originally in the water blown out has already been deposited on the plates, it follows that there will be actually more scale formed the more often the water is blown off. It is the lime that does the mischief, not so much the salt; if, however, the water were to attain a density about four times the normal amount—the equivalent of about 20 oz. per gallon—salt itself would be deposited, but, needless to add, it must never be allowed to reach that condition. Again, if the density be high, the more difficult to steam, the more liable the boiler is to prime, and the greater the chance of the plates becoming overheated. Then, too, it entails the expenditure of more fuel to keep up steam when the water is very salt, as, with the density, its boiling-point rises accordingly. Although in many cases it has been found to be of practical advantage to keep the density as high as 15 oz., from the consideration of safety it is advisable that it should not exceed 10 oz. per gallon; and, if the boiler be fed from the sea, the water should be frequently tested by means of the salinometer, and the boiler brined as required, so that this degree of saltness may not be greatly exceeded.

To maintain the boilers in a safe working condition is probably the most important duty of the marine engineer, and the donkey-boiler demands special attention in this respect, as, owing to its intermittent use, it is more prone to deteriorate than a boiler more constantly under steam. After leaving port it ought to be opened up and thoroughly cleaned, if there should be sufficient time to do so before the next port is reached, or before steam is required in it again for any purpose, and ashes should not be left about, or in the furnace. The furnace-bars should be frequently removed, and the furnace sides thoroughly scraped and cleaned about the fire-level, as ashes are apt to collect between the bars and the adjacent plates, and, becoming damp by absorbing moisture, they will induce the corrosion of the plates with which they may be in contact.

In a boiler of the ordinary vertical type, grooving often occurs in the furnace crown around the base of the uptake, where the plate is fretted by the bending action due to the alternate expansion and contraction of the uptake in a contrary direction to that of the furnace sides, and is most noticeable where the furnace crown is unsupported by stays. On the other hand, if the crown be too rigidly stayed, the extension of the furnace sides, when heated, will produce an upsetting action on these plates immediately above the rivet attachment to the shell, where grooving may result or the rivets leak.

Leakage from the vertical seams of the firebox frequently occurs, and, if allowed to continue, local corrosion of the plates may be expected. Such leakage should therefore be arrested as soon as possible, by paring and caulking the edge of the plate, and reriveting the seam if necessary.

One of the principal sources of danger to which a donkey-boiler of this description is subjected, is the overheating of the plates constituting the heating surface. These plates in their normal condition may be amply strong for the work they have to perform, but, if allowed to become overheated, their strength when in that condition may become suddenly reduced to such a dangerous extent as to result in an explosion or serious collapse.

This overheating is usually due to shortness of water, although it might also be caused by the accumulation of scale or greasy deposit on the heating surface, by the metal near the fire being too thick (the result perhaps of careless patching), by a cramped water space, or by defective circulation.

Shortness of water may be due to priming, to neglect on the part of the man in charge in not putting on the feed when required, or indirectly to the faulty condition of the water-gauge cocks, which may show a false indication of the water-level through neglect or ignorance in testing them. The water may also be forced out of the boiler owing to the blow-off cock leaking or not being properly closed.

Priming is usually attributable to insufficient steam space, in which case the only remedy is to keep the working level of the water as low as possible, consistent with safety, and fire the boiler regularly and at frequent intervals. The violent priming of the boiler may often be greatly reduced, if not altogether checked, by closing the steam stop-valve for half a turn or so.

It is comparatively unusual to find a ship of the ordinary tramp class with a donkey-boiler of sufficient size for the work it is expected to do, and, when only provided with a small vertical boiler containing very limited steam space, considerable trouble is often experienced by priming, and inability to keep steam whenever there is a sudden or excessive demand for it, as, for instance, when all the winches are working at one time, or sometimes even when only heaving up the anchor with the windlass. Of course this cannot be remedied by those in charge of the boiler, although it is not unusual for the mate to imagine that the second engineer might improve matters if he liked. Even engineers are unable to accomplish impossibilities, and if, after the fire has been cleaned, steam cannot be kept for the winches when taking in six bags or cases at a time, why, then a sling must be made up of five or less. Neglect on the part of winchmen to use the brakes when lowering away may also cause quite an unnecessary expenditure of steam.

CHAPTER IV

IN THE ENGINE-ROOM

Going on Watch—Oiling—Steam Jackets—Pistons—Cylinders—Escape-Valves—Clearance—How to put the Engine on the Top Centre—Packing—Slide-Valves—Indicator Cards—Calculating the Horse-Power—Combining Diagrams—Crossed Diagrams—Valve-Gear—Reversing-Gear—Linking Up—Stop-Valves—Steam Pipes, Joints, etc.—Bearings—Cranks and Crossheads—Flaws in Shafting—Guides—Condensers—Air-Pump, Valves, etc.—Edwards' Air-Pump—Circulating-Pump—Main Feed-Pumps—Feed-Heaters—Weir's Direct-Contact Feed-Heater—Weir's Surface Feed-Heater—Weir's Feed-Pumps—Feed-Filters—Weir's Evaporator—Morison's Evaporator—Kirkaldy's Evaporator—Bilge-Pump Connections—Water Service—Working on Watch—Turning-Engine—Position for Leaving the Engines—Governors—Aspinall's Governor—Holding-Down Bolts—Opening Up—Breakdowns—Before leaving Port—Spare Gear—Cleanliness—Painting the Engine-Room—Ladders and Gratings—Dynamo.

Going on Watch.—Never omit to go round the engines when going on watch, and do not simply trust to your mate's report that she is working all right. Go round and examine everything thoroughly, and satisfy yourself that everything is as it should be before letting the watch go up, and then, if anything goes wrong, you cannot be put off with the usual excuse that she was working all right at four, eight, or twelve o'clock, as the case may be. On the other hand, if anything has been giving trouble during your own watch, or if you have had the water running on any bearing, or have tightened up any of the glands, this should be mentioned to the relieving engineer, otherwise it does not give him a fair chance.

After a little experience one is enabled, without leaving the starting platform, to detect by the throb of the engines any little irregularity in their motion.

A strange knock in any of the cylinders or valve-casings can be heard very distinctly by placing the ear to any convenient piece of metal, such as a straight-edge or spanner, the other end resting against the cover of the cylinder or casing in question.

Unless the steering-engine be situated in the engine-room where it can be attended to while on watch, it is advisable for each engineer to make a practice of visiting it, either before going on duty below or after being relieved, in order to tighten any nuts that may have become slack, adjust any leaky glands, and see that the engine generally is in order.

Oiling.—It is a good plan to keep a gauge for the oil-boxes, and at eight bells see that they are filled up accordingly. If this be done, it will prevent all unnecessary arguments as to who did not fill up the boxes, and why more oil was used in this watch than in that. Some engineers prefer to oil the cranks and crossheads by hand, discarding the use of the syphon pipes altogether; but perhaps the better plan is to give a little oil by hand as well as to use the syphons, giving a drop of oil down the pipes now and again. For bearings bushed with white metal, a thin mineral oil is often used with advantage, the bearings working cooler and wearing less than when oiled with a thicker lubricant.

The worsteds should not be placed in the syphon pipes indiscriminately with any number of strands, but regard must be had to the work that the particular bearing in question has to perform, the amount of oil to be given, and also the nature of the oil used. Rangoon oil will run down a worsted about ten times as quickly as castor oil, so that if a bearing be originally oiled with castor oil, one-tenth the number of strands may possibly suffice if Rangoon oil be afterwards used. The author has run fairly large main bearings successfully in the tropics with Rangoon oil, using only one thin strand of worsted in each syphon pipe (of which there were three in each bearing), giving no oil by hand. It is rather risky to do this, however, as the worsted might readily get broken, and, if not noticed, that particular part of the bearing would get little or no oil. A common mistake is to cram too many worsteds down each tube, and the strands, being squeezed together, prevent the oil from running freely. In any case, after a certain period the worsteds will become clogged and fail through ordinary wear, unless renewed frequently. It is inadvisable to mix different kinds of oil for the cups or boxes, as it is seldom that they are of the same specific gravity, and naturally the lighter oil eventually rises to the surface and runs down the worsteds to the bearings, the heavier oil remaining at the bottom of the cups.

In oiling an engine the desideratum is to give a little at a time and often, so as to keep the bearings in a regular and constant state of lubrication. For an ordinary going job the cranks, crossheads, and eccentrics may be oiled, say, every twenty or thirty minutes, and the main and tunnel bearings, valve-gear, pump-links, etc., every hour—swabbing the rods too about every half-hour.

If much oil be used in the cylinders, it will probably find its way into the boilers and cause the plates to pit or become overheated, not to mention the minor evil of rendering the condenser tubes foul and inefficient. Oil should accordingly be used very sparingly for the pistons and valves, and the condition of the rubbing surfaces may be taken as a guide to the proper amount to be given. An abnormal amount of oil is often necessitated by too tight an adjustment of the piston-rings, but, after this defect has been remedied, the quantity of oil used should be gradually reduced until a hard skin has been worked up on the surface of the metal, for, if the supply be suddenly curtailed, the cylinders will probably cut up. With the piston-rings properly adjusted, little lubrication, further than that afforded by the condensation of the steam, should be required in the cylinders to enable them to acquire a hard and highly polished surface like glass.

For lubricating the pistons, piston-rods, slide-valves, and spindles, it is desirable to use only the best quality of mineral oil, having a high flash point, so that it will not volatilise when subjected to the high temperature of the steam. This class of oil contains less acid than those derived from animal or vegetable substances, and is therefore less deleterious to the boilers.

Steam Jackets.—A diversity of opinion still exists regarding the economical utility of the steam jacket for the cylinders, even in ordinary compound engines; but, as in the majority of cases its use has been attended by a reduced consumption of fuel, it would seem that any objections that may be raised against it are outweighed by the actual economy that it usually effects, and the practical advantage of being enabled to gently heat up the cylinders before starting the engines.

The rationale of steam jacketing is readily explained: —If one element or material be placed in contact with another at a different temperature, the natural inclination will be for an equalisation of the temperatures, the one which is the hotter giving up part of its heat to the other until the temperature of both becomes equal. Let this rule now be applied in considering the heat of the cylinder, as affected by the working steam. Steam, on first being admitted to the cylinder, remains at the same pressure—and therefore the same temperature—until it is cut off; it is then expanded, and, as the pressure falls, the temperature will fall correspondingly, consequently the temperature of the sides of the cylinder is reduced to a proportional extent. Steam of the same initial pressure as before is then admitted to the other end of the cylinder for the return stroke, and, coming into contact with the metal already cooled by the exhaust steam, is partly condensed. It follows, therefore, that the greater the range of temperature between the initial and exhaust steam, the greater will be the condensation in the cylinder. The jackets are designed with a view to prevent this condensation, by maintaining the sides of the cylinder at a more equal temperature and keeping the steam comparatively dry. Steam should be supplied to the jackets of at least the same pressure, and therefore the same temperature, as that of the initial steam in the cylinders. Of course condensation will occur in the jacket itself, but not to such an extent as would take place in the unjacketed cylinder. The water in the jacket should be drawn off as soon as formed, by draining it into the hot-well, where it will assist in heating the feed-water. If the water be allowed to collect in the jacket, it will cool the cylinder very rapidly, and thus, by inattention, the jacket may bring about a state of things which its presence is supposed to prevent. It is therefore better to lose a little steam, by letting it blow through into the hot-well, than to allow the water to accumulate. A drain trap, with gauge glass attached, should always be provided, so that one may see at a glance if the jacket be clear of water, and whether the drain to the hot-well requires to be opened or closed a little more. At one part of the revolution work is wasted by the jacket in heating the exhaust steam, but the loss is not very considerable. Heat is also lost by radiation from the outside of the jacket, and should be prevented as much as possible by lagging with hair felt or some other non-conducting material. Some engine-builders make the cylinder covers double, and fit them with connections to allow steam to be admitted inside, in the same manner and for the same purpose as in the jackets.

If, during the cycle of operations, the expansion of steam be carried out in more than one or two cylinders, the total amount of condensation in them will be reduced proportionally, for the variation of temperature in each individual cylinder will be minimised the more there are of them. Consequently there is not very much condensation in the cylinders of triple-expansion engines, and they are therefore seldom fitted with jackets, except in the case of the high-pressure cylinders. Then, too, with these engines a slight amount of liquefaction in the cylinder is beneficial rather than otherwise, for the water lubricates the piston, and is then re-evaporated and does useful work in the next cylinder, the only loss of power resulting from the expenditure of heat in the process of re-evaporation, which is not very great.

From conclusions arrived at in modern practice, it would seem that, if the losses and gains by steam jacketing be compared together, it will leave a balance in favour of jacketing for double-compound engines, but, in the case of triple-expansion engines, any benefit that would be derived from the jackets is so slight that it scarcely warrants their use, except for the high-pressure cylinders.

Pistons.—A common mistake is to have the packing-ring too tight in the cylinder, thus causing a waste of power and an unnecessary drag on the engine. Very little pressure at the back serves to prevent the steam from leaking past. When overhauling the pistons, therefore, care must be taken not to give too much compression to the springs. Of adjustable piston-springs Buckley's were for a long time those most commonly used, and with them a very little vertical compression, by means of the junk-ring, will give a great lateral pressure on the piston-rings. From the results of actual experiments with these springs, it has been concluded that a pressure of only $\frac{1}{2}$ lb. per square inch of surface pressing against the walls of the cylinder is sufficient to keep the packing-rings perfectly tight, when subjected to a moderate pressure of steam. It is rather difficult to tell the exact amount of pressure given to the packing-rings for a given amount of vertical compression, but excellent results have been obtained by giving only $\frac{1}{8}$ inch compression to a low-pressure piston of 60 inches diameter.

The "Lancaster" arrangement of packing-rings and springs (Fig. 8) is now extensively adopted, and is very similar to Buckley's, in that the lateral and vertical pressure of the rings is obtained by means of the spring acting against their inclined inner surfaces. The springs are helical, of circular section, and are made to exact gauge, so as to ensure steam-tightness without any friction beyond what is absolutely necessary. To alter the length and tension of the spring, to compensate for any wear

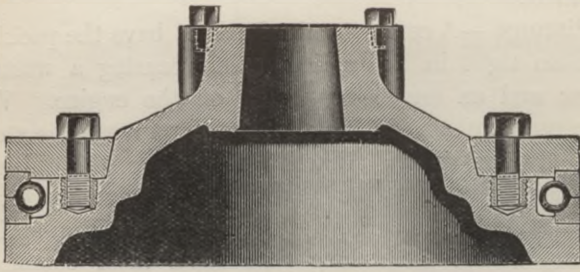

Fig. 8.—Piston with Lancaster Packing-Rings and Spiral Spring.

of the cylinder or rings, the ends screw into each other. The rings are made from a special mixture of cast iron, containing principally cold-blast iron and hæmatite, which gives an exceedingly strong, hard, close-grained material, capable of taking a high polish.

Another form of spring made by the same firm, Messrs. Lancaster & Tonge Ltd., is that known as the "serpent coil." This is admirably suited for use in piston-valves (Fig. 9), as the spring offers great resistance to collapse when passing over the steam ports, and at the same time only a moderate outward pressure is exerted on the side of the valve-chamber.

Lockwood & Carlisle's piston-springs and rings are also in great favour for large pistons. Instead of one spring being provided, there is a combination of springs to give two distinct actions, one to press the packing-rings outwards against the walls of the cylinder, and the other to

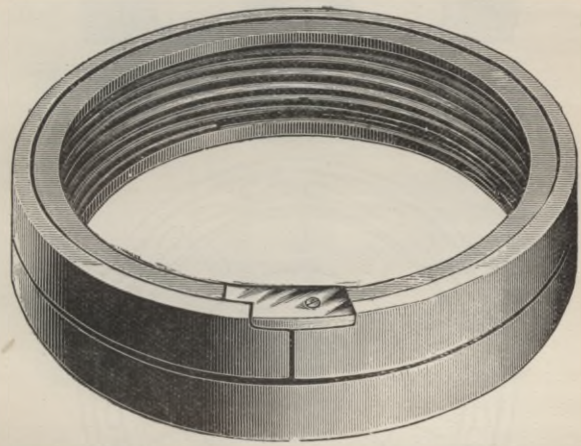

FIG. 9.—Lancaster Piston-Valve Packing-Rings and Serpent Coil Spring.

press the rings apart against the flat surfaces of the junk-ring and the flange of the piston; and the section of the packing-rings is L-shaped, there being no inclined surfaces for the springs to act against.

The method of forming the packing-ring in one piece, and pressing it outwards by means of springs placed at the back, reacting from the piston, is seldom to be met with except in old engines. Some of the objectionable features of this arrangement may be removed by fitting a floating ring between the packing-ring and the piston

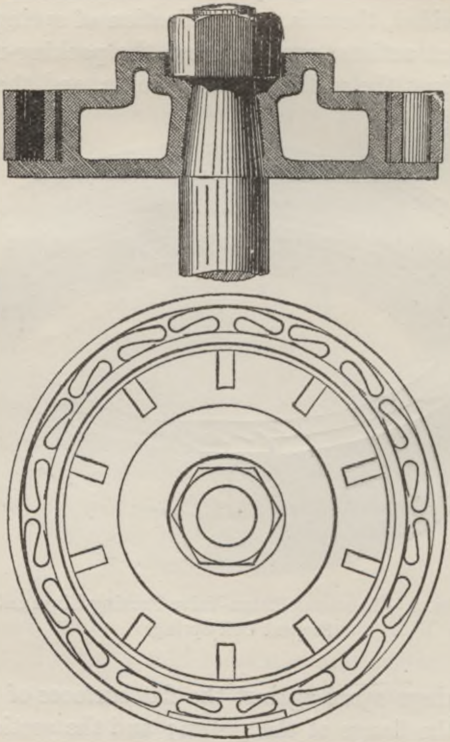

FIG. 10.—Piston with Floating Ring.

for the springs to act against. This allows the piston to have a little side play, independently of the springs, which will consequently exert a more equal pressure all round the packing-ring than could otherwise be secured. Fig. 10 represents a piston provided with a floating ring of this description, the junk-ring having been removed.

With Buckley's and analogous rings, the junk-ring never requires to be rebedded on the piston, as the spring causes the packing-rings to follow up any wear that may occur between them and the piston or the junk-ring. A single packing-ring, made in one piece, will, however, wear slack in time; and, when such is the case, the junk-

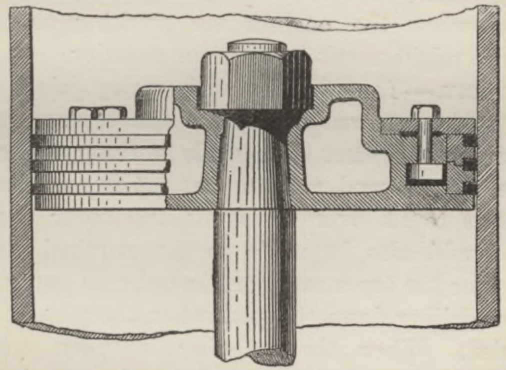

Fig. 11.—Piston with Ramsbottom Rings.

ring should be refitted at the earliest opportunity, leaving the thickness of paper between it and the packing-ring, or only just sufficient clearance to prevent the latter from being bound when the junk-ring is secured in place.

For pistons of a moderate size, Ramsbottom rings are now universally used. Being unadjustable, the outward pressure which they exert is out of ready control, and perhaps herein lies the secret of their undoubted success.

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Of course the rings can be "pinned" out after they have worn sufficiently to demand this. These rings are usually fitted in what is termed a "bull-ring," which is a combination of packing-ring holder and junk-ring, but Fig. 11 shows an arrangement whereby a piston originally fitted with a single packing-ring, pressed outwards by springs, was adapted for use with Ramsbottom rings.

Check-plates, copper split-pins or other satisfactory means should be adopted for preventing the junk-ring or bull-ring bolts or nuts from being loosened by the vibration when the engines are working, as such an occurrence might result in a serious casualty.

Cylinders.—The cylinder and casing joints do not require to be renewed every time the covers are lifted, and, in order to protect them while working at the piston or valve, it is a good plan to cut out two or three thin iron plates to fit over the studs and cover the joints. Plates should also be made to the required form for placing over the top steam port, in order to prevent nuts, etc., from falling down the port when the piston is being overhauled. When the bull-ring is taken out, care should be taken that nothing is dropped to the bottom of the cylinder that would be likely to cause damage if left there, as great difficulty may be experienced in recovering it, and all loose nuts, chisels, etc., should be removed from the top of the cylinder and piston before lifting the ring.

The cylinders should be slightly bell-mouthed at the top, in order to facilitate putting in the packing-rings. The bevel should not be carried down too far, but only sufficiently to allow the packing ring to wash past about $\frac{1}{8}$ inch or so, and thus prevent a ridge being formed. If extended too far, a nasty click will be produced by the ring springing in and out as it passes over the bevel.

Escape-Valves.—It is to be feared that the pernicious practice of overloading the escape-valves is very prevalent, and has resulted in the fracture of many a cylinder and cylinder cover. The overloading, however, usually arises from carelessness or ignorance rather than deliberate intention, and, after an escape-valve has been taken adrift, the regulating screw is frequently run down, it matters not to what extent so long as the valve is tight under steam. A simple calculation will show that two or three additional turns of the compressing screw may make a tremendous difference in the load applied, and entirely defeat the object of the valve's existence. Each valve should be adjusted to lift at a pressure a few pounds above the working load, and a thimble or distance-piece of the required thickness should then be fitted to the regulating screw to prevent it from being screwed further down.

The passages to the escape-valves at the bottom of the cylinders are liable to get choked up with oil and dirt, and they should be examined occasionally and cleaned out if necessary.

Clearance.—As the brasses of the engine wear, the clearance at the bottom of the cylinder should be noted from time to time, and one should be satisfied that there is no danger of the piston-rings passing over the edge of the chamber and jamming. In most engines it would not be possible for this to happen, but it is always best to be certain, for many accidents have been caused by faults in design which had not been anticipated. On the very first opportunity, unless it has been already done, the crosshead should be opened up, the brasses taken out, the piston lowered until it rests on the bottom of the cylinder, and a permanent chisel mark made on the guide-shoe in line with a corresponding mark on the guide-plate. The clearance may then be found at any time, by merely putting the engine on the bottom centre and measuring between the two marks.

The clearance between the piston and the cylinder cover may be ascertained by disconnecting the top end, wedging up the piston-rod from the jaw of the connecting-rod, and making a mark on the guide-plate in line with the mark on the guide-shoe previously referred to. The distance between these two marks when the engine is on the top centre is, of course, equivalent to the quantity to be found.

How to put the Engine on the Top Centre.—First turn the engines till the crank is nearly at the uppermost position, scribe a line across the top of the crank web, parallel with the side (namely, in a thwartship direction), and, in line with this mark, put a centre-dab on the column or condenser, a little above the level of the top of the crank web. Make a gauge or trammel of, say, $\frac{1}{2}$ inch iron, pointed at the ends, and of the length required to reach from the centre just made to the top of the crank web; holding one end of the gauge in the centre referred to, with the other mark the line on the crank web (see Fig. 12). Now place a mark across the side of the guide-shoe and guide, and turn the engines over the centre until the mark on the guide-shoe again corresponds with that on the guide. Repeat the operation of marking the line on the crank web with the gauge, holding it as before; with a pair of compasses, find the centre of the line between the two gauge marks, and mark the position permanently with a centre-punch. Hold the gauge in place, and turn the engines back again until the dab on the crank web comes to the free end of

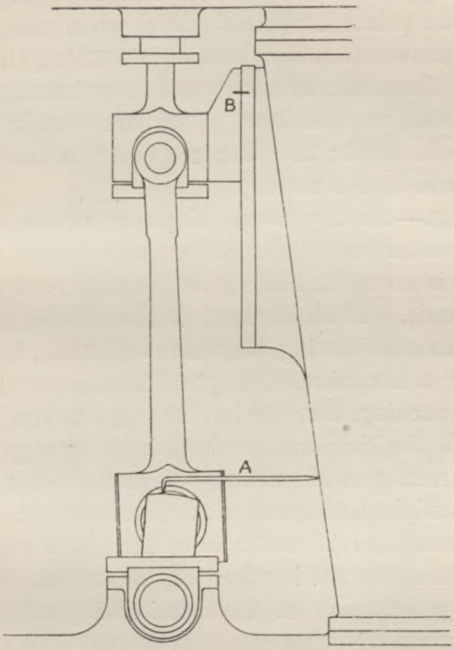


Fig. 12.—Putting the Engine on the Top Centre.
A. Gauge. B. Mark on Guide and Shoe.

the gauge. The crank is then on the top centre, and the gauge can be retained for future use.

This method is absolutely correct when the top of the crank web has been turned in the lathe about an axis corresponding to that of the shaft; but, in the case of a built crank, there may be a slight discrepancy, as, for a gauge of a given length, there is only one position for centring it to give an accurate result. No appreciable error is likely to occur, however, if the gauge be reasonably long and the points kept fairly level when using it; but to insure perfect accuracy, instead of scribing the line on the top of the crank web, it would be necessary to draw it at the side, in the form of an arc struck from the centre of the shaft; in other respects the mode of procedure would be the same.

Packing.—As any escape of steam means a loss of hot fresh water out of the boilers, care should be taken that there is no undue leakage at the piston-rod or valve-spindle glands. If steam start to blow badly at any of these glands after having been screwed home, it is better to stop for a few minutes, if possible, and put in a turn or two of packing, than to let the engines run for days, blowing all the time, and perhaps have to stop after all before the next port is reached. Nevertheless, it is better to allow a slight leakage of steam, and have the friction reduced accordingly, than to have the gland screwed up so tightly that the rod is wiped dry at each stroke.

At the present day an advance is being rapidly made in the direction of higher steam pressures. Two hundred pounds of steam pressure is now common enough, and everything points to still higher pressures becoming commonly used. With these increasingly high pressures the temperature of the steam is proportionally greater, and, in order to meet the demand for a packing more durable than that composed of mere vegetable substances, such as cotton or rubber, which rapidly chars, becomes hard and necessitates frequent renewal, asbestos packing became popular for a brief period, but in most cases its further use has been discontinued owing to its tendency

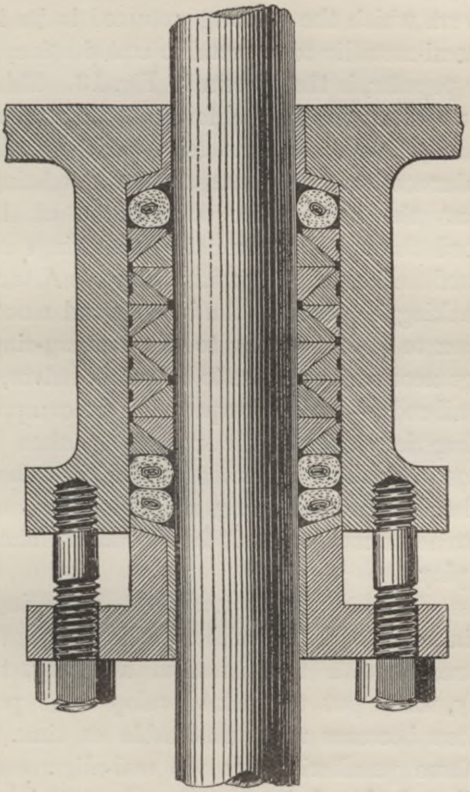


Fig. 13.—Ordinary Metallic Packing.

to score the rods. Semi-metallic packing, composed of soft or fibrous material with strands or cores of metal running through it, has been tried with varied success, and the failure of such packing to give complete satisfaction has led to the general adoption of packing of a purely metallic nature.

One form which the packing assumed in its transition from a semi-metallic to a metallic constitution, which is still very popular, is that shown in Fig. 13. This packing requires no alteration in the form of the stuffing-box or gland usually fitted, and consists of white metal rings of a triangular section, cut into segments, these being pressed up against the rod by the compression of the gland, transmitted through intermediate brass rings acting on the inclined surface of the packing-rings. A turn or two of soft packing is placed at the bottom and mouth of the stuffing-box to give a spring to the packing-rings. The brass rings necessarily require to be cut in halves,—except for the tail-rods,—and, consequently, the compression of the packing-rings against the rod being taken from the brass rings, the latter are forced up against the sides of the stuffing-box, which, being rigid, does not allow the packing to accommodate itself to the rod if it should have any side play.

Engines do not always turn out according to the original intentions of the builders. Although they may be constructed with mathematical accuracy, they will frequently, when put to work, develop some peculiarity which often becomes more noticeable as time rolls on. One of these peculiarities is the mal-alignment of the piston-rod, and though it may often be put right with a little trouble, still in some cases it baffles all the attempts of the engineer to remedy. When the packing is held in a rigid stuffing-box, it is impossible to keep a rod steam-tight when it runs out of line, for the rod in its motion from side to side forces the packing away, and as it is not sufficiently elastic to follow these lateral movements, a passage is made for the escape of steam. If an attempt were to be made to stop the vibration by tightening the gland, one can perhaps form a faint idea of the power that would be spent, and therefore lost, for the friction would be increased enormously.

The method of squeezing the packing in the stuffing-box by means of the gland is a most unscientific proceeding, because there is no means of knowing what pressure is being put on the rod, though it may be found too late that too much pressure has been applied. There can be no question that the screwing-up acts as a brake on the engine, causing a loss of power that is by no means inconsiderable. Recognising this fact, several engineers have at various times taken out patents for metallic packing for which the end-on pressure of the gland is not required, the packing-rings being retained in their place by an arrangement of springs requiring adjustment and careful fitting to begin with.

The conditions which an ideal packing would require to fulfil would seem to be somewhat as follows:

A. It must keep the rod steam-tight and at the same time oppose a minimum of friction to its passage.

B. It must be durable.

C. It must be easily removed for examination, that is, it must not be liable to stick hard and fast.

D. It should be adaptable for old rods as well as new ones.

E. It should be as simple as possible in construction, and, when once adjusted, should be perfectly automatic in its action.

The next condition is one which is very difficult to satisfy, and severely taxes the ingenuity of engineers in trying to attain the required result without introducing complication. The condition is this:

F. The packing must be free to follow the rod should the neck-bush be slack, or the rod not in perfect alignment, and yet it must not be so easy that it does not help the rod to keep in alignment, and this means that there must really be a flexible neck-bush.

It is quite unnecessary to mention in detail even a few of the numerous patent packings which have been invented with a view to fulfil the above conditions. An exception may, however, be made in selecting a typical packing which has been used for a considerable time in a great number of steamers, and, according to the testimony of those who have sailed with it, it would seem that its success is very well deserved. The packing referred to is that manufactured by the United States Metallic Packing Company Limited, at their works at Bradford. Referring to Figs. 14 and 15, this packing consists of eight blocks (5, 5A) which are held in strong rings (6), having pockets or horns holding springs (7). These blocks are put together in two sections, four blocks to a section. Each section is composed of two packing-blocks (5) and two guide-blocks (5A). The joints between the blocks in one section are at right-angles to those in the other section, thus breaking joints. The packing- or working-blocks consist of thin gun-metal cases filled with Babbit metal. The guide-blocks are of solid gun-metal, and are not in contact with the rod. The actual length of surface of each packing-block is as nearly as possible one-third of the circumference of the rod, and the thickness of the blocks varies from $\frac{3}{4}$ inch to 1 inch. On the top and bottom of the packing-blocks are two plates (4), which entirely cover the blocks and the springs. Between the horn-rings (6) and the inner surface of the packing-case (1) there is a space that varies in width according to circumstances, but it is generally about $\frac{1}{4}$ inch. On the lower side of the packing there is a ball (3), and a socket made into the packing-case (1), which is secured to the cylinder bottom by the studs (2). On the upper side of the packing there are several follower springs, which act upon a plate (8) having a lip with about $\frac{1}{32}$ inch play in the follower spring-bush (9), the object of the lip being to prevent any lateral movement of the plate, which would cause a shearing action on the springs. It will be noticed that by this construction the packing may have a direct sliding movement between the top and bottom plates (4), and the ball-ring (3) on the one side, and the follower spring-plate (8) on the other; or may have a rocking motion between the ball-ring (3) and the socket in the packing-case (1); or the packing may combine both motions at once. Hence the packing follows the rod, and the rod has perfect freedom of lateral motion.

Steam is admitted into the packing-case (1) through the clearance space between the lip of the plate (8) and the spring-bush (9), and exerts a pressure on the packing-blocks (5); there is thus a pressure on the rod due to the steam, plus the springs, to produce a steam-tight joint. As the pressure in the cylinder varies, so does the pressure in the packing-case vary. On the outward stroke there may be very little pressure between the piston and the packing, in which case there would not be much pressure on the rod beyond that exerted by the springs, which may be taken at about $1\frac{1}{2}$ lb. per square inch.

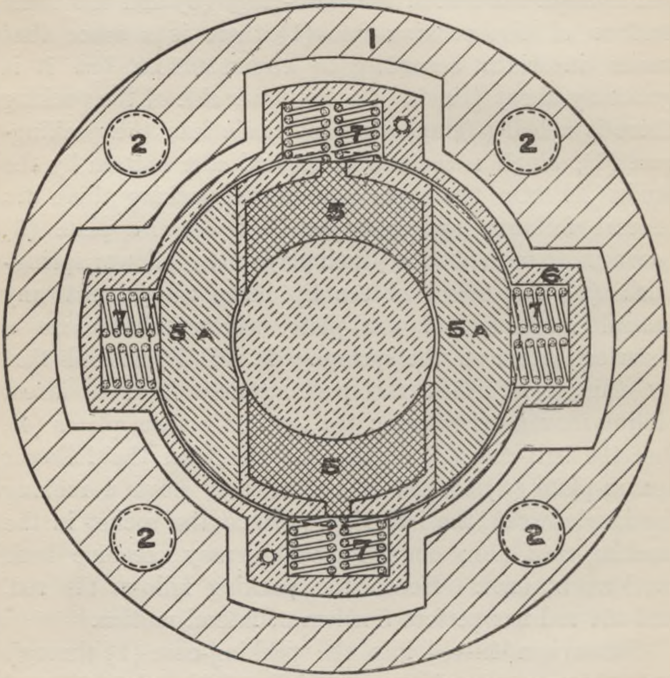


FIG. 14.—United States Metallic Packing Company's Packing-Box.

The "duplex" packing is an adaptation of this arrangement for use with very high pressures. As will be seen from Fig. 16, this is simply a combination of the block packing just described, with the addition of a modification of the ordinary wedge packing. The latter is not intended to be steam-tight, its function being to wire-draw the steam, and so relieve the pressure on the block packing. The tapped holes shown in the

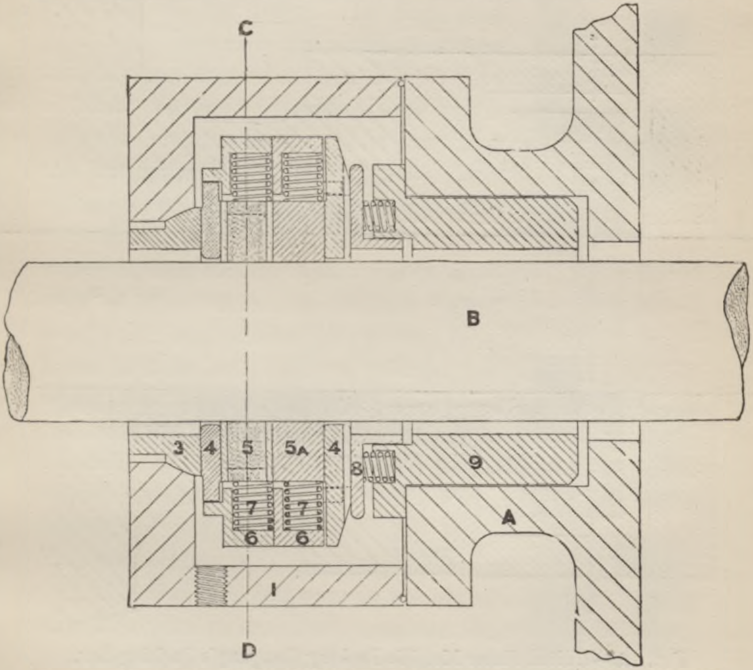


FIG. 15.—United States Metallic Packing Company's Packing-Box.

figure at the side of the casing are for drain cocks or valves, for drawing off any water formed by condensation of the steam.

For rods and spindles where metallic packing is not fitted, a soft packing should be selected from the numerous forms now manufactured with a view to securing tightness by the steam pressure acting at the

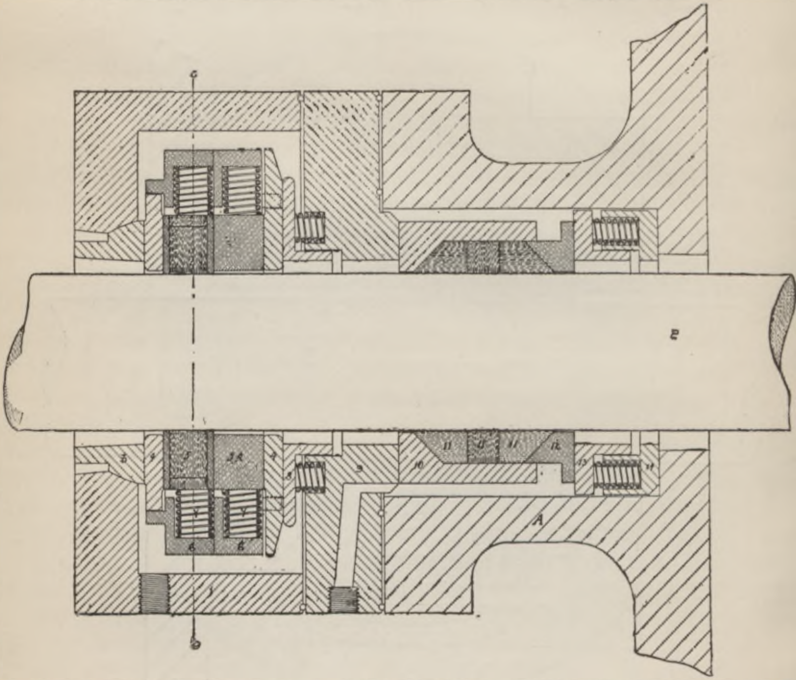


FIG. 16.—United States Metallic Packing Company's Packing-Box.

back, rather than by forcing the packing against the rod by screwing up the gland.

Some soft packings mark the rods very badly if allowed to remain in the same position for any length of time. This may be prevented by covering the rods with a mixture of white lead and tallow, and turning the engines so that the parts thus coated are in contact with the packing. The rods can be wiped clean before starting, and all the grease that will find its way into the boilers by doing this will do no harm. In any case it is best to move the engines a few inches every day when in port.

Slide-Valves.—If not already in the ship, a wooden batten should be made, and the first time the slide- or piston-valve is drawn for examination, a number of lines should be drawn across this batten, corresponding to each steam and exhaust edge of the valve. A similar batten should also be made for the cylinder face. These battens may then be painted between the lines representing the ports and bars, and afterwards varnished, so that the marks may not be so readily effaced by dirt (see Fig. 17). When setting the valve, all that has to be done is to place the crank on the top centre and, with the link full over in the ahead or astern gear as required, measure the distance from the top of the cylinder face to the top of the valve, place the two battens edge to edge in a similar position, and the lead and relative position of all the ports can be seen at a glance. The same operation can then be gone through with the crank on the bottom centre, in order to find the amount of lead, etc., for the

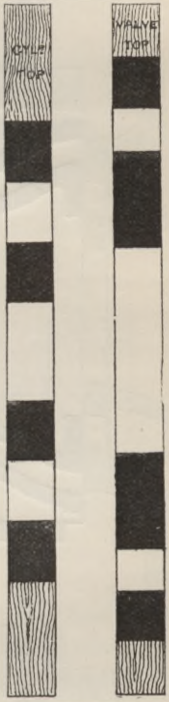


Fig. 17.—Battens for Main Slide-Valve.

up stroke. With an ordinary slide-valve or a piston-valve having the steam-edge outside, the amount of lead at the top can be taken by means of a small wooden wedge, but this is not possible with a valve having an expansion-valve at the back or with a piston-valve having the steam-edge inside, and a reference must then be made to the battens. Having determined the position of the valve to give the required lead, a gauge can then be made which, when placed on the edge of the cylinder valve face or the valve-chamber, will just touch the top of the valve.

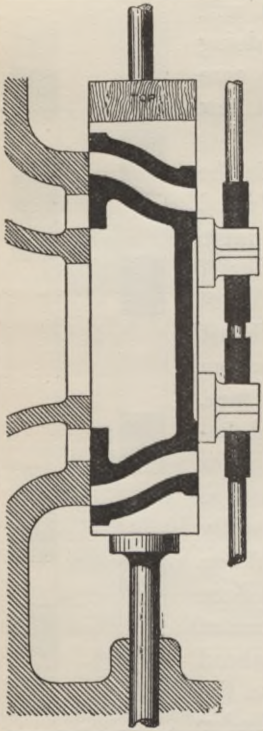


Fig. 18.—Setting the Expansion-Valve.

If an expansion-valve of the usual design be fitted, it is a good plan to get a board of the same breadth as the total thickness of the main slide-valve, planed up true on both edges, and to mark on it a diagram representing a section of the main slide. The bottom of the board can then be formed so that when resting on the collar of the valve-spindle—the valve being removed—the various ports in the drawing occupy the same position, relative to the cylinder face, as the ports of the valve when in its place. By turning the engine round, the cut-off at each different grade of expansion can then be noted, and the relative position of the ports for each position of the crank. This will be made clearer by a reference to Fig. 18, which shows the board in position.

As the expansion-gear is arranged for working the engines ahead, the valve will, when going astern, partially close the ports at a time when they require to be open, so that when working the engines coming into or leaving port, the expansion-valve must be thrown out of gear in order to prevent the engines hesitating or refusing to reverse.

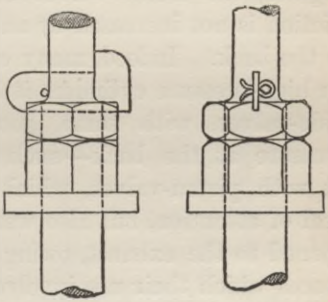


Fig. 19.—Cotter for Valve-Spindle Nuts.

When putting in the slide-valve, care must be taken not to screw up the valve - spindle nuts too tightly, or it may cause the valve and gear to knock when working, if it does not actually keep the valve off the cylinder face. They should be set up so as to allow the spindle to have a little side play in the valve, and if the cotter above the top nut be checked into it for a depth of about $\frac{1}{4}$ inch—as shown in Fig. 19—there will be very little danger of the nuts slackening back.

Should the slide-valve gall when working, it will be found advantageous to bore a number of holes, say 1 inch diameter and $\frac{1}{4}$ inch or $\frac{3}{8}$ inch deep, in the valve face with a flat centre-drill. Steam is enclosed in the holes as they pass over the bars of the cylinder valve face, and so relieves the pressure on the back of the valve to a slight extent, besides assisting in the lubrication of the rubbing surfaces. A marked benefit is also often derived from letting dowels of white metal into the valve face.

Modern practice seems to favour the use of piston-valves for the high-pressure cylinders alone, the ordinary slide-valves being used for the mid- and low-pressure engines, the latter valves being preferable where the friction is not increased by an excessive pressure of steam at the back. Indeed, many engineers consider that even for high-pressure cylinders it is better to use the ordinary slide-valves, with some good gear for relieving the pressure at the back—such as Church's—rather than fit with piston-valves, which not only require a great deal of attention, but also waste a lot of steam whenever opened to the exhaust, owing to the excessive clearance spaces which their use involves.

Indicator Cards.—It is neither desirable, nor yet within the scope of this short treatise, to mention in detail all the distortions that would probably be made in the indicator cards through incorrect setting of the valve, want of injection water, priming, etc. With experience and a little thought one will soon become expert in reading cards, and be able to tell at a glance if anything be radically wrong. Nevertheless one or two features of the indicator card itself, which are often overlooked, may be examined.

If a pressure of, say, 70 lbs. per square inch be exerted on a piston which has a back pressure of 10 lbs. on the other side, only 60 lbs. of the former pressure will be available for overcoming friction and forcing the piston along, the remaining 10 lbs. being absorbed in overcoming the resistance offered by the back pressure. In like manner, a single diagram, as delineated by the indicator, merely shows the fluctuation of pressure on one side of the piston at the various stages throughout a complete revolution of the engine. In order to determine how much of this force is effective in causing the

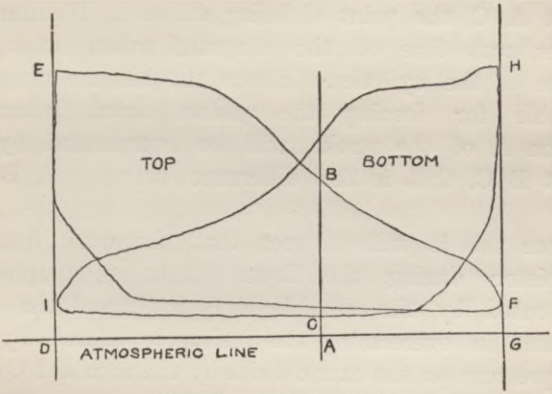


FIG. 20.—Indicator Cards.

piston to move, a diagram must be obtained from the other side of the piston, so as to ascertain the back pressure during its progress.

This will be more clearly understood by referring to Fig. 20, which represents a double card, the diagram on the left hand being taken from the top, and the one on the right being taken from the bottom of the cylinder. The length, D G, of the diagram represents the length of the engine's stroke.

In considering the down stroke, take any point A, from which raise the vertical line A B, cutting the expansion line at the point B. The height A B, measured by the scale of the indicator-spring, represents the pounds pressure, above the atmosphere, pressing on the piston after it has traversed the distance D A and arrived at the position A.

The back pressure at this point must be found from the other diagram, and is represented by the height A C, the point C being where A B intersects the exhaust line of the diagram taken from the bottom of the cylinder. Hence the balance of power available for forcing the piston down, when in position A of the stroke, will be represented by the height B C, that is the difference between A B and A C.

From this it will be seen that the work done on the piston during the down stroke is graphically represented by the area D E B F G, and the work expended in overcoming the resistance offered by the back pressure on the exhaust side by the area D I C H G. Hence the unbalanced work resulting in the movement of the piston will be the difference between these two quantities, and will be equivalent to the shaded part of Fig. 21, minus the area A B C, which represents the work done in compressing the steam enclosed in the cylinder, and bringing the piston gradually to rest at the end of the stroke. The mean height of the shaded area is equivalent to the mean effective pressure forcing the piston down until it comes to the relative position of C, the pressure is then the same on both sides of the piston. As the piston advances, the downward pressure is outbalanced by the ever increasing back pressure.

Let the mean effective pressure up to the point C (Fig. 21) be found from the indicator card, by dividing the shaded area by ordinates in the usual way, determining the average height, and comparing with the appropriate scale for pressures; call this M, and the distance of C from the steam admission end of the

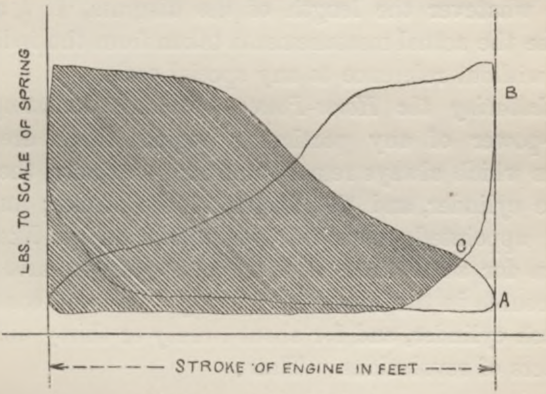


Fig. 21.—Indicator Cards.

diagram taken from the top of the cylinder, call L. Also, let the mean effective pressure expended in compressing the steam on the other side be found in a similar way from the average height of the area A B C; call this *m*, the distance of C from the line A B call *l*, and the length of the card S. Then the value of M, considered for the whole of the stroke,

$$=\frac{M \times L}{S}.$$

Similarly, the value of m, considered for the whole of the stroke,

$$=\frac{m \times l}{S}.$$

Hence the mean effective pressure throughout the down stroke

$$=\frac{M \times L - m \times l}{S}.$$

As the various *lengths* will have the same relative value whatever the length of the diagram, L, l, and S may be the actual measurements taken from the indicator card, without reference to any special scale.

Calculating the Horse-Power.—When calculating the horse-power of any particular engine, there are two factors which always remain constant—namely, the area of the cylinder, and the length of the stroke; and, on being appointed to a ship on which one is likely to remain for some time, it is a good plan to save time and trouble in the future by making a table of constants for each cylinder, and for about twenty or thirty different numbers of revolutions. Thus:

$$\frac{\text{Area of cylinder} \times \text{stroke in ft.} \times 2 \times x \text{ number of revolutions}}{33{,}000} = \text{constant}$$

for x number of revolutions.

Then, when it is desired to calculate the I.H.P., all that has to be done is to multiply the mean pressure, as found by the indicator for each engine, by the constant for the number of revolutions at which it is working, and the product will be the required power.

Combining Diagrams.—Although it may not be of much practical value, it is interesting to plot out and combine the indicator cards taken from the different cylinders, and so compare them with the theoretical

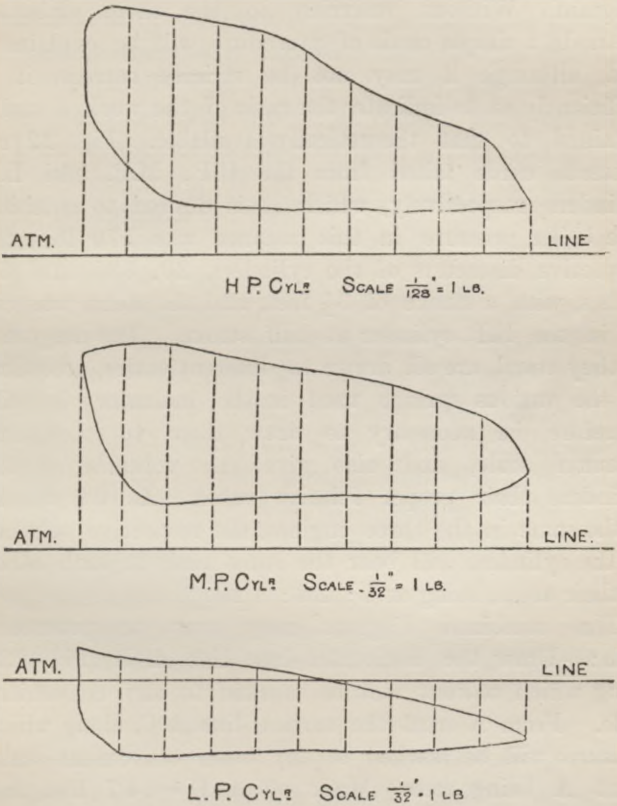


FIG. 22.—Diagrams from Triple-Expansion Engine.

diagram, as it would appear if the expansion of steam were completed in one operation and in one cylinder.

There are several ways of doing this, owing to a diversity of opinion as to where the steam admission end of the M.P. and L.P. cards should be placed in the combined diagram. Without referring to the more elaborate methods, a simple mode of procedure will be explained; and, although it may not be strictly correct, it is sufficiently so to indicate the ratio of the work actually obtained to that theoretically available. Fig. 22 represents cards taken from the H.P., M.P., and L.P. cylinders respectively, which it is desired to combine. The boiler pressure in this instance was 170 lbs., the respective diameters of the cylinders, 20, 33½, and 54 inches, with a stroke of 3½ feet, and the steam was cut off in the H.P. cylinder at half stroke. The diagrams, as they stand, are all drawn to different scales, according to the various springs used in the indicator; it will, therefore, be necessary to draw them to the same common scale, and also give the volumes of the cylinders their proper relative value. As the stroke is the same in the three engines, the respective volumes of the cylinders will bear the same ratio to each other as their areas, being as 1 : 2·8 : 7·29.

The combined diagram may now be proceeded with:—Draw the horizontal base line A B (Fig. 23), along which *volumes* will be marked to any convenient scale. From A erect the vertical line A C, along which *pressures* will be marked to any other convenient scale, point A being zero. Mark off A D = 14·7 lbs., and draw the atmospheric line D E parallel to A B. From A set off A F, A G, and A H equal to the volume given by the clearance at one end of the cylinder, together with that of one steam port, calculated for each cylinder respectively. In this case, the volume of the H.P. cylinder being taken as unity, A F = ·08, A G = ·16, and A H = ·4. From F, G, and H draw vertical lines parallel to A C. These will give the respective positions for placing the steam admission ends of the diagrams. From F mark off F J = the volume of the H.P. cylinder = 1; from G mark off G K = the volume of the M.P. cylinder = 2·8; and from H mark off H B = the volume of the L.P. cylinder = 7·29.

Now divide each of these quantities into the same number of equal parts as in the diagrams (ten being the usual number), and draw ordinates accordingly. Having done this, take each diagram separately, measure the pressure of steam along each ordinate, using the scale of the indicator-spring and starting from the atmospheric line, and transfer to the corresponding ordinate in the

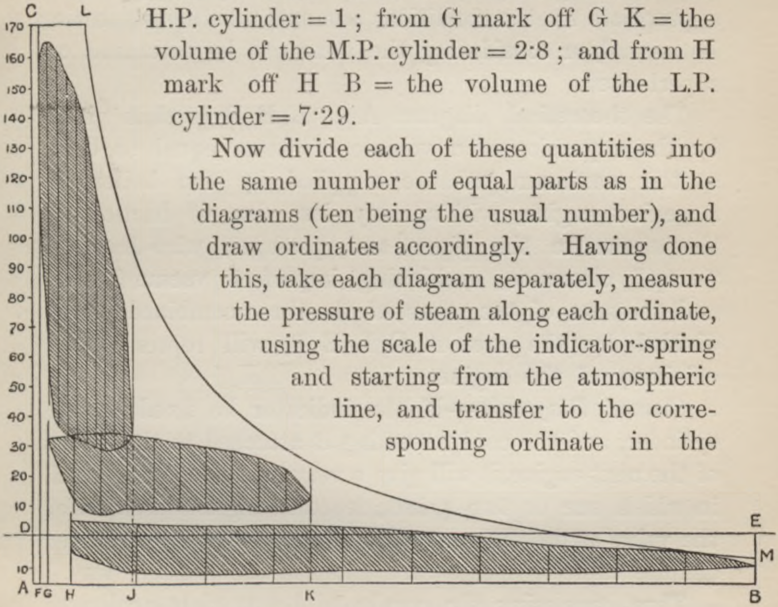


FIG. 23.—Combined Diagram.

combined diagram, using the scale selected to represent pressures. All the points being thus marked off, and connected by a line for each diagram separately, a representation of the cards in their approximate relative value is obtained. On A C mark off the boiler pressure at C. Draw C L parallel to A B, and equal to the volume swept by the piston before steam was cut off, + the volume embraced by the clearance and steam port in the H.P. cylinder. The theoretical expansion curve L M can then be drawn from the point L, determining the various points in the curve by using the equation appropriate for the conditions assumed, whether adiabatic, isothermal, or considering the steam to be saturated or superheated.

The theoretical diagram A C L E B is that given by the expansion of a volume of steam equal to C L, at the maximum pressure supplied by the boiler, in a perfect engine, without any loss due to friction of the steam in the pipes and passages, wire-drawing, "drop," clearance, cushioning, imperfect vacuum, etc.; and the sum of the areas of the three combined cards, divided by the area A C L E B, will represent the efficiency of the engine.

Crossed Diagrams.—If the indicator be fixed to one cylinder, and the cord actuating it attached to the levers of the next engine, it will give a very curious-looking card, in which one or two points, representing the position of the valve at the different parts of the stroke, have a more definite value than in a card taken in the ordinary way.

Thus, supposing the cranks to be at right-angles to each other, then the lines which represent the different points in the valve's motion at the end of the engine's stroke, instead of being at each end of the card, in a crossed diagram appear in the middle; consequently, the amount of lead is more clearly shown, and the points at which the compression commences and terminates become more emphasised.

These features of a crossed diagram will be more evident by studying the specimens here given, which represent cards taken off an ordinary compound engine, the cylinders being 34 inches and 60 inches diameter, by 3·75 feet stroke; steam, 60 lbs.; cut off at 11 inches; throttle fully open; vacuum, 25½ inches; and revolutions, 52½; the cranks being at right-angles to each other and the high-pressure crank leading.

Fig. 24 is a double card taken from the H.P. cylinder,

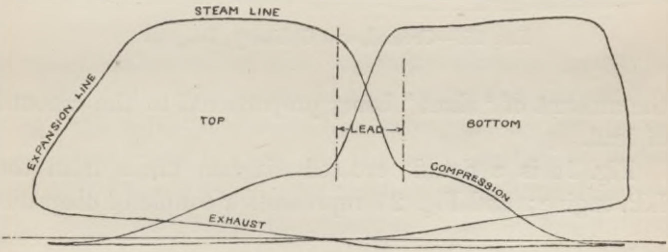


FIG. 24.—Crossed Diagrams.

the indicator cord being attached to the levers on the L.P. engine.

Fig. 25 shows a couple of diagrams taken from the bottom of the H.P. cylinder, the one drawn with the full line being taken with the indicator cord fastened to the H.P. lever in the ordinary manner, and the one dotted being delineated with the cord made fast to the L.P. lever.

It will be noticed that, in the former, the lead line is drawn at a time when the barrel of and the indicator is moving at its slowest speed, and therefore becomes nearly vertical, little or no idea of the amount of lead being given; whereas in the latter, the barrel is moving at its quickest speed when steam is first admitted, and the line consequently assumes a diagonal direction,

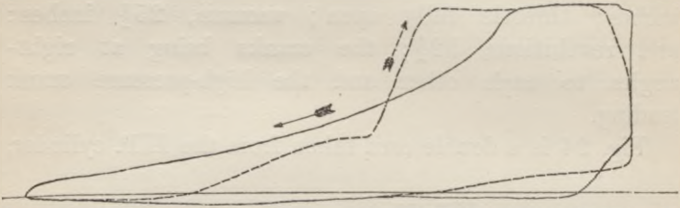


FIG. 25.—Crossed, and Ordinary, Diagram.

the amount of "slant" being proportional to the amount of lead.

Fig. 26 is a double crossed diagram taken from the L.P. engine; and Fig. 27 represents a couple of diagrams

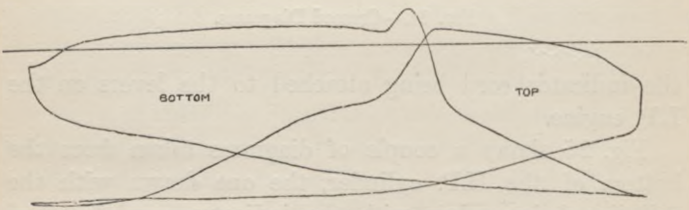


FIG. 26.—Crossed Diagrams.

taken from the top of the L.P. cylinder, the one being taken with the indicator cord fastened to the H.P. lever, and the other with it fastened to the L.P. lever.

Valve-Gear.—The link blocks in the valve-spindle heads, working constantly at the one end of the links, will cause the bars to wear more at the go-ahead end, and a ridge will soon be formed if the metal be at all soft. If such be the case, it is advisable to pin a couple

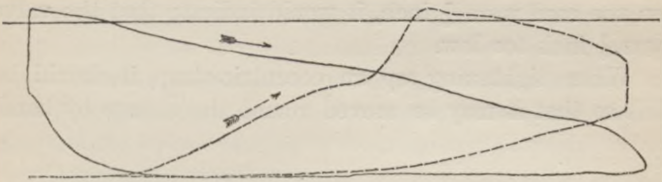


FIG. 27.—Crossed, and Ordinary, Diagram.

of steel plates on to this particular place, as shown in Fig. 28. Old files answer admirably for this purpose.

As the valve-gear wears, the valve will require to be raised from time to time, and the usual method of doing this is to place a liner under the foot of the eccentric-rod. The thickness of the liner required can be found to a nicety by means of the indicator card, without lifting

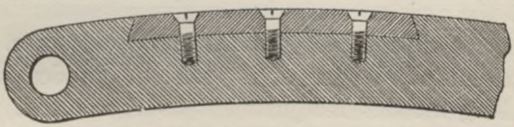


FIG. 28.—Quadrant Link pieced at End.

the casing cover or even looking at the valve, after having a little experience with the particular engine in question. Thus, supposing Fig. 29 to represent a double card showing the valve too low, A being the point of intersection of the expansion lines, and B C the vertical centre line of the card; then, if the cards be always kept the same length, experience will show the proportion that the distance between point A and the line B C bears to the amount that the valve requires to be raised. For instance, the ratio might be as 2 : 1, then if the distance on the card were $\frac{1}{4}$ inch, it would indicate that the valve was $\frac{1}{8}$ inch too low.

When tightening up an eccentric-strap, it should be left so that it may be moved round the sheave by hand,

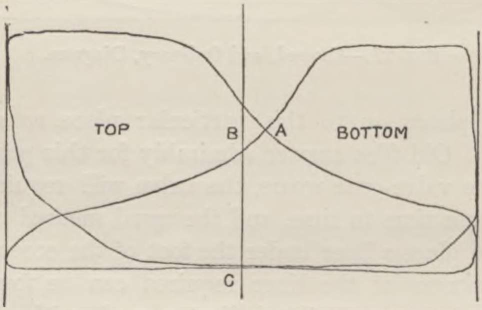


FIG. 29.—Card showing Valve too Low.

without the assistance of a bar to give a greater leverage—the eccentric-rod being disconnected of course. This will prevent all danger of it "seizing," besides wearing just as long without readjustment as it would if set up tighter, for it would then wear away more quickly.

It is a good plan to fit a pan below the eccentrics, which can be filled up with either oil, or soap and water, in which the eccentrics are allowed to work. It is a well-recognised fact that the use of the "bath" is the most successful method of lubricating, and, if thus provided, the eccentrics will work much better and cooler.

Reversing-Gear.—There is considerable diversity of design exhibited in starting-engines, but that patented by Mr. Brown perhaps bears the palm for handiness in working, and by its aid one is enabled to put the links over with almost as much facility as one could pull over the reversing lever of a winch. It usually gives very little trouble at any time, but when it does refuse to work it will generally be found that a piece of grit or dirt has got below one of the pump valves, and caused the trouble by preventing it from closing properly.

"All-round" reversing-gear, worked by a small engine, is now very commonly fitted, as the main engines may then be very efficiently heated up if, during the operation, the reversing-gear be kept slowly working. Moreover, by disconnecting the reversing-engine from the valve-gear, it can be utilised for turning the main engines when in port.

If the engines have been running constantly for many days without being stopped, it sometimes happens that the reversing wiper-shaft gets rusty where it passes through the supporting brackets, causing difficulty in throwing over the gear when required. This has occurred in several ships, and it is advisable to lift the covers of the brackets occasionally for examination, and take out the shaft and clean it if necessary. When coming into port, on first getting the order to stop the engines, it is always best to put the gear right over and give the engines a turn or two astern to see if they will reverse readily, if only for one's own satisfaction.

Linking up.—It is in many cases seldom required to work the engines up to their full power, and they can be adjusted to work at the required speed either by partially closing the throttle-valve and reducing the steam pressure if thought desirable, or by keeping the throttle fully open and linking up. The latter is the better and more economical method, for it is manifestly very wasteful to first expend heat in raising the steam to a pressure above that required, and then lose power by the friction of the steam as it is wire-drawn by the partially closed throttle-valve.

With triple-expansion engines it will always be found better to keep the throttle-valve fully open and link up, thus taking full advantage of the expansive property of the high-pressure steam.

Linking up, however, beyond a certain extent, has its disadvantages, for the travel of the valve is thereby reduced, consequently the valve face is liable to become worn unevenly, and, although the valve cuts off quicker, all its other movements are also hastened—the steam is admitted sooner, and the exhaust opens and closes sooner, perhaps causing negative work to be done by the excessive compression.

It is desirable for the smooth working of the engines to get the pressure on the cranks distributed equally, by making the engines develop as nearly as possible the same power. This is usually effected by linking up, for which purpose the reversing-lever for each engine is generally made with a slot at the end, carrying a block having a pin at each side to which the drag links are attached, the position of the block in the lever being regulated by a screwed spindle passing through it. By this arrangement each engine can be linked up separately to a small extent. For freedom of action in going astern, the slot in the lever is made at such an angle that the valve has its full travel when the gear is put fully over, in whatever position the sliding block may be. Referring to Fig. 30 which shows the link in full ahead gear, it will be seen that, if the sliding block be caused to move to the other end of the slot, the engine will be linked up to

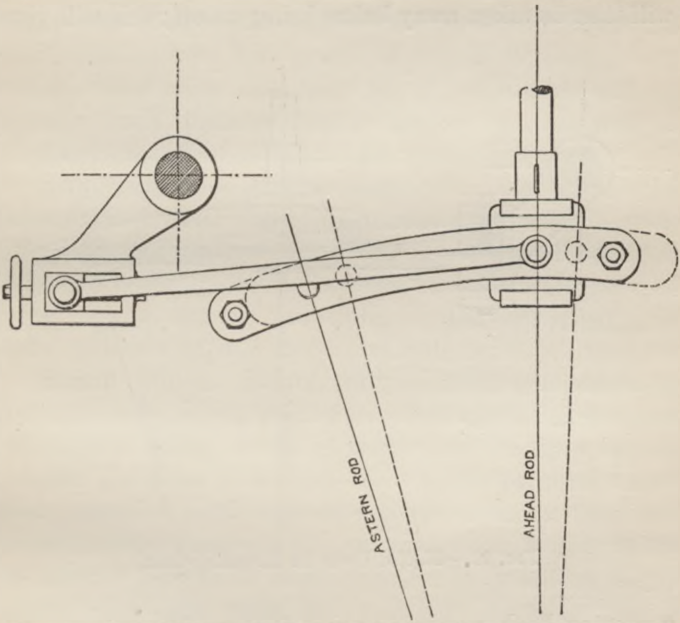


FIG. 30.—Slotted Lever for Reversing-Gear.

the extent shown by the dotted lines; but, if the gear be reversed, the lever will assume the position indicated in Fig. 31, and the engine will be in full astern gear at whatever end of the slot the block may be set.

By linking up the H.P. engine, the terminal pressure of the steam will be reduced, therefore the initial pressure of the M.P. engine will be less, and consequently the power of the M.P. and L.P. engines will be reduced.

Linking up the M.P. engine will have the effect of increasing the pressure in the M.P. casing, as less steam will then be taken away before being cut off; this will give

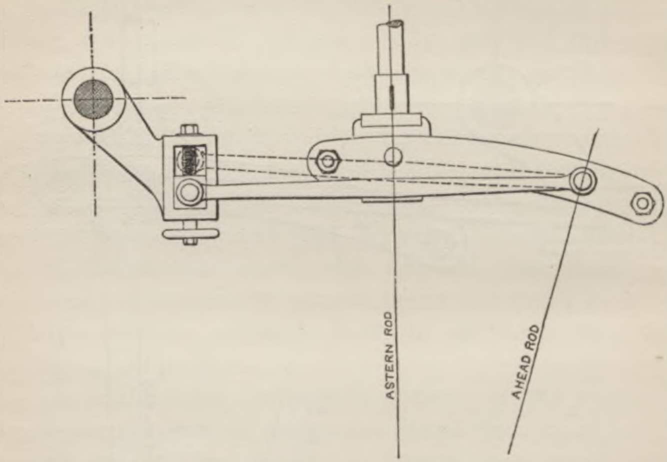


FIG. 31.—Slotted Lever for Reversing-Gear.

a greater back pressure to the H.P. engine, reducing its power; the power of the L.P. engine will remain very nearly the same, for, although the M.P. engine will have an earlier cut-off, its initial pressure will be greater, and the steam will exhaust at very nearly the same pressure in both cases.

Linking up the L.P. engine will increase its power by causing a greater pressure in the L.P. casing, the power of the M.P. engine will therefore be decreased by reason of the additional back pressure, but the H.P. engine will not be affected, consequently the power will remain as before.

Linking up both M.P. and L.P. engines will increase the power of the L.P. engine and decrease that of the H.P. engine, but the power of the M.P. engine will remain very much as before; for although there will be greater back pressure acting against it, this will be counterbalanced by the increased initial pressure.

Stop-Valves. — Before opening a stop-valve the accumulated water should be drained off if possible; but, if a drain cock be not fitted, the valve should be eased back very gently, or the sudden rush of water in the pipe, acting on the principle of the water-hammer, may cause the pipe or stop-valve to burst.

Steam Pipes, Joints, etc. — Until comparatively recently, main steam pipes were made almost exclusively of copper, owing to its strength and ductility, which enables the pipes to be easily bent to the required "set," and provided with expansion-bends whereby they can accommodate themselves to any movement that is likely to occur. Unless of large diameter they can be solid-drawn, and such pipes are preferable to those having longitudinal seams: should, however, a blow-hole or flaw exist in the ingot from which the pipe is made, it is possible that, in the process of manufacture, this may be drawn out into a long defect, which may weaken the pipe to a dangerous extent and at the same time be concealed from view. That flaws do exist in the form of cracks in the internal surfaces of such pipes was forcibly demonstrated in the case of a disastrous explosion from a steam pipe, which occurred in a vessel some two years ago, killing seven men. Another interesting, and, it is believed, unique feature in the instance referred to, was the rapid external wasting of the pipe, due, it is suggested, to the corrosive action of the asbestos lagging with which it was covered, where wetted by sea water which had penetrated between the pipe and the lagging. The failure of the pipe was attributable to the reduction in its thickness resulting from the external wasting, and the presence of an internal defect of the nature described.

When over about 6 inches diameter, copper pipes are generally made from rolled plates, bent to the required shape; the edges are then bevelled, overlapped, and brazed together, the line of brazing usually being zigzagged or cramped. For the high pressures now in vogue this is not a satisfactory method of making large pipes, as very few, if any, pipes fashioned in this way are wholly free from latent defects in the brazing, and serious calamities are constantly occurring from their use. In some cases of failure at the longitudinal joint, the brazing has had the appearance of having deteriorated, and was found to be abnormally deficient in zinc, but it is difficult to determine whether this was caused by electrolytic action while in use, or by volatilisation during the process of brazing. The only practical means of averting danger with these pipes is by the application of a suitable hydraulic test, and periodical examination of the seams, as far as possible, both inside and outside the pipes, reloading with spelter all edges which are deficient in that respect. Some makers take the precaution of "wiring" all main steam pipes having brazed seams, by binding them at intervals of 6 to 8 inches with rings made of, say, $\frac{1}{2}$ inch iron rods, put on hot and twisted at the ends to secure them in position; in such cases, however, the thickness of the pipe is usually less than would otherwise be considered necessary.

The weakness of a pipe due to defective brazing is naturally accentuated by any vibratory stresses to which the pipe may be subjected. Most failures occur immediately behind the flange, and the following are the principal reasons why this should be the case:—(1) Because the quality of the copper is often locally weakened by overheating while brazing; (2) because the junction of the flange and the pipe is a sharp corner extending round the pipe at right-angles to its axis; (3) because the whole of the strain due to vibration or shock is magnified and concentrated at this part.

Joints for pipes subjected to any great pressure, such as main steam and feed pipes, are sometimes made in the manner patented by Mr. Pope (Fig. 32), and designed with a view to eliminate any danger of the pipe giving out through defective brazing at the flange. The pipes are flanged round slightly at the ends, and held together in metallic contact by steel flanges, which are placed on the pipes previous to being flanged and afterwards bolted together.

Mr. C. Geddes has also patented what he terms a "Safety Flange," in which the edge of the spigot into which the pipe is inserted is corrugated, and forms a series of lugs or brackets, the advantages claimed for which are:—(1) They strengthen the pipe at its weakest part by protecting the line of brazing; (2) the strengthening brackets grip the pipe and receive the vibrations, which would otherwise be concentrated at the line of brazing; (3) the junction between the flange and the pipe is not in a plane at right-angles to the axis of the pipe, but the strains are distributed over a larger area of pipe surface; (4) the pipe is supported at points by the strengthening brackets, and the material between these points accommodates itself to the varying strains. The

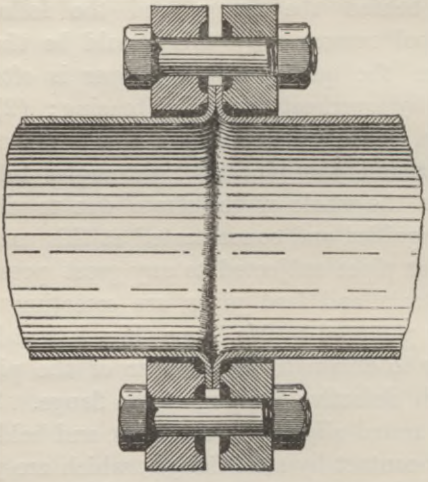


Fig. 32.—Pope's Pipe Joint.

line of brazing does not extend above the base of the brackets, and for facility in brazing these are cast slightly open, and afterwards hammered close to the pipe. Fig. 33 shows where the ordinary pipe is liable to give way; Fig. 34, Geddes' Patent Flange; and Fig. 35, the flange applied.

Copper pipes made by the electro-depositing process are specially liable to fail immediately behind the flange, and their anticipated success has not been realised in practice.

The failure of copper pipes, of any description, to give complete satisfaction, has led to the extensive adoption of wrought iron and mild steel for main steam pipes subjected to a high pressure. In these pipes the longitudinal joints are usually lap-welded; but, owing to the unreliability of welded steel when in tension, it is customary to rivet a strap over the weld when the pipe

FIG. 33.—Fractured Pipe.

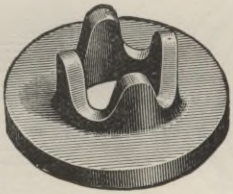


FIG. 34.—Geddes' Safety Flange.

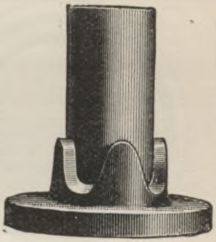


FIG. 35.—Geddes' Safety Flange applied.

is made of this material: comparatively small steel pipes are also frequently drawn from the solid, and are then, of course, seamless. The flanges are made from iron or steel plates, riveted or screwed on to the pipe with a vanishing thread; and, in the case of iron pipes, they are often welded on. Owing to their rigidity, these pipes are made as far as possible in straight lengths, and provision is made for their movement by fitting suitable expansion-sockets. Care should be taken to maintain these joints in good working condition by renewing the packing before it becomes hard. It should also be seen that the nuts on the studs for the guard flanges are not inadvertently screwed up while the pipes are hot, otherwise damage will probably occur on the contraction of the pipes when cooling; and it is advisable to dispense with the use of jam-nuts and fit a split-pin through each nut and stud, having previously adjusted the nuts when the pipes are cold.

If pipe flanges were bedded together, or scraped up

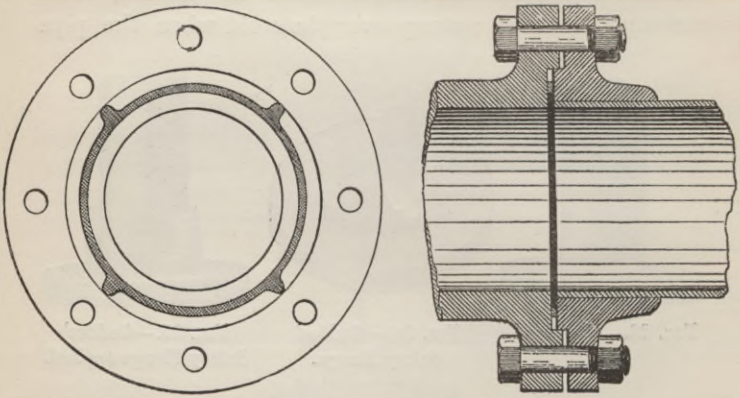


FIG. 36.—Metallic Joint for Steam Pipe.

true to a surface plate, nothing but a coat of paint would be required before screwing them together. This refinement is, however, seldom to be met with in practice, although the flanges should be sufficiently fair to enable tightness to be secured by a thin jointing medium. It may entail the expenditure of a little extra labour at first in bringing the flanges up to a good bearing, but future trouble with the joint will be prevented by the operation. The jointing materials now on the market have quite as varied a character as the packings, being fibrous, vegetable, semi-metallic, metallic, plastic, flat, corrugated, etc. The selection will necessarily be governed by circumstances, but a metallic joint is usually to be preferred. If the flanges be formed with a spigot and faucet, an excellent joint may be made of thin sheet copper, from $\frac{1}{32}$ to $\frac{1}{16}$ inch thick, cut out in the form of a ring, from $\frac{1}{8}$ to $\frac{3}{16}$ inch broad, as shown in Fig. 36. The four projections shown in the figure are lugs to hold the ring in the centre of the recess in the flange while screwing up.

Bearings.—The pressure on the bottom half of a bearing must, for a vertical load, be considered as acting not on an area equal to the actual bearing surface—that is, the area represented by the length of the bearing multiplied by half the circumference—but by the area of this surface as represented in plan on the horizontal plane, or the length multiplied by the diameter. For instance, imagine Fig. 37 to represent the bottom half of a brass supporting a shaft, then the total load on the surface represented by the arc B D (multiplied by the length of the bearing) is equal to the total load on the surface D E, if the distance between the verticals A B, C D, and point E, measured horizontally, be equal. The length of the arc E D may be twice as long as the arc B D, however; consequently, although the total load be the same on both surfaces, the average pressure per

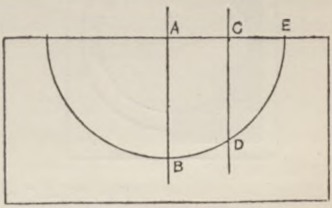


Fig. 37.—Bearing.

square inch will be twice as great on B D as on D E. Hence it will be understood why the surface at the sides of a bearing are of very little actual use, and they may with advantage be partly cut away, as shown in Fig. 38, so as to allow the oil to pass from the top half to the lower brass; but the recess should not be carried along quite so far as the fillets, or the oil will escape without lubricating the bottom brass.

From the above reasoning it will also be seen that the best place to admit the oil to a bearing carrying a

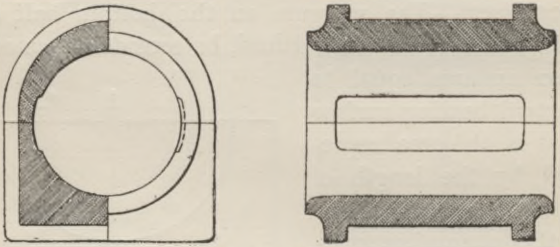


Fig. 38.—Crosshead Brasses.

steadily revolving shaft is not directly on the top, but at the side, where the pressure is not so great.

For eccentrics, main bearings, etc., where the motion is usually in one direction, the oil-gutters should be cut leading away from the oil-hole in the direction of motion, as shown in Figs. 39 and 40. It is useless to extend them in the other direction, for it not only destroys useful bearing surface, but the oil will obviously not flow in that direction against its adhesion to the journal, and the engines are seldom or never worked for a very long continuous time going astern.

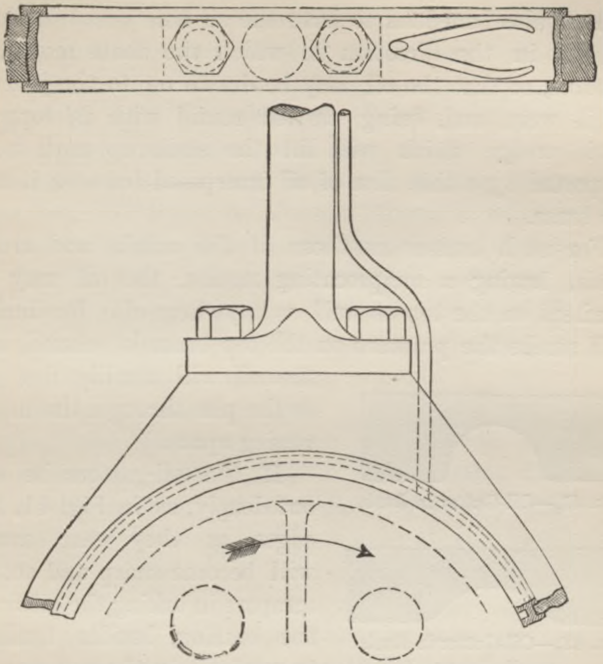


FIG. 39.—Oil-Gutters in Eccentric Strap.

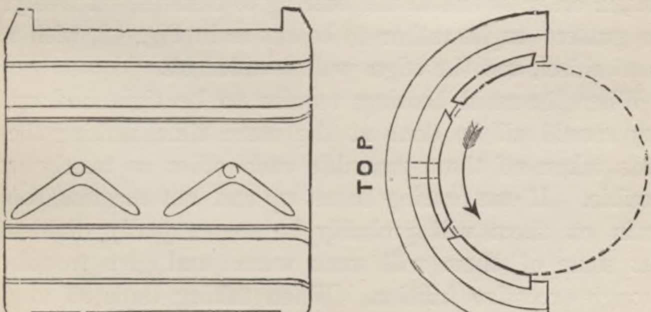


FIG. 40.—Oil-Gutters in Bush.

It is also beneficial to have the oil-hole bored inclined slightly in the direction in which the shaft moves, if possible, so that the oil may be drawn on to the journal as it were, and, being carried round with it, form a liquid wedge which will lift the shaft up until it is supported by a thin film of oil interposed between it and the brass.

For such brasses as those of the cranks and cross-heads, having a reciprocating motion, the oil may be admitted on the top as well as anywhere else, for during each stroke the pressure on the top brass is relaxed, and the oil will readily flow on to the pin through the intervening space.

FIG. 41.—Oil-Gutter in Bush.

FIG. 42.—Oil-Gutter in Bush.

If the oil-gutters be cut out deeply, as in Fig. 41, the edges, as they wear away, will become sharp and act as scrapers in taking the oil from the bearing, besides tending to retain it in the gutters; so that, in order to enable the bearing to take the oil freely, the gutters ought rather to be cut as in Fig. 42, with a broad chisel, and the edges well rounded off.

When the main bearings require to be tightened up, they should all be done at the same time, making the leads taken off them resemble each other as nearly as possible. If one bearing be set up and not the rest, the strain on them will probably be so unequally divided that some of them will work warm and give trouble through excessive friction. When taking leads off any bearing, a better idea of the manner in which they bear on the journal will be formed if they be placed diagonally from corner to corner than if simply laid square across the shaft.

Cranks and Crossheads.—When overhauling the cranks and crossheads, the pins should be carefully examined to see if any flaws are making themselves apparent. If there be a crack there, a mark with a centre-punch should be made at each end of it, so that it may be seen when next examined whether it has extended. Circumferential flaws weaken a shaft more than those running in a longitudinal direction, as they reduce the effective diameter. Should a crack be discovered in a position likely to seriously weaken the forging, the depth to which it extends should be ascertained, so that it may be seen whether it necessitates the renewal of the part affected. This may generally be done by boring a hole at the flaw with a small flat-pointed drill, carefully watching the borings to note when they cease to break off at the crack, and taking out the drill from time to time in order to examine the hole. If this should not be feasible, a rough idea of the extent of the damage may be formed by heating the forging with a "blower," and noting the amount of oil which exudes from the crevice, and the distance between the edges when the metal is thoroughly warm.

Sometimes a slight lamination is found on the surface of a pin or shaft, more especially when made of iron, where the metal has not been welded together properly during the process of forging. This should be raised and cut off, and the surface carefully scraped and smoothed up afterwards with an old file.

With the modern style of built crank, flaws are not so frequently met with as was the case with the old form of solid crank, for not only are such cranks freer from imperfections to start with, but the grain of the metal lies in a direction better calculated to withstand the working stresses.

After being at work for some time, crank bushes of the usual circular form will be found to come in at the sides when cold; consequently, when they are remetalled they should not be eased too much at these parts, for, when working and the heat comes on the inside, they will open out clear. Tightening up the bolts also helps to make them spring out.

It is generally unnecessary to take leads off the cranks, except for the purpose of ascertaining whether the bushes are bearing evenly or "cape-and-corners." When the bushes require to be adjusted and time is limited, if the parting-pieces be taken out, the nuts tightened up equally on each side with a spanner by hand, and their position then marked, one will easily find out, after one or two trials, how far back from the marks the nuts must be placed for that particular crank. The liners can then be stripped to suit, leaving them slack enough for the nuts to draw up, say $\frac{1}{2}$ inch or $\frac{5}{8}$ inch past the working marks, for adjustment in intermediate ports. In this manner a crank may be tightened up in a fraction of the time that it would take if leads were taken off.

A propos of marking the nuts, instead of the rough and ready way of continually scraping out the old marks and making fresh ones with a scriber, it is a good plan to mark all the large nuts permanently, as shown in Fig. 43. The distance between the mark on the bolt and the nearest mark on the nut can then be gauged with a pair of compasses previous to slackening the nut back. Another very neat arrangement is made by securing a small brass pointer to the top of the bolt or stud by means of a screw-pin, about which it can be turned and directed to a permanent mark on the top of the nut, and afterwards tightened in position.

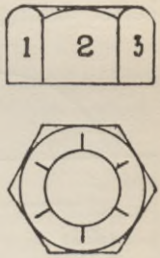


FIG. 43.—Marked Nut.

If time permit when overhauling the cranks, the oil-pipes should be taken down and cleaned, either by blowing steam or hot water through them, or pouring down a solution of caustic soda.

Guides.—If the condensed water in the cylinder jackets be allowed to accumulate, through neglecting to draw it off as formed, the contraction of the metal forming the bottom of the cylinders, consequent on it being cooled, will bring the guides closer together, thus tightening on the guide-shoes and causing them to work warm. Whenever a guide gets hot, therefore, the steam should be opened fully to the jackets so as to help to expand the guides apart. The engines should at the same time be slowed down if possible, and the guide slaked with a copious supply of oil, thickened with a little white lead, until the heat has somewhat abated.

If the combs on the guide-shoes do not pick up the oil from the cups and distribute it over the surface of the guides as they should, thus causing them to work warm, matters may sometimes be improved by placing combs of leather at the back of the brass combs.

Condenser.—In the case of the long fore-and-aft condensers now commonly fitted, a great deal of the cooling surface does little or no good, consequently the amount of surface might be greatly reduced could it be better arranged. It has in some cases been considered beneficial to fit the tubes so as to form a V-shaped channel, as shown in Fig. 44, instead of carrying them square across the top of the condenser. With this arrangement it is claimed that the steam, on entering the condenser, spreads over the surface of the tubes in a more efficient manner.

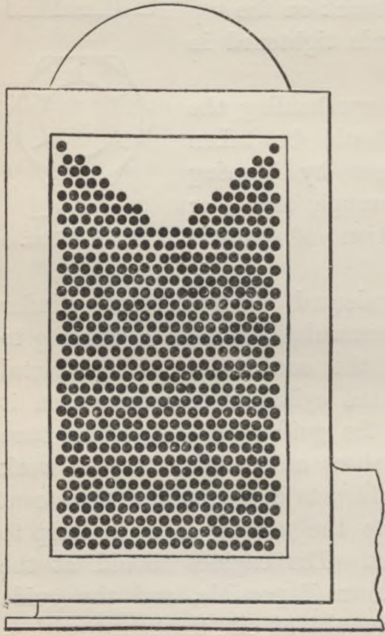


Fig. 44.—Method of Tubing Condenser.

In long condensers, also, the centre tube-plates, which are meant to carry up the weight of the tubes, may sometimes interfere with the steam getting to the end of the condenser, unless suitable perforated baffle-plates be placed under the exhaust pipe, or some other efficient arrangement be provided for carrying the steam over these plates.

It does very little good in the way of cleaning the tubes to give injections of caustic soda when under way, while by so doing a quantity of dirt and grease may be put into the boilers. The best way is, when in port, to fill the condenser with a strong solution of caustic soda and let it remain there for the night, running it out afterwards and then scalding the tubes with steam or hot water, in order to wash off the grease loosened by the soda. If the air-pump be fitted with rubber valves, they should be taken out while doing this, otherwise they will be damaged by the caustic soda. When the tubes become very dirty—that is, too dirty to clean with caustic soda—they will require to be drawn, and, together with the condenser, thoroughly cleaned. For the purpose of drawing the tubes some ships are provided with tube

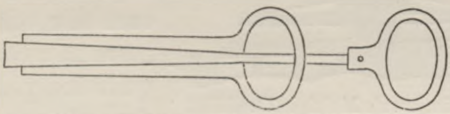


FIG. 45.—Condenser Tube-Extractor.

extractors, somewhat like or similar in principle to that shown in Fig. 45. The tubes ought not to be very tight, and, if an extractor be not at hand, they can be started just as well with a pair of pliers.

Air-Pump.—When packing the air-pump bucket, it should not be left so tight a fit that it requires to be hammered down into the chamber. It should descend by its own weight, otherwise it will constitute an unnecessary drag on the engine. Brass packing-rings are now frequently fitted instead of packing the buckets in the old-fashioned way with coils of Manilla rope, and this is certainly a preferable arrangement. Provided the bucket is a fairly good fit in the pump chamber, however, there is absolutely no need for it to be packed at all, and if there be no packing, no power can be wasted on it, and no breakdowns can occur in consequence of it getting out of order. When designed for use without packing, it is usual to turn a few grooves on the periphery of the bucket to secure a water-seal.

Rubber and fibre valves, too, are being discarded for the more durable ones made of metal, such as those of Kinghorn, Beldam, Thompson, etc., which are unaffected by hot water or engine oils. Kinghorn's "Multiplex" valve is one of those most extensively adopted. This valve is shown in Fig. 46, and consists of a number (usually three) of superimposed metallic discs, each disc being free to move on a central stud quite independently of the others. The bottom and intermediate layers are perforated with a number of holes, these being so placed that, when all the discs or layers are closed together, no passage way through them is formed. As the valve opens, the discs or layers open simultaneously or independently, allowing particles of air or water to pass in between them—these particles act to cushion the impact of the valve against both guard and seat, thereby lessening the sound of the impact, as well as minimising the strain on both valve and stud. In the unlikely event of either all or part of the discs or layers getting fractured or carried away, these being thin and pliable, no damage is done to the pump, as is often the case with some of the other forms of valves. Should either of the

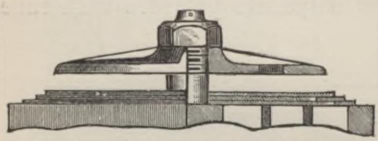


Fig. 46.—Kinghorn's Multiple Dead-Lift Pump Valve.

intermediate layers get fractured, which seldom occurs, the layers remaining intact serve to keep the action of the pump from being seriously impaired.

Another form in which Kinghorn valves are made is shown in Fig. 47. The valve consists of a thin metallic flap, fitted with a guard, having the bottom curved upwards, to limit the flexure of the valve when working. Sometimes the valve is made in two layers, that at the bottom being perforated with holes, as in the case of the disc valves, to cushion the impact of the valve on striking the grid or the guard, and to provide a double security against damage.

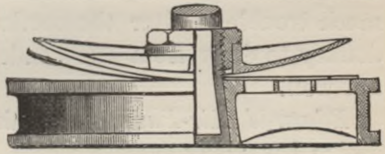


FIG. 47.—Kinghorn's Flexible Pump Valve.

Fig. 48 illustrates one of Beldam's corrugated valves, which are very strong and at the same time light, and they are also adapted to any class of pump.

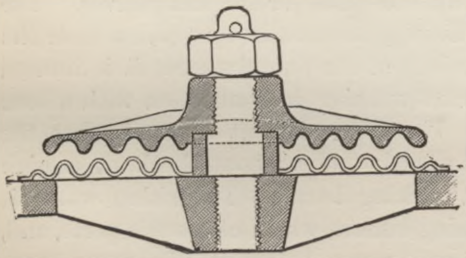
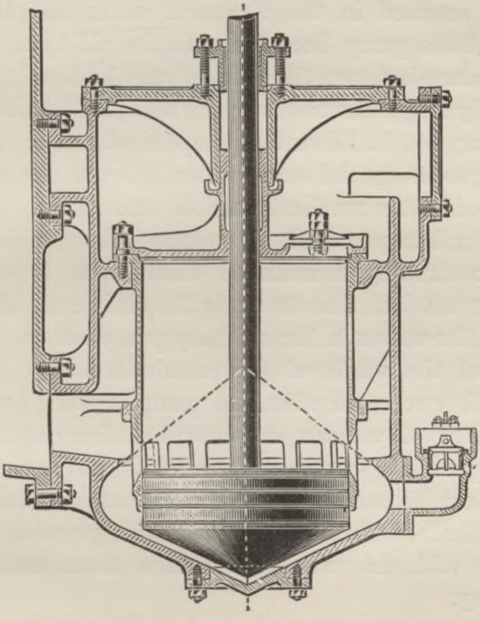


FIG. 48.—Beldam's Corrugated Pump Valve.

A great loss of fresh water generally occurs at the hot-well overflow when starting the engines, after they have been standing for some time. Where the donkey has a connection from the bottom of the condenser, this loss can be avoided by pumping the water from it into the boilers before starting the main engines. In most cases, however, the donkey merely draws from the hot-well, and, although it may be kept running whilst starting the engines, it is not capable of preventing the loss at the overflow. In many instances where there is such an arrangement as the latter, it would not require much trouble to alter the suction pipe, and fit it for the donkey to draw from the condenser as well as from the hot-well.

Edwards' Air-Pump.—An air-pump of the ordinary design has many defects which have been circumvented by Mr. Edwards in his patent pump, and, in describing this very successful appliance, some of the principal objections to the older type of pump will be alluded to. The essential feature of Edwards' air-pump is that the water is dealt with mechanically, and is in no way dependent on the pressure in the condenser to drive it into the pump, As will be seen by a reference to Fig. 49, there are no foot or bucket valves. The condensed steam flows continuously by gravity from the condenser into the base of the pump, whence it is diffused by the conical bucket working in connection with a base of similar shape. Upon the descent of the bucket, the water is projected silently and without shock, at a high velocity, into the working barrel. The rising water is followed by the rising bucket, which closes the ports, and, sweeping the air and water before it, discharges them through the valves at the top of the barrel.

In the old pump the air has to find its way through the water into the barrel as best it can, for the water traps it out. Moreover, after the air has opened the valve it has to change its direction and travel horizontally through the contracted opening due to the lift, and then travel vertically again, the water being against it the whole time. In Edwards' pump clear air inlets are maintained, and when the air and water come into



No Foot or Bucket Valves.

FIG. 49.—Edwards' Air-Pump.

contact, the water is travelling at a high velocity into the barrel and the water is employed to assist the air in.

Before an air-pump can discharge, all the air in the working barrel above the bucket must be compressed to a pressure slightly in excess of the atmosphere. Immediately the bucket descends, the air bubbles remaining in the clearance water expand, and occupy space in the pump which should be available for a fresh supply of air from the condenser. With a large top clearance, the more air the pump has to deal with the greater is the quantity retained in the clearance water, and the more inefficient the pump becomes. In the old type of pump the clearance between the bucket and head valve seat is necessarily large, due to the space occupied by the bucket valve, etc.; but in Edwards' pump this defect is remedied, as, owing to its special construction, the top clearance can be reduced to the smallest possible amount.

The further practical advantages about this pump, which so strongly recommend themselves to engineers who have not had time to study the design, are that two-thirds of the valves in the ordinary pump are not required at all, and the whole of the remainder can be cleaned, examined, or renewed when the pump is going full speed, without loss of vacuum or water, by taking off the door at the top of the pump. The result is that a cheap type of valve can be used until it is worn out, without risk of inconvenience or breakdown; and it is possible to go to sea even with old valves, and renew them easily while under way.

Another very great practical advantage is the enormous reduction in the time required to overhaul the pump; because, when it has once been thoroughly tried and afterwards examined so that it is known to be sound, it will rarely be necessary to open it up for examination. Again, the cost of renewing two-thirds of the valves, etc., the first cost of the door in the barrel, and the time occupied in opening and closing it, are all saved; and the whole of the valves can always be got at in whatever position the engines may be, and without disconnecting any gear.

How to Renew the Valves in Edwards' Pump while under Way.—Hold the valve down with the left hand, slacken the nuts, and then place the spanner, nuts, and guard *outside* the pump in some convenient position. Don't attempt to lift the old valve off; the pump will drive it off far more quickly and cleanly than can be done by hand. While the old valve is being held down with the left hand, hold the new valve in the right hand ready to put it on, but quite clear of the old one, so that the latter will not be stopped when it is being driven off. Watch the pump crosshead, and immediately it begins to descend, slide the left hand off the valve, but leave the end of one finger just touching it (not holding or checking it). The next time the pump discharges, the valve will be driven right off the stud. Immediately you feel it has gone, slide the left fingers over the seat, and raise them to make sure the old valve will not return; place the new valve over the stud, and the atmosphere will at once drive the new valve hard down on to its seat; then hold the valve down until the guard and nut, etc., are replaced.

No tools must be used which could possibly pass down through the seat, and care must be taken not to leave anything in the pump when or after making the change.

Circulating-Pump.—The friction of the water passing through the condenser tubes is very considerable, and if the circulating-pump be so arranged as to discharge into the condenser, the work of overcoming the friction devolves on the pump, to work which then means the expenditure of a lot of power. This is avoided if the suction pipe be led *from* the condenser, the water then flowing in by reason of the head of water outside, the pump merely having to lift it overboard; moreover, the condenser is not subjected to so great a pressure.

Should at any time a patch require to be put on any of the pumps where cracked or corroded away, a very good putty to use can be made of cement and tar. The patch may not be a very good fit, but if some of this putty be put on before screwing it up in its place, it will be found to be quite tight afterwards, for it dries in a remarkably short time, and is then as hard as concrete. It is not suitable, however, where there is much heat, as the tar then melts and runs out; but, where subjected to cold water, nothing is better. The American preparation termed "Smooth-on" is an excellent cement for anything of this sort, and will in many ways be found extremely useful for stopping leakage from water, steam, or oil.

Main Feed-Pumps.—The feed-pumps often give a great deal of trouble, and when they are working irregularly it will often be found that the suction inlet valves are open too much, and the pumps, after two or three strokes, clear the hot-well of water, and for the next few strokes they will be choked with air and refuse duty, the overflow being in full action meantime. The inlet valves should be open just sufficiently to keep the suction pipe full of water. A small hole bored through the suction valve, or both it and the discharge valve, will often relieve the pump of the heavy thumping. A better arrangement to relieve the valves, however, is to fit a small cock on the suction valve chest above the valve, and connect by a pipe to the hot-well or feed suction pipe. The cock can then be kept fully open or partially closed, as found necessary.

Feed-Heaters. — It is quite as much for the purpose of increasing the durability of the boiler, as from an economical point of view, that feed-heaters have been so extensively used—more especially since the introduction of high-pressure steam and the triple-expansion engine. In the first place, by introducing the water into the boiler at a high temperature, there is not so great a local variation of temperature, and consequently less strain on the plates and landings due to unequal expansion. Then, again, the corrosion of the boiler plates may, in some measure, be attributed to the oxygen of the air that is mixed up in the feed-water, but by the use of suitable feed-heaters this free air is expelled, and the corrosion thereby greatly reduced. A lot of the heat, that would be otherwise usefully employed in heating the water, is wasted in heating this air, which, being a bad conductor, still further hinders the raising of steam, and it will consequently be found far more difficult to keep steam when the feed is not heated than when a heater is used.

The Weir system of feed-heating on the compound principle is generally acknowledged to be the method which secures the greatest amount of advantage with the least expenditure, and may result in a fuel economy of from 5 to 8 per cent., according to the steam pressure carried and the number of expansions in the engine.

Fig. 50 represents a sectional view, showing the general construction of Weir's direct-contact feed-heater.

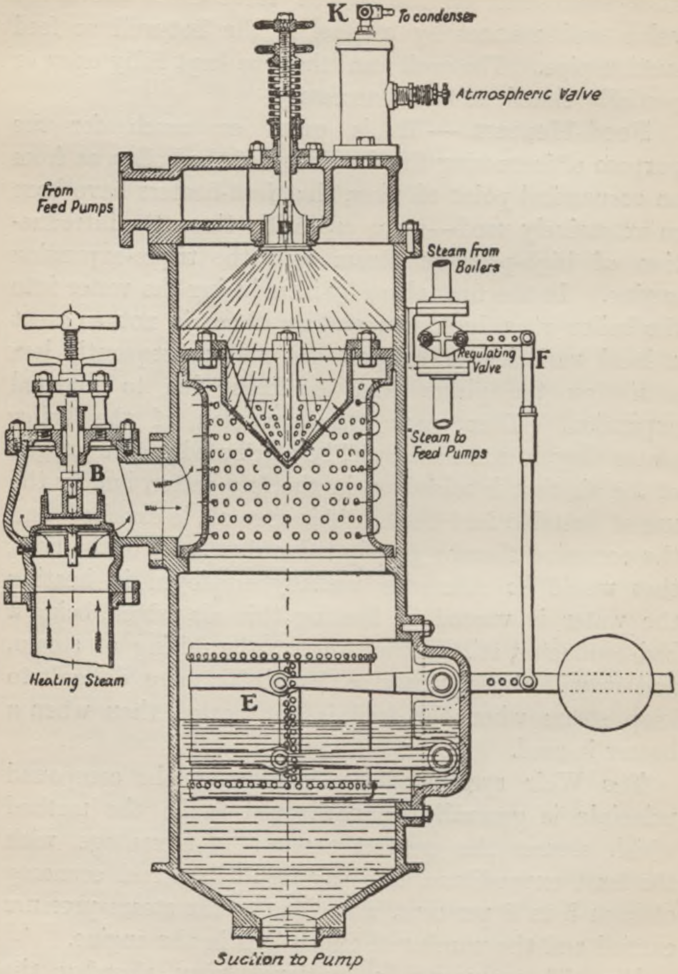


Fig. 50.—Weir's Direct-Contact Feed-Heater.

The feed-pumps attached to the main engines are used to take the feed from the hot-well, and discharge it into the top of the heater. It passes the spring-loaded valve on the cover in the form of a thin sheet, and is instantly heated by contact with the steam, which is taken from the low-pressure casing of the main engines and the exhaust of the auxiliary engines, such as those connected with the feed-pumps, electric light, forced draught, etc., and is admitted to the heater through the non-return valve at the side of the apparatus. This steam admission valve can be opened to admit the necessary amount of steam to the heater, but it closes by its own weight in case there is no flow of steam into the heater ; it is also fitted with a dashpot, which allows the valve to close gradually, and prevents hammering on its seat in case of fluctuations of pressure. Below the spring-loaded spray-valve a circular ring and conical spray-piece with perforations are fitted, to mix the water and steam uniformly. As the pressure in the heater is generally much less than that of the heating steam before passing the inlet valve, the effect of this lowering of the pressure and sudden heating of the water is to liberate the air in the water, which rises to the air-vessel on the top of the heater, whence it can be drawn off, either to the condenser or the atmosphere, through a small cock on the top. The feed-water is thus rendered non-corrosive, and falls to the bottom of the heater at the boiling temperature due to the pressure. It is then removed and forced into the boilers by the " Weir's " donkey, the speed of which is automatically controlled by the amount of water in the heater. The float shown in the lower part of the heater is a pan, with water-tight bottom and sides, but open on the top. It is suspended on two levers, so as to move up and down in a parallel motion; the top lever spindle is carried through the door at one end, and is balanced by a level and weight. The float is always full of water, and the weight is adjusted to balance when one-half is submerged in the water. To the weight lever another lever is attached, which actuates the throttle-valve and controls the supply of steam to the pump drawing from the heater. When the water in the heater rises, the float is raised, and the throttle-valve opened; and when the water-lever is lowered, the float follows, and the valve is closed. The water-level is thus kept constant in the heater, and the pumps are completely filled with water. The regulating cock for steam to the donkey-pumps is made with a parallel key; the pressure of the steam keeps it perfectly steam-tight, although it may have worn slack in the shell; the pressure also keeps the shoulder of the key against the bottom of the stuffing-box, so that the stuffing-gland is always kept slack. (It is well to keep the gland packed, in case of leakage.) A relief-valve and the necessary pressure gauges are also fitted to the heater, which should be placed at some height above the pumps, as the hot water, being at the boiling temperature, must force its way into the pump by gravity, the necessary height depending on the efficiency of the pump. Six or eight feet is sufficient with a good pump, but twenty feet or over is usually available aboard ship, and when this is the case should be utilised.

A point of the greatest importance is the relation of the temperature of the feed-water to the pressure in the heater. When the heater is fairly clear of air, the temperature of the feed-water should be as follows :—

Pressure in L.P. Receiver.	Temperature of Feed.
5 lbs. vacuum, ...	180°
2 lbs. "	190°
1 lb. "	200°
0 lb. atmospheric pressure, . .	205°
1 lb. pressure, ...	210°
2 lbs. "	213°
5 lbs. "	220°

If the heater shows a lower pressure than the casing, the cock to the condenser is too far open, and should be closed until only open far enough to take away the air which enters with the feed-water. If this be properly understood and practised, the pumps will always work well ; but if the pressure in the heater be allowed to fall below that corresponding to the temperature of the feed, the pump will instantly start to knock and work irregularly. To prevent this, an atmospheric inlet valve is fitted on the air-vessel, and the spring of this valve should be adjusted to balance the atmosphere, and no more, when the pressure in the heater is below that of the atmosphere. In most cases, when the engines are working at full speed, the pressure in the heater is greater than that of the atmosphere, and in this condition the spring should be left quite slack, as the pressure will keep the valve closed.

The feed-heater seldom or never requires any repairs, but ought to be opened up and cleaned about once in twelve months.

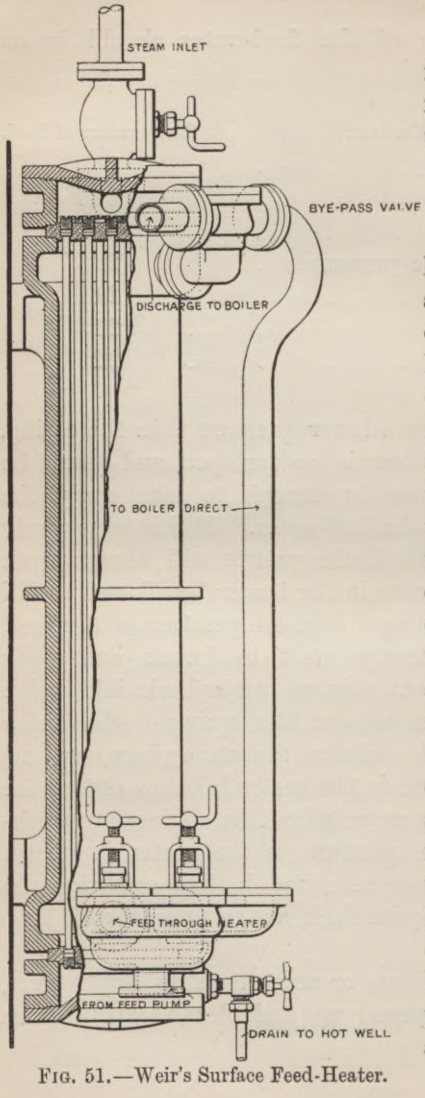


FIG. 51.—Weir's Surface Feed-Heater.

In cases where, from want of head room or other reason, the direct - contact feed-heater is inadmissible, Weir's patent surface feed-heater is used with advantage. This style of heater is shown in Fig. 51, and consists of a cast-iron or gun-metal shell, according to requirements, in which is placed a number of heating tubes. The end covers can be readily taken off for access to the tube ends, and, by the arrangement of by-pass valves the feed-water can be sent direct to the boilers should it become necessary at any time to shut off the heater. It is placed in any convenient position between the feed-pumps and the boilers, and forms practically a portion of the main feed pipe. Direct, intermediate, or exhaust steam is used, the temperature to which the water is raised depending on the steam pressure available. The heater is lagged with planished sheet steel.

Weir's Patent Feed-Pumps.—These well-known pumps are generally fitted in pairs, each single pump being entirely independent of the other as regards working. They are designed to work at a moderate speed, each single pump, unless in special cases, being suitable for supplying feed-water for the full engine power. They thus last longer and work more satisfactorily than pumps running at a high speed. They also

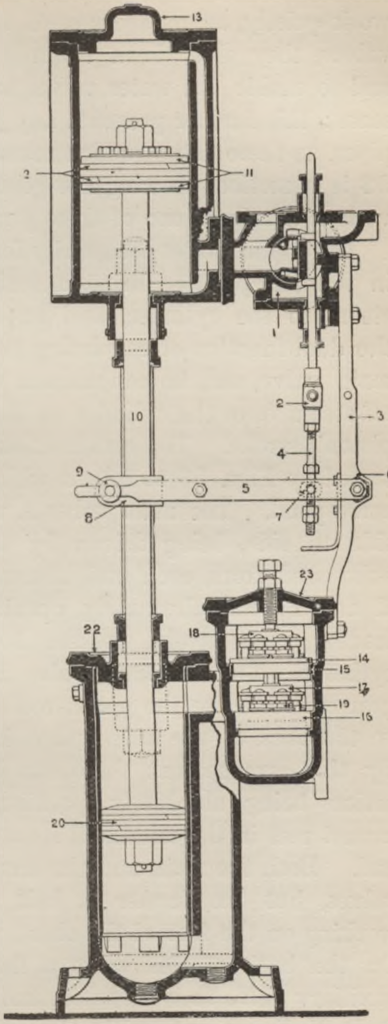


FIG. 52.—Weir's Feed Donkey-Pump.

work quietly, as, on account of the special type of steam valves, they slow down towards the end of the stroke, and so enable the water valves to settle quietly on their seats ; this further prevents any jar or shock in the feed-pipes, as there is no sudden reversal of the piston. Fig. 52 is a section showing the general arrangement of the various details of one of these pumps.

The steam valves necessarily form an important feature in the pump, there being a main valve for distributing steam to the cylinder, and an auxiliary valve having the dual function of regulating the steam for working the main valve, and, in conjunction with this valve, cutting off steam from the cylinder at the required period of the piston's stroke. The construction of these valves is illustrated by Figs. 53 to 58, in which the reference letters correspond. The main valve A moves horizontally from side to side, being driven by steam admitted to, and exhausted from, each end alternately through the ports E and F, and alternately opening the ports C and D leading, respectively, to the bottom and top of the cylinder. The auxiliary valve B is actuated by lever gear connected to the piston-rod of the pump, and moves on the back of the main valve A in a vertical direction. By this arrangement there can be no dead centre, the action being absolutely positive, for the main valve cannot rest in the middle of its stroke, but only at either end. Both the main and the auxiliary valves are slide-valves, but the former is half round, the round side working on the face of the chest, which is bored to suit. On the back of this valve a flat face is formed for the auxiliary valve to work upon, and on this face the ports C D E F are cut, with the exhaust port H in the centre. Both ends of the main valve are lengthened to project beyond the valve-chamber face; they are turned cylindrical, and work in loose caps or cylinders, each of which is held in position by the end cover and a face cast on the chest for the purpose.

The action of the valves is as follows:—When the piston is at the bottom of the stroke, the main valve is on the right-hand side of the chest, in which position the port C, leading to the bottom of the cylinder, is open to the steam pressure. This port remains open until the piston is at half stroke, when the auxiliary valve begins to move upwards, and closes the port at about three-quarters stroke, the remaining portion of the stroke being completed by the expansion of the steam shut in the cylinder, or by more steam admitted through the by-pass, which will be described later. As soon as the piston has completed the up stroke, the auxiliary slide opens the exhaust port E, leading to the left-hand end of the main slide, and, the right-hand side being open to steam through the port F, the main valve is thrown over towards the left, until the port E is closed, and a cushioning action is produced by the enclosed steam, which prevents the valve from hitting the cover on the end of the chest. In this position the port C, which admitted steam to move the piston during the up stroke, is open to exhaust, the port D, leading to the top of the cylinder, being open to steam, and a succession of operations is performed during the down stroke very similar to that described for the up stroke, until the cycle is completed.

Under certain conditions it is necessary to admit steam to the cylinder after the auxiliary valve has closed the main port C, or D, on the face of the main valve, as,

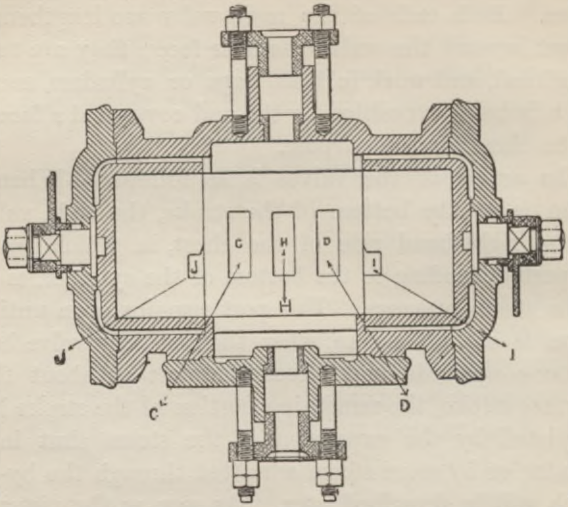


FIG. 53.—Sectional Front Elevation of Valve Chest, the Valves being removed.

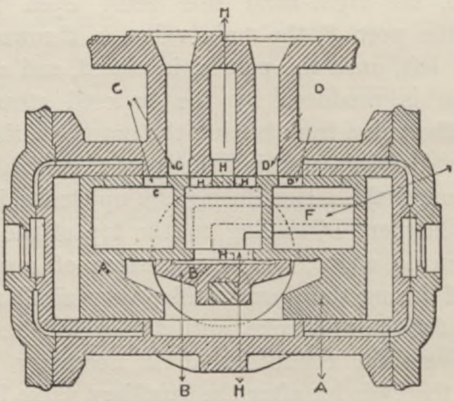


FIG. 54.—Sectional Plan, showing Valves in position.

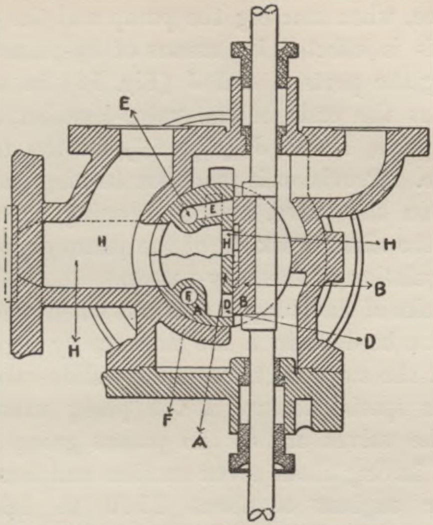


FIG. 55.—Sectional Side Elevation.

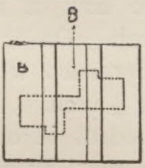


FIG. 56.—Auxiliary Valve.

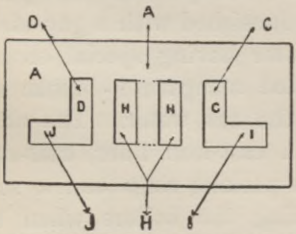


FIG. 57.—Main Valve Face.

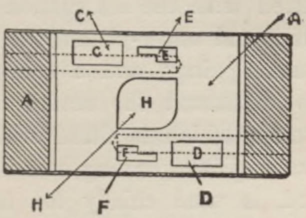


FIG. 58.—Main Valve Back—Face for Auxiliary Valve.

for instance, when starting the pump and the cylinder is cold. This is effected by means of by-passes, arranged by cutting the ports I and J (Fig. 53) in the caps or cylinders at the ends of the valve-chamber, and corresponding ports, I and J (Fig. 57), in the face of the main valve. Provision is made for turning each of these cylinders on the valve, and so opening or closing the port, and the silent working of the pump depends on the proper regulation of these by-passes.

The stroke of the pump is constant when once adjusted, and this can be done in a few minutes by regulating the position of the stops on the auxiliary slide-valve spindle.

Another special feature is the pump valve arrangement. The valves are of the patent group type, each valve seat having about seven suction and four discharge valves for engines of about 1500 to 1600 I.H.P. They are specially designed to give a large opening with a small lift, for the free flow of the hot water, the maximum lift being $\frac{1}{4}$ inch. On the discharge valves are light springs, the compression when the guards are bearing on the studs being $\frac{1}{8}$ inch.

The pumps are independent of one another, but are interchangeable in every part, except that the pump fitted with the sea suction is furnished with a gun-metal liner and water-piston, the latter having special ebonite packing-rings, and a cold-rolled manganese - bronze rod to withstand the action of the sea water. The other pump, which is fitted with a cast-iron liner, cast-steel water-piston, having cast-iron packing-rings and a steel rod, is used chiefly for feeding the boilers when the heater is in operation, one pump being of sufficient size to do all the work. The pumps are so arranged,

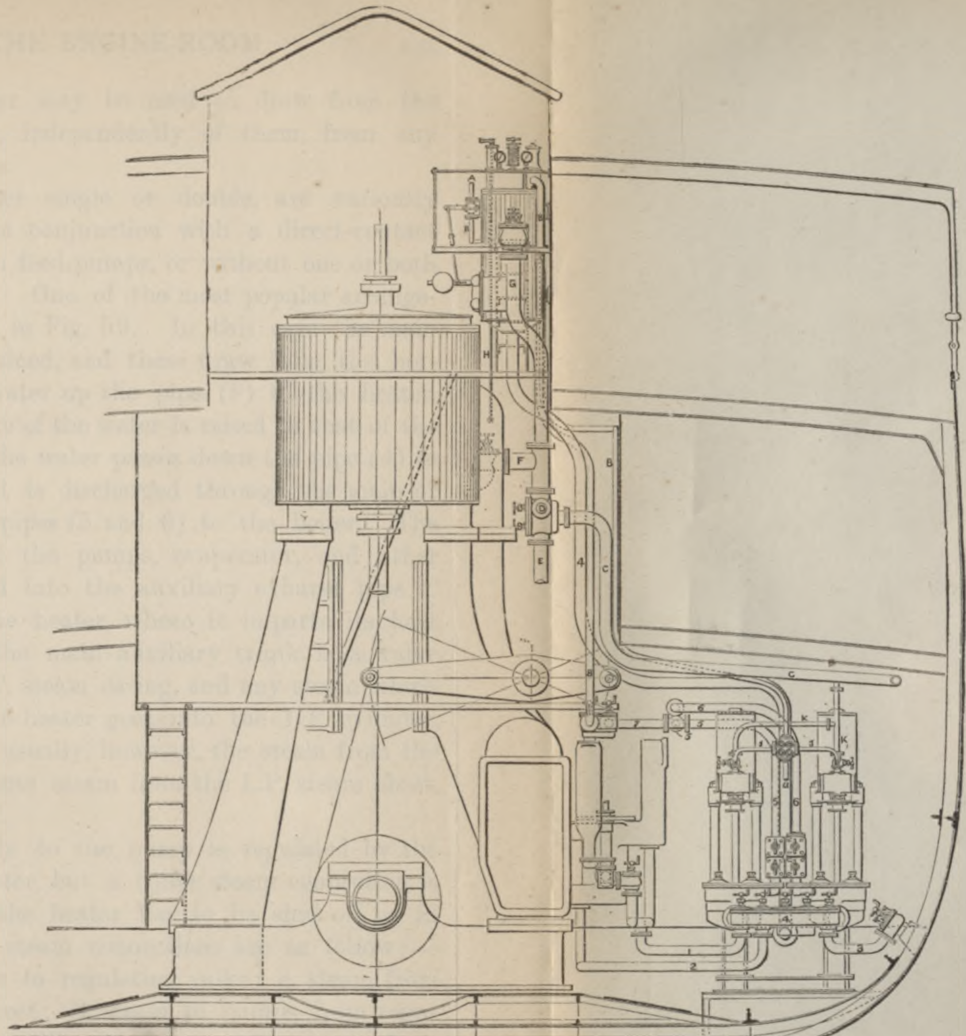


FIG. 59.—General arrangement of Weir's Feed-Heater and Donkey-Pumps with Main Feed-Pumps.

however, that either may be used to draw from the hot-well, heater, or, independently of them, from any other desired source.

The pumps, either single or double, are variously arranged to work in conjunction with a direct-contact feed-heater and main feed-pumps, or without one or both of these appliances. One of the most popular arrangements is that shown in Fig. 59. In this case the main feed-pumps are retained, and these draw from the hot-well and force the water up the pipe (8) to the heater. Here the temperature of the water is raised to that of the heating steam, and the water passes down the pipe (4) to the pump, whence it is discharged through the main or donkey line of feed pipes (5 and 6) to the boiler. The exhaust steam from the pumps, evaporator, and other auxiliaries, is turned into the auxiliary exhaust pipe C and conveyed to the heater, where it imparts its heat to the water; on the main auxiliary trunk is a valve F leading to the L.P. steam casing, and any steam which is not utilised by the heater goes into the L.P. cylinder, doing useful work; usually, however, the steam from the auxiliaries supplements steam from the L.P. steam chest, through the valve F.

The steam supply to the pump is regulated by the float-gear in the heater, but a boiler steam connection is also made in case the heater has to be shut off, as in port. The various steam connections are as follow:—A, steam from boiler to regulating valve; *a*, steam from boiler to pumps direct; B, steam to pumps from regulating valve; C, auxiliary exhaust; D, steam from evaporator; E, exhaust to condenser; F, steam from low-pressure casing; G, steam to heater; H, air pipe to condenser; J, steam to pumps; and K, exhaust from pumps. Besides the heater suction (4), these pumps have also suction connections from the condenser (2), and the hot well (1), and likewise from the sea (3).

The system of Weir feed-heater and direct-acting pumps with automatic control gear, in case where no feed-pumps are fitted to the main engines, is shown in Fig. 60. In this arrangement the steam used in the main engines, which is condensed in the surface condenser, is discharged by the air-pump into the float-tank (1). This delivery being intermittent, it is necessary to regulate the feed-pumps, in order to insure their complete filling with water, and prevent the admission of air. To do this there is in the float-tank a float, the same as in the heater, which operates the steam valve H, and controls the working of one of the pumps, gradually opening the valve as the water rises in the float-tank, and shutting it off when the water in the float-tank falls below a certain level. The pump connected with the hot-well delivers the water through the pipe (3) into the heater through the spray-valve already described. The exhaust steam from the various auxiliaries, which is turned into the auxiliary exhaust pipe C, is conveyed to the heater, where it imparts its heat to the feed-water, the heated feed-water, as it accumulates in the heater, raises the float controlling the steam admission valve J of the second pump, and, passing from the heater down through the pipe (2) to this second pump, is forced by it into the main feed supply pipe (4). On the main auxiliary exhaust trunk C is a valve K leading to the low-pressure steam casing, and any steam that is not utilised by the heater goes into the low-pressure cylinder, doing useful work;

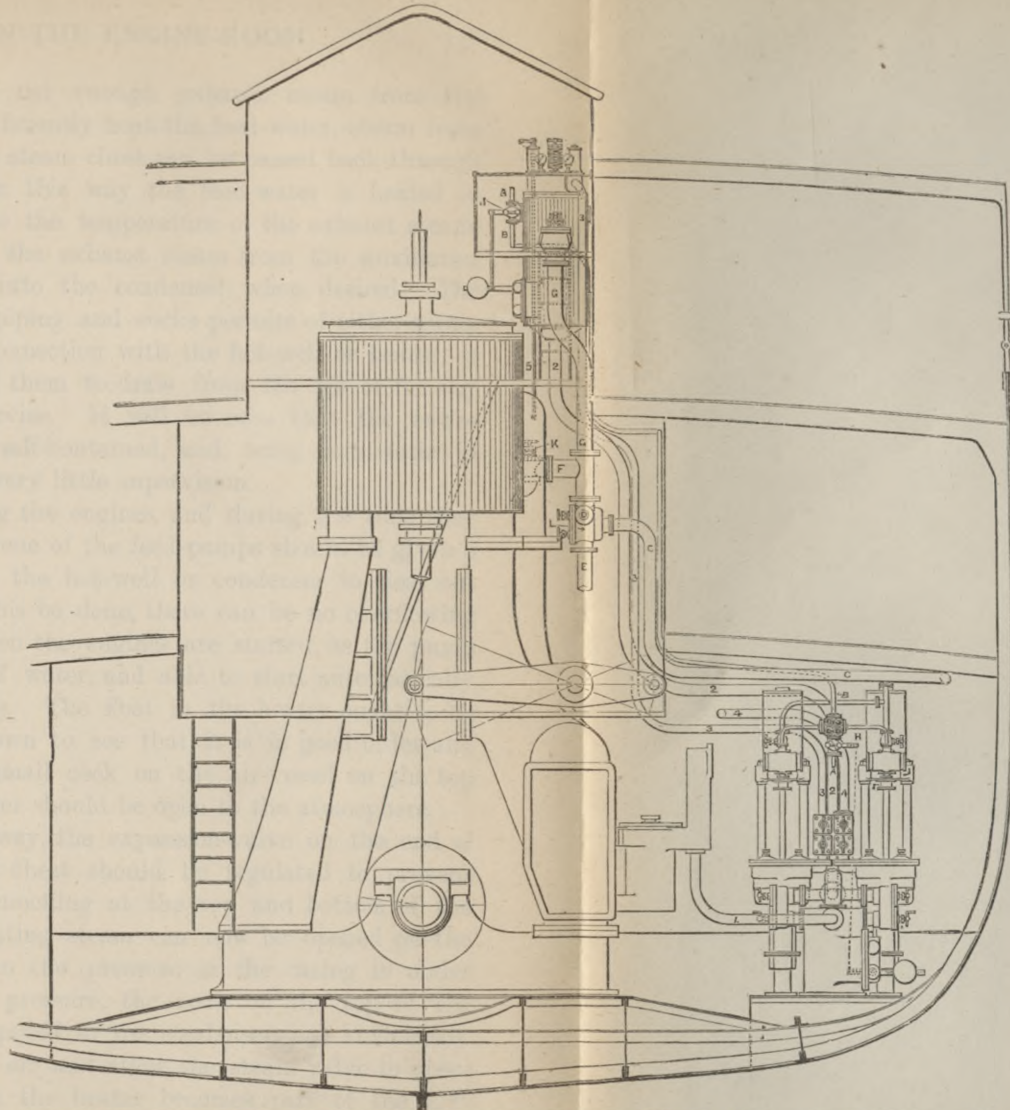


FIG. 60.—General arrangement of Weir's Feed-Heater and Donkey-Pumps without Main Feed-Pumps.

or if there be not enough exhaust steam from the auxiliaries to sufficiently heat the feed-water, steam from the low-pressure steam chest can be passed back through the valve K ; in this way the feed-water is heated in the heater up to the temperature of the exhaust steam. By the valve L the exhaust steam from the auxiliaries can be turned into the condenser when desired. The arrangement of piping and cocks permits of either pump being used in connection with the hot-well or heater, or independently of them to draw from the sea or for any other desired service. It will be seen that the entire arrangement is self-contained, and, being automatic in action, requires very little supervision.

Before starting the engines, and during the time they are warming up, one of the feed-pumps should be given a few strokes from the hot-well or condenser to clear out the water. If this be done, there can be no overflowing of the heater when the engines are started, as the pump will be cleared of water, and able to start automatically as the heater fills. The float in the heater ought to be moved up and down to see that it is in good order and not stiff. The small cock on the air-vessel on the top of the heater cover should be open to the atmosphere.

When clear away, the expansion-valve on the end of the steam valve chest should be regulated to prevent the pump from knocking at the top and bottom of the stroke. The heating steam can now be opened on the heater, and, when the pressure in the casing is under the atmospheric pressure, the cock on the top of the heater must be opened to the condenser just sufficiently to take away the air and allow the steam valve to open. In this condition the heater becomes part of the L.P.

casing, and retains the same pressure; and, as the steam condenses by contact with the water entering the heater, more steam is admitted through the steam valve, the whole balancing itself and requiring no further attention, unless the speed of the engines be altered, when the heater will require to be readjusted.

Should the pump at any time work irregularly, this will be due to one of the following causes:—

(1) The regulating-valve getting out of order.

(2) Spring on the atmospheric-valve on heater being too tight.

(3) Cock to condenser being too far open.

(4) Dirt getting into the group valves (which causes the pump to jump at the end of stroke), or damage to the valves.

Should the pump slow down, as it will do if there be priming, the expansion-valves should be opened. Slowing down may also be due either to the check-valves on the boilers not being sufficiently open, or to the exhaust cock closing.

It is of the greatest importance that, when any irregularity is noticed, it should be seen to *at once*, and the cause ascertained.

The steam valve requires to be examined at least every three months, and, if required, faced up. This is seldom necessary; but should the valve not bear on the bars between the exhaust and steam ports, it must be let down on them to a proper bearing. This is very important, as the high-pressure steam will cut away the metal if allowed to pass. A little attention in time will keep the valve in good order, and often save the fitting of a new valve, and the reboring of the chest.

Feed-Filters.—As the number of auxiliary engines exhausting into the main condenser increases, so does the difficulty of keeping the feed-water free from oil,

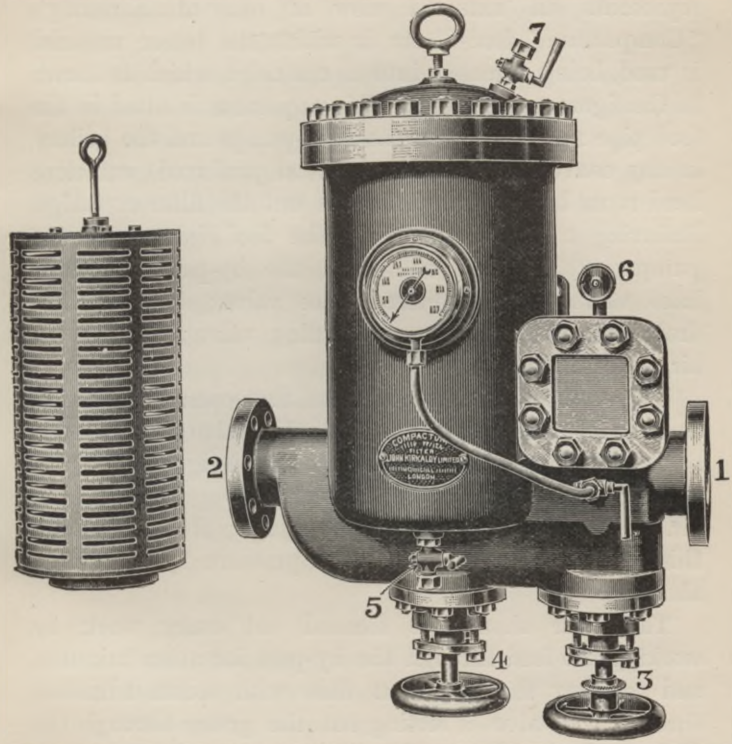


Fig. 61.—Kirkaldy's Feed-Filter.

and in most large vessels feed-filters are now fitted to intercept any grease that would otherwise pass with the water into the boilers, where the presence of such matter is always a source of possible danger. The principal difference in the design of these appliances merely has reference to the filtering medium adopted, which is usually towelling or cocoa-nut fibre. Fig. 61 represents an external view of one of Kirkaldy's "Compactum" feed-filters in which the latter material is used, being rammed into a cartridge, which is shown in the figure on the left. This apparatus is fitted in the feed pipe range, between the feed-pumps and the boilers, in any convenient position (vertical preferred), sufficient head room being allowed to take out the filter cartridge. Referring to the figure, 1 is the feed inlet from the pumps; 2, the feed outlet; 3, the by-pass and filter inlet valve; 4, the filter outlet valve; 5, the filter drain cock; 6, the steam cleaning valve; and 7, the air outlet cock.

To put the filter into operation, first open the valve 4, and then 3; this latter is a double valve, and is open to the filter when the spindle is screwed right in. Open the air cock 7 for a few moments to get rid of the air. Note the pressure on the gauge; if all in order, this should not exceed the boiler pressure by more than about 10 lbs.

The filter should be cleaned out every week by working the feed through the by-pass for a few minutes, and scalding the cocoa-nut fibre with steam admitted through the valve 6, letting out the grease through the drain cock 5. When the charge wants changing, put the feed through the by-pass, open the air and drain cocks, remove the cover, lift out the filter cartridge by means of the eye-bolt provided for the purpose, put in the spare cartridge, close up, and change the feed through to the filter again. As the cocoa-nut fibre is very cheap, the greasy charge can be burnt, and a fresh supply rammed into the cartridge with a wooden rammer, or hammer shaft, ready for the next change.

Evaporators. — It is scarcely necessary to point out the many and various advantages to be derived from the use of evaporators, as they have come to be recognised as necessary auxiliaries in every well-equipped engine-room. The question which presents itself to superintending engineers is, not whether an evaporator should be used, but what evaporator should be adopted. All evaporators are the same in principle, in that sea water is evaporated by means of steam admitted to submerged heating pipes; there are, however, numerous designs which essentially differ in the arrangements to secure efficiency, and facilitate cleaning and working.

Weir's Evaporator.—The general arrangement of this evaporator will be understood by a reference to Figs. 62 and 63, in conjunction with the following list of parts, each part being similarly marked in the different views shown in the figures:

1. Shell of evaporator.
2. Main door of evaporator (1) for withdrawing tube coils (6).
3. Hand cleaning door.
4. Baffle plate, or deflector.
5 Shelves for supporting tube coils (6).
6. Evaporating tube coils.
7. Inlet steam couplings for coils (6).
8. Drain outlet couplings for coils (6).
9. Coupling nuts for 7 and 8.
10. Inlet steam header.

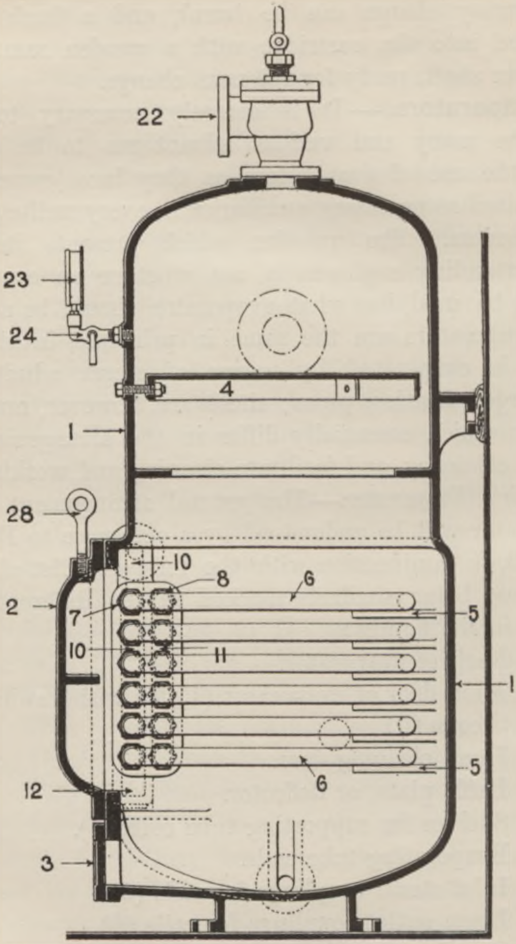


FIG. 62.—Weir's Evaporator.

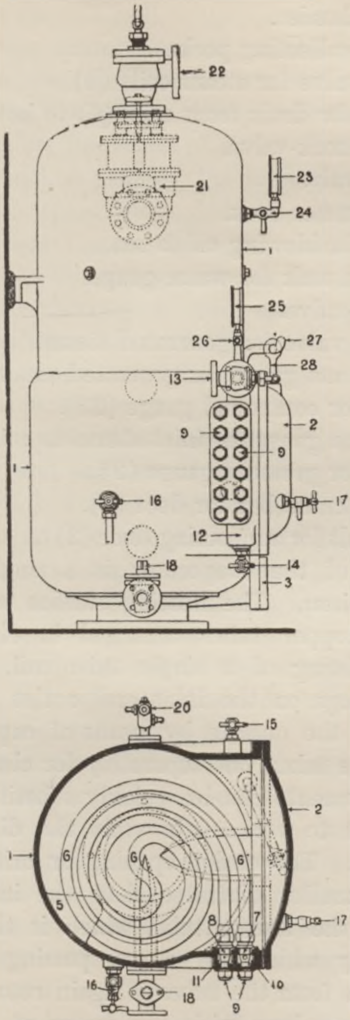


FIG. 63.—Weir's Evaporator.

11. Drain header.
12. Drain collecting pocket.
13. Inlet valve for steam coils (6).
14. Valve for drain from coils (6) to hot-well.
15. Feed check-valve.
16. Brine-valve.
17. Salinometer cock.
18. Cock for blowing off to sea.
20. Bottom cock for water-gauge.
21. Safety-valve.
22. Outlet valve for generated steam.
23. Compound gauge for generated steam in shell (1).
24. Cock for compound gauge (23).
25. Pressure gauge for inlet steam to coils (6).
26. Cock for pressure gauge (25).
27. Swing crane bar for door (2).
28. Eye-bolt for supporting door (2) on crane bar (27).

The shell of the evaporator is a single casting of close-grained iron, The heating surface is composed of solid-drawn copper tubes arranged in elements, each element consisting of a single tube coil, with special hollow couplings on the inlet and outlet ends, secured in place from the outside by means of cap-nuts. Each element can be taken out separately for cleaning; moreover, spare elements can be quickly substituted and the evaporator set to work again while the dirty tubes are being cleared. The outlet opening or orifice from the tubes is of smaller diameter than the inlet, with the exception of the lowest tube, which is the same area throughout, by which any steam passing through the smaller outlets from the tubes is again returned through the evaporator, along with the water of condensation, and drained to the hot-well. By this means the pressure in the stand-pipe chamber at the outlet end is always lower than in the chamber at the inlet end, and a constant current is kept up through all the tubes, thus preventing any accumulation of air or water.

To provide against priming, the tube space is separated from the steam space by a deflector, which allows the steam to rise, but throws down the water so that it is returned again to the water space.

Steam is led directly to the evaporator from the boilers, and the steam of evaporation is conducted to the heater or L.P. casing, or to the condenser if the evaporator is to be worked in port.

The feed-pump for the evaporator is usually fixed to the condenser, and worked off the air-pump levers, the suction being taken from the bottom of the circulating discharge, so that the pump can only draw solid water and not air, and a stop-valve is fitted to this pipe for regulating the feed. When the evaporator is to be worked in port, a connection having a spring-loaded relief-valve is made to one of the engine-room pumps for feeding it, or a separate steam donkey, or a sanitary tank with float control gear is fitted.

In large passenger vessels where the economy of compounding the evaporators becomes of sufficient value, the double effet arrangement may be fitted. In this case two evaporators are provided, and the evaporated steam from the first is led into the tubes of the second. The drain from the first is led by a double valve to the hot-well in the usual way, or to the steam inlet of the second evaporator, and that from the second is led through and cooled down in the fresh water condenser, and can be led to the ship's tanks for the use of the passengers and crew. The generated steam from the second evaporator can be led to the L.P. receiver for boiler make-up, or to the condenser or distiller. The advantage in compounding evaporators is a gain, approximately, of about 30 per cent., and in long passages this means a considerable saving in coal.

To start the evaporator, first fill it to half-glass in ordinary sizes, but in small sizes to about an inch from the top of the glass, then open the drain valve about a turn and a half. Next admit steam to the tubes gradually, and allow the pressure in the shell to rise to about 7 lbs.; then open the outlet valve just far enough to maintain at least 5 lbs. pressure in the shell. With these connections open, the evaporator is in working order, and it is then necessary to regulate the feed supply by the suction valve off the feed-pump, and blow down as required in order to keep the water at a density of from 12 to 15 oz. The brining can be effected by means of the bottom or by the surface blow-off cock, both of which are led to the same pipe communicating directly with the sea.

To entirely change the water in the evaporator, shut the outlet steam valve and open the bottom blow-off cock; when the water has been blown out (which will be done rapidly), close the inlet steam valve. The cold feed-water entering will then condense the steam, and hence create a vacuum in the evaporator, causing the sea water to be rapidly drawn in through the blow-off cock. On the appearance of the water in the gauge-glass, the bottom blow-off cock must be shut. Then set the inlet and outlet steam valves, and the evaporator is in working order again, the whole process only occupying a few minutes. By this method of working, which should be followed at least every four hours, the hard scale is cracked off the tubes, and will accumulate at the bottom of the evaporator, whence it must be removed by the sludge hole door before it reaches the tubes.

Before taking out the tubes for cleaning purposes, steam may be admitted to them and cold water played on their outer surface. In this way scale is loosened, and to a great extent cracked off. When replacing the tubes, some thin jointing material should be inserted between the shoulder of each coupling and the main casting, in the recess provided for it. Before jointing the door in place, it is advisable to admit steam to the tubes and see that the joints are tight.

Morison's Evaporator.—It is impossible for any apparatus to be a success in a steamship unless it is simple and handy, and this is especially the case with an evaporator, as, although the expansion of the heating coils tends to throw off portions of the scale, periodical examination for scaling and cleaning is absolutely necessary. Morison's evaporator, manufactured by Messrs. Richardsons, Westgath, & Co. Ltd., of Hartlepool, certainly possesses in a marked degree the desirable feature of handiness, and it would be difficult to arrange an apparatus in which the coils could be scaled or replaced with greater ease or rapidity. Fig. 64 is an illustration of this evaporator, from which it will be seen that the heating coils are mounted on two tubes, one forming the inlet for steam, and the other the outlet for the condensed water. These terminate in sockets which fit over hollow plugs on which they can revolve, and on which they are kept steam-tight by cap-nuts. When it is desired to clean the coils, the tubes are turned on the

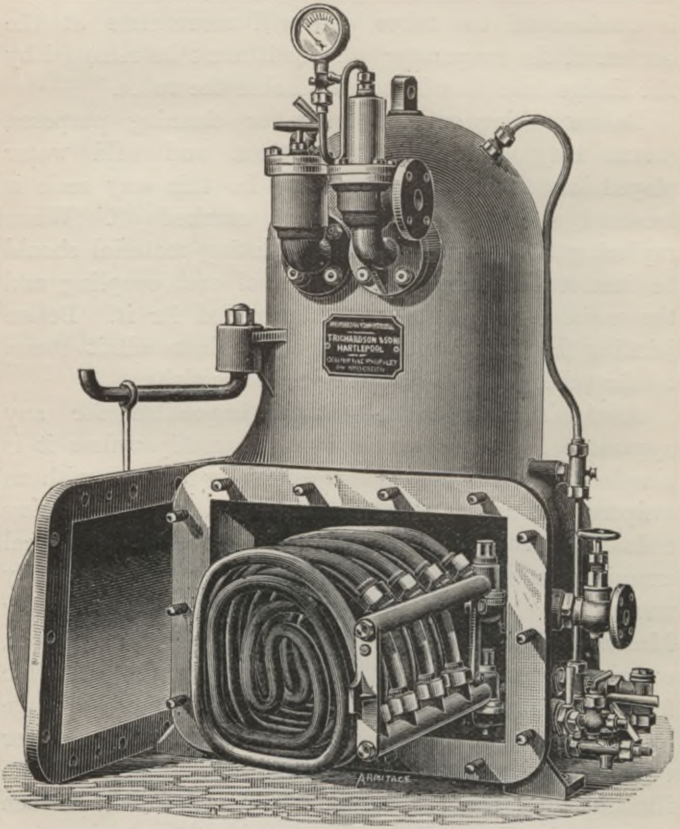


Fig. 64.—Morison's Evaporator.

plugs, thus bringing the entire heating surface outside the evaporator; and, if it be desired to replace the working coils with a spare set, they are simply lifted off the plugs and the others put on.

When it is considered that an evaporator used with sea water decreases rapidly in efficiency with any accumulation of scale, the ability to replace a working set of coils with a clean spare set becomes of great importance, because the apparatus employed may be made of much smaller size and less weight.

A very simple apparatus for scaling the coils of this evaporator has been devised by Mr. Morison, and consists of a small vessel arranged to discharge a spray of steam and paraffin; and, while the coils are revolved outside the evaporator, the flame from the spray-lamp, playing on the scale, causes it to become detached by the sudden expansion, so that it is very easily and quickly removed. In addition to being simple and expeditious, this method avoids the danger of damaging the coils by severe hammering.

Kirkaldy's Evaporator.—The general design of this apparatus will be readily understood by a reference to Fig. 65, the various mountings being as follows:—1, vapour valve leading to condenser, feed-tank or elsewhere, as required; 2, safety-valves; 3, atmospheric-valve; 4, steam inlet to evaporator coils, either from the main or auxiliary boilers; 5, condensed steam outlet from evaporator coils, connected to either feed-tank, hot-well or condenser; 6, water-gauge; 8, drain cock connected to bilge-pump, or to a pipe run into the bilge; 9, brine-valve connected to non-return valve on bilge-pump; 10, feed-valve connected to either main discharge, sea, or to a special pump for feeding purposes.

The evaporator is easily managed, and, when once

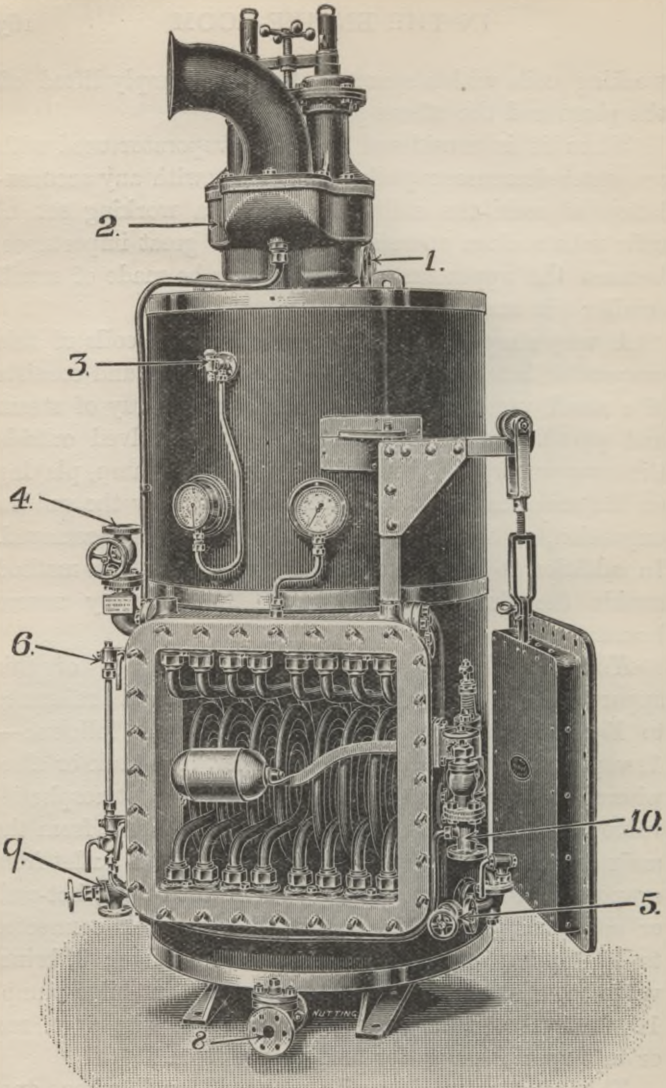


FIG. 65.—Kirkaldy's Evaporator.

set, requires very little attention, as the admission of the salt water is regulated automatically as the vapour is withdrawn, by means of the float-gear, which will be noticed in the illustration. The outlet valve 1 is a combined equilibrium- and stop-valve, to prevent a vacuum being formed in the evaporator, or to close it off from the condenser when connected thereto.

Bilge-Pump Connections.—Too much attention cannot be paid to the bilges, bilge-pumps, and connections, and the rose- and mud-boxes should be cleaned out periodically, even though the pumps appear to be working all right. If a practice be made of doing this, it may prevent some unpleasant bilge diving when the ship is rolling.

If a small atmospheric-valve be placed on the bilge-pump so as to allow the air to be expelled, the pump will be found to work far better.

Water-Service.—While not refraining from the use of either the hose-pipe or water-service merely on account of the mess which their use generally involves, they should not be used too rashly. Many a bearing which was simply working a little warm, and would soon have been all right if sufficiently supplied with oil, has been badly cut up by injudiciously applying cold water, which has the effect of suddenly contracting the bush and causing it to grip the pin or journal. If a bearing be set up too tightly, in most cases it is far better to stop for a couple of minutes or so and slacken the nuts, than to run on with the water-service cock open and risk spoiling the bearing, and then perhaps have to stop after all. Discrimination, however, must be exercised with regard to stopping for a hot bearing.

On one occasion an eccentric-strap got hot and finally seized on to the sheave, bending the eccentric rod just as the links were put over in the act of stopping the engines. Had the engines been kept moving slowly this might have been averted.

A piston-rod will often work far warmer on slowing down than when the engines are running at their ordinary speed.

Working on Watch.—Any form of laziness or inattention to one's duty, such as sitting down or working at odd jobs while on watch, is to be discouraged. The engineer of the watch should be continually on the alert to discover any irregularity, not only in the working of the engines, but in the work of the men placed under his charge; for any laxity in this respect often engenders carelessness on the part of others, and the machinery will not get the attention it demands.

Turning-Engine.—Previous to turning the main engines in port, it should be ascertained if the propeller be clear, also that no block or anything that would jam any of the moving parts has been left about the engines; for if the turning-engine be very powerful, considerable damage may be done before being noticed. For this reason it is a mistake to have too powerful a turning-engine, or its power multiplied by too much gearing.

After all the work has been finished in port, before trying by steam, a complete turn should be taken out of the engines with the turning-gear to see that everything clears.

Position for leaving the Engines.—A three crank job may be left in almost any position as far as starting the engines is concerned, for usually there is no difficulty experienced in doing so, in whatever position the cranks may be lying. It is, however, advisable to leave the high-pressure crank on the top centre, and so prevent the accumulation of a large body of water on the top of the piston when heating up. This will reduce the chances of a broken cylinder cover when taking a turn out of the engines. A slide-valve will, by lifting off the face, allow the water in the cylinder to escape when starting the engines. Piston-valves, on the contrary, are unable to afford any such relief, and many attribute the number of split H.P. covers to their use, although in most cases these casualties might have been averted had due care been exercised and the escape-valves operative.

Governor.—In many cases of broken shafts considerable damage has been done to, and by, the engines before their racing could be checked; and ever since the shaft of the *City of Paris* broke, and was the cause of so much damage being done afterwards, the advisability has been strongly urged of having a suitable governor always working at sea, whereby immunity from the occurrence of such possibilities might be ensured. The action of such a governor would require to depend on the accelerated speed of the main engines, and not be controlled by the mere rising and falling of the ship's stern.

If the governor provided be one of those noisy appliances driven off the main shafting, there is naturally a reluctance on the part of the engineer to keep it continually working, and it therefore becomes useless as an emergency governor. It should, however, be thoroughly oiled and put into gear occasionally, say once a week, and allowed to run for five or ten minutes.

This will ensure it being kept in working order and ready for immediate use when required in heavy weather: it is not pleasant to have to start and ease rusty joints, etc., when the ship is rolling about.

A governor which is eminently adapted for marine work is that patented by Mr. Aspinall, which requires

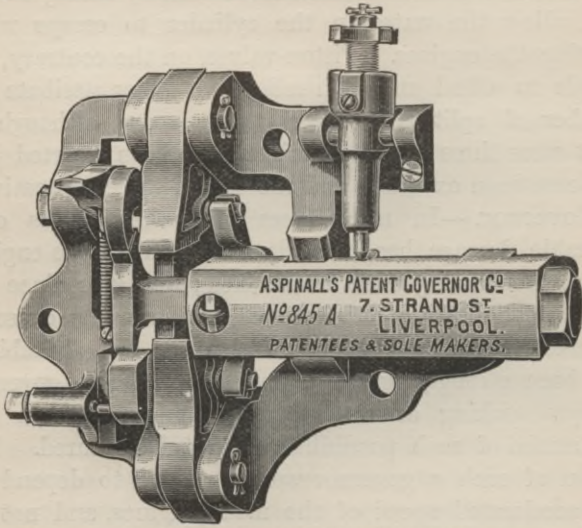


FIG. 66.—Aspinall's Governor, Outside View.

no special steam cylinder or driving ropes, use being made of the pump lever to regulate the throttle-valve. It is exceedingly sensitive, certain and powerful in its action, and not only prevents racing in rough weather, but shuts off the steam entirely in case of a shaft breaking, etc. Fig. 66 shows an outside view of this appliance, Fig. 67 the governor in position, and Fig. 68

a general arrangement of the gear, which may be modified according to circumstances. Referring to Fig. 67, the governor consists of a hinged weight W, operating two pawls P P, carried on a frame which is bolted to the pump lever or other reciprocating part. When the

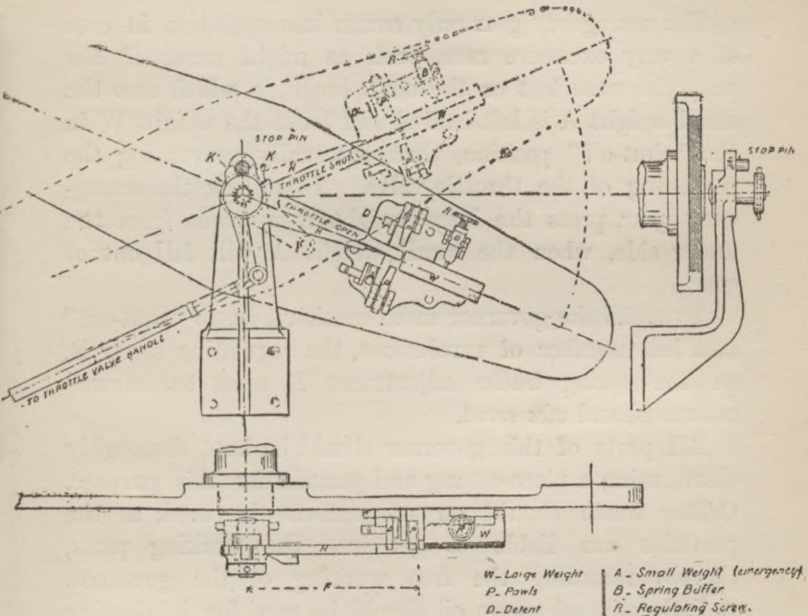


FIG. 67.—Aspinall's Governor in Position.

revolutions are increased by about 5 per cent. above the normal speed, the weight W is left behind and reverses the position of the pawls, causing the bottom one to engage with the lever H, lifting it throughout the whole upward stroke, and thus shutting off steam by closing the throttle-valve. On the return stroke the detent D is lifted, liberating the weight W, and, if the revolutions have moderated, the position of the pawls is again altered, the top pawl now engaging with the lever H, depressing it, and thus reopening the throttle-valve.

The emergency gear only comes into operation in case of a very excessive race, such as might occur if the propeller were lost or the shaft broke, in which case the small weight A is left behind and locks the weight W in the "shut-off" position, thus effectually preventing the reopening of the throttle-valve. To unlock the emergency gear, press the large weight W upwards from the under side, when the small weight A will fall out of gear.

To make the governor more sensitive, *i.e.* to "shut-off" at a less number of revolutions, the regulating screw R, on the spring buffer adjustment B, must be screwed outwards, and *vice versâ*.

All parts of this governor should be kept thoroughly clean, using a piece of rag and paraffin for this purpose. Cotton waste should on no account be used, as the particles are liable to get into the working parts, thereby retarding the free working of the governor. A little mineral sperm oil should be used for lubricating purposes, and oils of a clogging nature should be avoided. The large weight W should be tipped upwards by hand regularly once a day, for by so doing the gear will be kept in efficient working order. The governor gear should, of course, always be connected to the throttle-valve as soon as the vessel is clear of port.

It may be mentioned that an adaptation of the

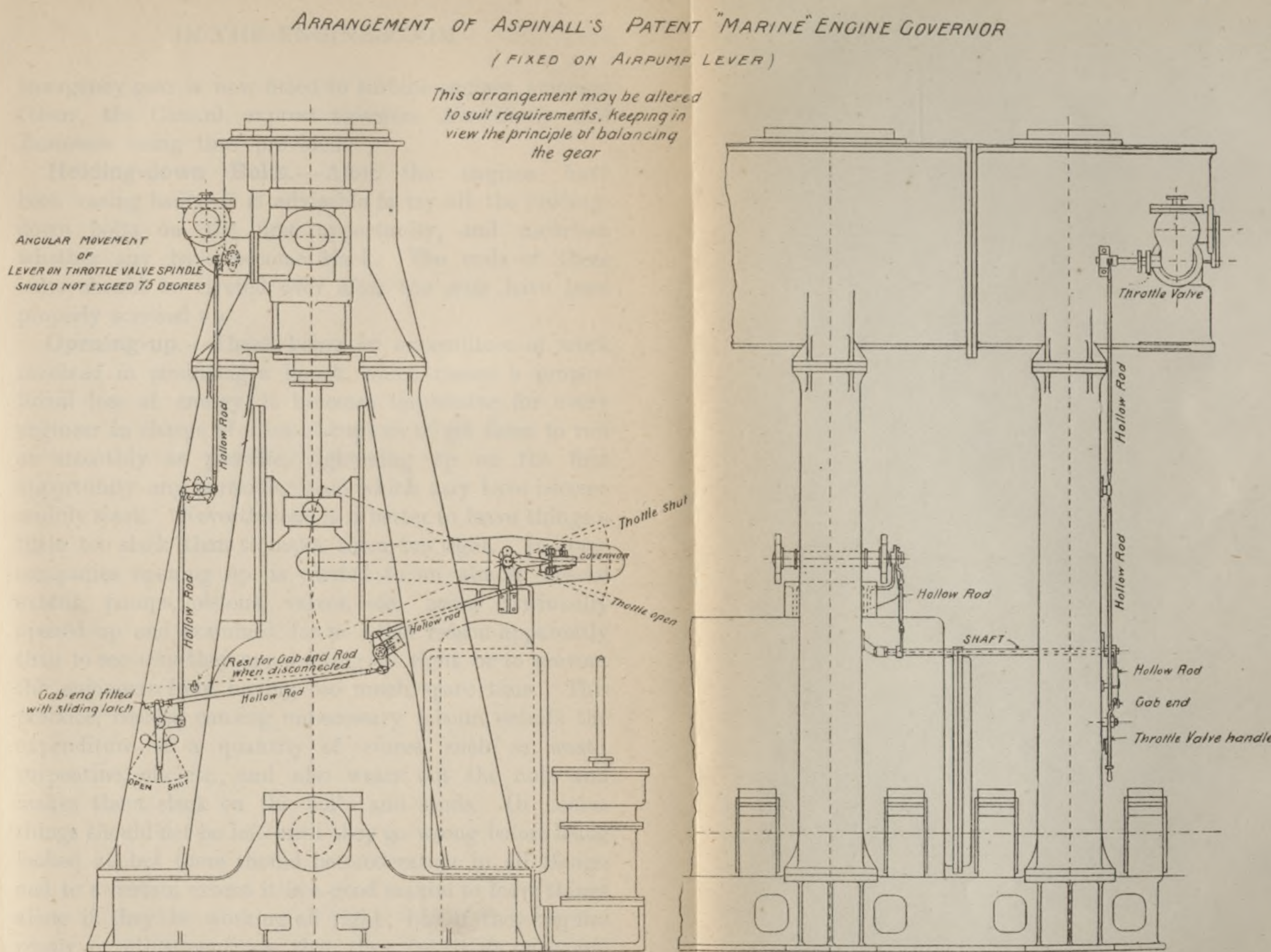


FIG. 68.—Gear for Aspinall's Governor.

emergency gear is now fitted to turbine engines, amongst others, the Cunard express steamers *Mauritania* and *Lusitania* being thus provided.

Holding-down Bolts.—After the engines have been racing badly, it is advisable to try all the holding-down bolts on the first opportunity, and ascertain whether any have become slack. The ends of these bolts should be riveted over after the nuts have been properly screwed up.

Opening-up.—There being an expenditure of work involved in producing a knock, which means a proportional loss of energy, it becomes imperative for every engineer in charge of a set of engines to get them to run as smoothly as possible, tightening up on the first opportunity any particular part which may have become unduly slack. Nevertheless, it is better to leave things a little too slack than to make them too tight. In some companies opening up is carried to an almost absurd extent, pumps, pistons, valves, etc., being continually opened up and examined, for no other reason apparently than to see *why* they are working all right, or to prevent the engineers from having too much spare time. This practice, besides causing unnecessary labour, entails the expenditure of a quantity of stores, such as waste, turpentine, oil, etc., and also wears out the nuts and makes them slack on the bolts and studs. Of course things should not be left until they go wrong before being looked at, but there should be moderation in all things, and to a certain extent it is a good maxim to leave things alone if they be working all right; but if they require repair or adjustment, see that they get it at once, and that the work is thoroughly well done. Do not *merely* *take down and put together again in order to make a show in the log-book,* as is often done.

There is scarcely anything more detrimental to an engine than to stop and start it suddenly, or to frequently and rapidly alter the speed. Engines ought to be started and brought to rest as gradually as possible, avoiding any sudden jerk; and, after leaving port, they ought to be linked up to the required speed, and allowed, when practicable, to remain at that speed until the next port is reached. The working parts of the engines in coasting boats, which have to be continually eased, stopped, and started again, do not last half the time without readjustment that they would were the ship at sea on a long voyage, where the speed of the engines would be very much the same day after day, in which case they would run for days, if not weeks, without knocking to a serious extent, and the reason for this is very obvious.

Breakdowns.—When breakdowns occur, they may often be credited with having given a special stimulus to one's ingenuity, and it is surprising how methods of repairing the damage with the materials at hand suggest themselves—ways which one might never have thought of before: nevertheless, every engineer should prepare for emergencies by asking himself such practical questions regarding possible contingencies as he knows others have been called upon to answer more promptly than pleasantly. For instance, if this shaft were to break or that spindle to fail, what would be the best method of repairing it, and how could this be accomplished in the shortest time? By thus repairing imaginary breakdowns an engineer would find himself better qualified to grapple with the real thing whenever it presented itself.

Before leaving Port.—After all the work down below has been finished, it is well, before making a start, to go round the engines and make a final examination to see that none of the nuts have been left slack or split-pins forgotten, that there are no blocks of wood lying about, that the turning-gear is disconnected, and also that all spanners and tools used in overhauling have been returned to their proper places. It is also advisable to test the working of the engine-room telegraph, both from the bridge and the engine-room, as the casing that protects the chains or wires, where they pass through the bunkers, may have been damaged during the process of coaling; and if the telegraph be tried before leaving, it may prevent accidents when passing amongst the shipping going down a crowded river, or when working the engines in the docks.

Spare Gear.—The spare pump-rods, main bearing, and coupling bolts, connecting-rod bolts, etc., should be made fast with hangers to the bulkhead, or placed in some other part of the engine-room easy of access, so that they may be kept clean and always ready for use. If stowed away in some out-of-the-way corner in the store, they are apt to be forgotten or overlooked and get rusty and knocked about, and possibly, when required in case of emergency, there may be a difficulty in finding them. The tube-stoppers, too, may be hung up in some such handy position as in the passage from the stokehold to the engine-room.

Cleanliness.—The man who keeps his "tops" polished up, the lubricators and cocks shining, and the paint-work round the engine-room casing spotless, is not always the best man. All this may be for the sake of making a display as seen from the engine-room door, and calculated to deceive; for on going down below one may be met by anything but a pleasant smell rising from the dirty bilges, and remark the presence of rust here and there, the dirty condition of the stokehold, and the accumulation of dirt on the top of the boilers, besides many other things betraying carelessness and neglect in every direction. The efficient working of the engines is, of course, the paramount consideration, but an attentive engineer will also see that his engine-room, stokehold, and engines are kept cleanly (not necessarily polished), not only where mostly seen, but down the tunnel, under the flooring plates, at the back of the boilers, and such places where dirt and rubbish are often left to accumulate together.

For the bilges, cement was his very often used, but it cannot be recommended, for it is practically useless for preserving the iron, and only makes the bilges *look* clean. There are several very excellent bituminous enamels for coating the bilges, tank tops, and bunkers; but should none of these be procurable, it is a good plan to scrape the iron as clean as possible, and then, while perfectly dry, to give it a coat of Stockholm tar, put on hot, afterwards sprinkling it with a little Portland cement on the top.

In most boats there is very little time available for beautifying the engine-room by graining, and, were there sufficient time, it is not every one who could do it; but when painting, if the engine-room hatchway casing be panelled in different shades, it can be made to look very effective, and that with little more than the additional trouble of previously marking it off. It is a poor company, too, that cannot afford to provide four or five pounds of vermilion paint, which would go a long way in painting the inside of the pump levers, pump link brasses, spokes of wheels, etc., and assisting in improving the general effect.

Ladders and Gratings.—Canvas guards should be made and attached to the under side of any ladders or gratings from which dirt might otherwise drop on to any bearing or moving parts of the machinery below.

Some engineers take the trouble to round off with a file, and afterwards polish, the top edges of the side plates of the ladders in the engine-room. Although rather a refinement of detail, this certainly helps to give the engine-room a well-favoured appearance.

Dynamo.—Although the study of electricity is a speciality, and is not included in the course of training which a mechanical engineer usually undergoes, every sea-going engineer is now expected to be conversant with the science, at least in its more elementary stages, and understand its practical application to ship lighting; for there are now quite as many new boats with their installations of electric plant as there are without. An electrician is not always at hand for reference and advice, and it would not be very pleasant to be in charge of machinery in a ship, and have to deal with a power with which one was not fairly well acquainted.

Whatever the form of the dynamo may be, its action is based on the discovery of Faraday that, if a closed wire be moved across a magnetic space, a current of electricity will be generated in the wire. The coils of wire wound round the core of the armature, which revolves between the poles of the field-magnets, constitute this conducting ring. These coils are connected to the copper plates forming the commutator, which are insulated from each other, from which the brushes collect the intermittent currents and lead them off in a continuous stream along the main wires. There is always sufficient residual magnetism left in the core of the field-magnets to excite a feeble current in the wire wound round them when the dynamo is started; this current reverts to the magnets and excites still stronger magnetism in them; this again strengthens the current in the coils, and so on, until the result is a very powerful magnetic field.

The management of electrical appliances is, however, outside the scope of this treatise, and the reader is recommended to study Mr. Sydney F. Walker's very excellent book on the subject, which was written expressly for sea-going engineers

Refrigerating machinery and oil engines are also special subjects for study, which should not be overlooked by the engineer who is anxious to advance his position and fit himself for any situation that may possibly occur.

CHAPTER V

DOWN THE TUNNEL

The Tunnel Door—Thrust-Block—Lubrication of the Thrust-Block—Shafting—How to Test the Shafting for Fairness—Coupling Bolts—Youngs' Hydraulic Bolt Forcer—Stern-Gland—How to Plait a Square Sennit.

Tunnel Door.—The water-tight door to the tunnel should be kept in good working order by oiling

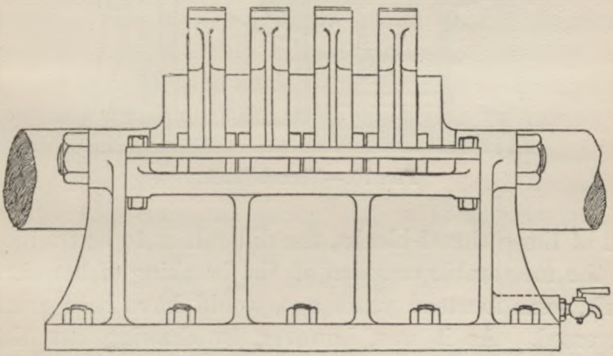


FIG. 69.—Thrust-Block.

the gear and trying it occasionally, so that it may be easily closed at any time.

Thrust-Block.—Figs. 69 and 70 represent a form of thrust-block which has come greatly into favour; and justly so, for the horse-shoe shaped bearings can be adjusted to a nicety to suit each collar on the shaft, and can be taken out separately for examination while the engines are working, without having to lift any cumbrous cover. The thrust collars, not being enclosed, are cooled by the air, and are thoroughly lubricated by revolving in oil or soapy water placed in the trough formed by the lower casting. Had the *Umbria* not been fitted with

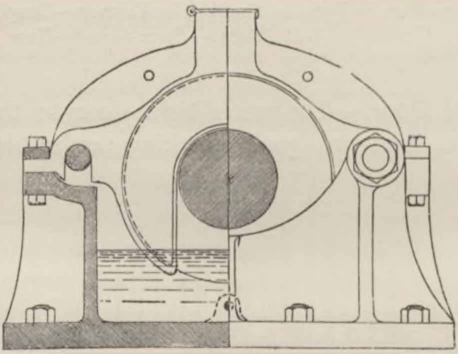


FIG. 70.—Thrust-Block.

one of these thrust-blocks, the difficulties to be overcome on the memorable occasion of the breaking of her thrust shaft, some fourteen years ago, would have been greatly increased. As it was, however, by drawing out three of the horse-shoe bearings, the spliced part of the shaft was allowed to revolve inside the main casting, without interfering with the rest of the thrust bearings.

Shafting.—Looking over a list of breakdowns, it is really astonishing to note the number of cases of broken shafts which occur annually, and so endanger the lives of those who happen to be in the ships that are unfortunate enough to suffer from mishaps of this description. It is a comparatively rare occurrence to find the shafting of a steamer in correct alignment, and this state of affairs is almost inevitable, for a steamship is not a perfectly rigid structure, but will spring to a certain extent under the different conditions of weather, freight carried, and manner of stowing. As an illustration of this, it is not unusual to find, in a water ballast steamer, that by running up the after tank one or more of the tunnel blocks will work warm, owing to the increased attrition due to the ship hogging. The additional strains set up in a line of shafting, by the springing of the ship in a heavy seaway, must sometimes be very great, and constitute the cause of very many shafts ultimately breaking. As the ship cannot be made perfectly stiff, the only remedy is to enable the shafting to spring with it in such a manner as not to subject it to any undue side or bending strains. This might be accomplished by making the couplings flexible—that is, to a limited extent—like universal joints, but it is surprising how seldom this has been done.

How to Test the Shafting for Fairness.—It may be seen if a shaft be fair with the adjoining length, by taking out the bolts and trying all round with a feeler between the couplings. It is better, however, to test the truth of the shafting by determining the position of an imaginary datum line above the shafting, and measuring the distance between this line and the couplings. This may be accomplished by sighting from a position well forward, where the line of vision down the tunnel is unobstructed, using battens placed above the first two couplings. The battens may be secured to blocks cut out to the required curvature to enable them to rest unsupported on the couplings; the true edge of the first batten should face upwards, and that of the second downwards, with an intervening space between it and the block to which it is secured. The distance between the edge of the latter batten and the coupling should be, if anything, the *least* amount greater than in the case of the former batten—assuming the diameter of the couplings to be the same. A third batten should also be made for the propeller shaft coupling, in a similar manner to the first, but having the true edge lower, or nearer to the coupling. Having levelled all battens in position, so that their true edges may be in parallel horizontal planes, a good lamp should be placed behind the last batten, and, at the same time, thin parallel strips should be rested or built up on the edge of this batten, until the light is almost obliterated, and can only just be seen as a thin bright line when viewed with the aid of a telescope, or pair of field-glasses, from the forward position. By comparing the composite depth of the last batten with that of the first, it will be seen whether there be any deviation from the truth in the line of shafting; and, should this be the case, each coupling may be sighted separately, in order to form a correct estimate of the thickness of liners required for making up the various bearings.

Coupling Bolts.—Previous to putting the bolts into the shaft couplings they should be well oiled, to prevent them from rusting and setting fast, for considerable trouble is often experienced in starting them again when disconnecting the shaft.

A stiff bolt may sometimes be started, after being warmed up, by putting as much strain as possible upon it at the end, with an ordinary screw-jack, and giving it a sharp blow at the side of the head. The best and easiest way of removing a stubborn bolt is, however, by means of the device known as "Youngs' portable hydraulic bolt forcer," illustrated in Fig. 71, and there

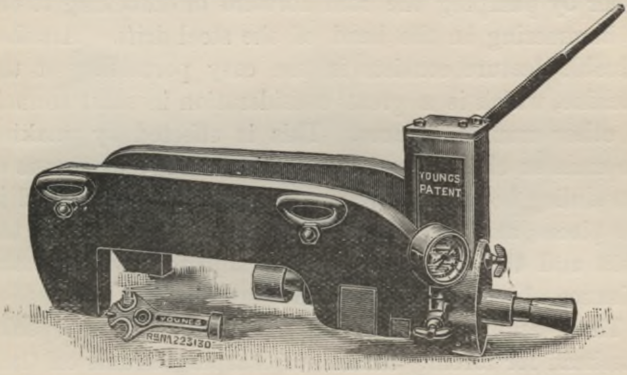


FIG. 71.—Youngs' Portable Hydraulic Coupling Bolt Forcer.

are very few bolts that can resist the treatment which this machine empowers. The novelty of the invention consists in having a hollow steel sliding ram, the ends or tails of which project through the front and back, respectively, of the cylinder. Inserted in this hollow ram is a steel drift which passes right through the centre of ram; a head is forged on one end of the steel drift, a shoe for the bolt is fitted on the other. The method of working is the same as in any ordinary hydraulic pump, the fluid being forced by the pump from the reservoir into the cylinder, and the ram is gradually forced forward until it presses the shoe, on the end of the steel drift, against the bolt to be forced out. Should the bolt show no sign of moving out of coupling when the maximum hydraulic pressure has been obtained, a sharp blow is given with a hammer on the head of the drift, which transmits a shock or "jar" to the bolt and starts it from its position, and it can then be ejected either by pumping the ram forward or knocking it out by hammering on the head of the steel drift. Another valuable feature consists in the easy portability of the machine, which is a great consideration in shaft tunnels or other cramped spaces. This is effected by making the arms or claws detachable from the body by means of two sliding bolts, so that the machine can be carried in two pieces, and the body placed first in position on the shaft and the claws afterwards adjusted, without the nuisance of having to screw and unscrew any bolts.

These appliances are also arranged with a special crosshead for forcing barrels or warping drums off their shafts.

It may be mentioned, by the way, that the leathers of a hydraulic jack should not be allowed to get dry when not in use, otherwise they will become hard and crack; and, in frosty weather, about an eighth part of glycerine should be mixed with the water retained in the pump.

Stern Gland.—The thread of the stern gland studs should be well cleaned, and afterwards coated with a mixture of white lead and tallow, to prevent them from corroding away, which they will readily do if of iron, but it is scarcely necessary to say that these should always be made of Muntz metal. Packing made of flax rope-yarn is the best for putting into the stern gland stuffing-box, greasing it well before putting it in. Now that patent packings can be obtained so cheaply, it is astonishing how few engineers can plait a piece of gasket packing. Formerly an engineer was a handy sort of man, who, when required, could manufacture a piece of packing, do a piece of brazing, make a plumber's joint, make a pattern, or weld a couple of pieces of iron together; but now many an apprentice engineer does very little else

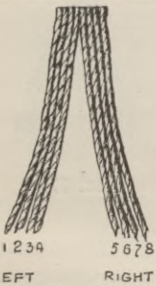


FIG. 72.

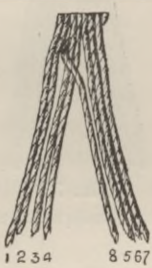


FIG. 73.

FIG. 74.

Plaiting a Square Sennit.

during his apprenticeship but bore and tap holes and fit in studs!

How to Plait a Square Sennit.—Take eight strands of spun-yarn, bind together at the one end, and make it fast in a vice or fix in any convenient position. Take half the number (*i.e.* four) of the strands and keep them on the left-hand side, the other half remaining on the right-hand side (see Fig. 72). During the process of plaiting, remember that the strands are always brought back to their own side. Then commence plaiting by taking the outside strand of either side—say, the right-hand side —from underneath, bring it up between the two centre strands on the left-hand side and across to its own side, it now becoming the inside strand (see Fig. 73). Then take the outside strand on the left-hand side from underneath, bring it up between the two centre strands on the right-hand side, and back again to its own side, making

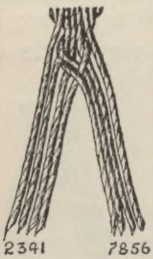


Fig. 75.

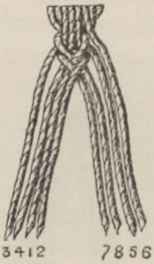


Fig. 76.

Fig. 77.

Plaiting a Square Sennit.

it the inside strand (see Fig. 74). Continue doing this, taking the outside strand from each side alternately, and the plait will take the form of a square sennit, having the appearance shown in Fig. 77. It will be of great assistance if, while plaiting, some one else will hold the strands—half the number in each hand. In this manner a sennit may be made, not only with eight strands, but with four, twelve, sixteen, or indeed any number, provided that number be divisible by four.

CHAPTER VI

THE PROPELLER

The Propeller—Its Efficiency—Friction of the Blades—Flexibility of the Blades—Propeller Shaft—Outer Bearing—Corrosion of Shaft—Cedervall's Protective Lubricating-Box—Taking off the Propeller—Youngs' Hydraulic Propeller Starter—Taking off the Blades—Putting on the Blades—How to Take the Pitch—Pitchometer—Conclusion.

The Propeller.—It is rather startling at first to find what a comparatively small percentage of the power developed in the cylinders is applied directly to forcing the vessel along. Neglecting the power absorbed in overcoming friction, and the various resistances offered by the engines, pumps, etc., it will be found that a great loss of work is due to faults of the screw itself. Its use is, unquestionably, a very wasteful method of propulsion, nevertheless it possesses so many merits, and appears to meet the requirements of the service so much better than any other known form, that it still holds its own, and it will probably be a long time before it is superseded by a more approved means of propulsion. At the same time, the rapidity with which one improvement in the marine engine succeeds another is really astonishing, and in this age of invention and scientific research it is quite impossible to say what developments may occur in the almost immediate future.

Although a propeller may be carefully designed to meet the requirements of a certain vessel, and have its diameter, pitch, and surface calculated by elaborate rules, it often happens that it might be replaced by another of a very different design, which would be more economical in relation to the power required to drive it, and, in fact, more suitable in every respect. So that really, in determining upon the propeller best adapted for a particular ship, one must be guided principally by the results obtained in previous cases, rather than by any hard and fast rules. Its efficiency is affected by so many influences, comparatively few of which are properly understood, that absolute reliance cannot be placed upon mere *formulæ*, that are too often based upon scientific theories which practice has proved to be unsound or unjustifiable, and one has to depend almost entirely upon *data* obtained from practical observation.

Placed as it is in the wake of the ship, the propeller is at a disadvantage to begin with, and its efficiency is often heavily handicapped by the bluff lines of the afterpart of the ship, which latter, acting like a pump plunger, causes a quantity of broken water to flow after it. It is of as much importance to have a clean run aft as to have a fine entrance, but desirable lines are often sacrificed for those of greater fulness which give increased carrying capacity to the ship.

As the blades travel in a direction oblique to that of the thrust, a considerable amount of power is absorbed by the friction of the driving surfaces in their passage through the water. Blades made of phosphor- or manganese-bronze can be made very smooth by buffing them up, and then present less skin resistance than those of cast-iron or steel; and in some cases where iron blades have been exchanged for others of bronze, the difference in favour of the latter has been made very apparent by the results obtained. Being free, too, from any tendency to corrode, bronze blades can be made thinner than those of iron or steel, and will cut their way better through the water.

Another reason why a thin blade should give better results than a thicker one is due to it being less rigid or "dead." As with an oar, a slight amount of spring adds to a propeller's efficiency, and the cause of this is not very difficult to find. The propeller ought to work with a steady, even pressure, and, if there be a certain amount of spring in the blades, it acts as a governor, whereby the evil effects of any irregularities in their rotation, consequent on the uneven motion of the engines, are mitigated, and the pressure on the water rendered more constant and uniform.

It has been found that the iron forming the stern of the ship is not greatly impaired by any galvanic action between it and the bronze, and objections to the use of the latter on this account must be more imaginary than real. Some ships fitted with a bronze propeller have the ship's plates in its immediate vicinity protected with zinc plates; but this is more as a precautionary measure than on account of any serious deterioration having been caused by galvanic action.

Propeller Shaft.—It was formerly customary with large propeller shafts to continue them beyond the propeller to an outer bearing in the rudder-post, in order to form a better support to the otherwise overhanging weight of the propeller; but in the event of an accident to the rudder-post, the shaft is liable to be bent or broken, or the propeller might be broken, or matters complicated in some other manner, and consequently the more modern practice is to dispense with an outer bearing. It may be mentioned, in passing, that most builders now make the rudder-post shorter than the propeller-post, as shown in Fig. 62, so that, should the ship take the ground, the strain will not come upon the weakly formed rudder-post.

The deterioration of propeller shafts, due to the galvanic action set up by the brass liners, is more rapid when the shafts are made of steel than it is if they are of iron, and the latter material is preferable for the manufacture of these forgings. Corrosion is prevented by encasing the shaft within a continuous liner, and thus protecting it from the water; but, when the length of the liner is considerable, difficulty may be experienced in obtaining a good fit, by the somewhat rough methods often adopted. Some makers heat the liner by means of a series of gas jets placed round it, the liner being first slipped on the shaft which is held in the lathe. After it has expanded sufficiently to enable it to be placed in its correct position, the liner is cooled from the middle outwards, towards the ends. If this be carefully done, tapping the liner to ascertain where it is gripping, and regulating the gas jets accordingly, a good fit may be ensured, even when the liner is fairly long. The heat to which the shaft is subjected during the operation is not likely to be so great as to damage the material, and all danger of the liner cracking by setting first at the ends is avoided.

In many cases the liner is made in sections which are shrunk on to the shaft separately; but this practice is not to be recommended unless the joints between the sections are made water-tight in some satisfactory manner, for although the intervening space may not be appreciable, the insidious action may go on unsuspected, wasting away the shaft beneath the butt, like a knife-cut, until it ultimately breaks. Brazing these joints is sometimes resorted to as a remedy, but, when heating the liners sufficiently to ensure efficient brazing, the shaft may be injured by the process, especially if it be made of steel. This danger has been emphasised in several instances in which the liner has been cast in place on a steel shaft, whereby extremely fine cracks have been produced in the latter, which crossed and recrossed each other in a peculiar manner, and extended to a depth of two inches or more.

Where two separate liners are fitted, the shaft is most susceptible to corrosion at the forward end of the after liner; and, when the wasting has extended to a considerable depth, it is advisable to chip off an inch or so from liner and wash away the metal on each side of the affected part, so that the working stresses may not be localised so much where there is a sudden change of section. The portion of the shaft between the liners should be thoroughly cleaned with paraffin and a wire brush, and then either covered with red lead putty, afterwards serving it with rope or marline, secured by an outer covering of canvas, sewn in place and painted on the outside, or treated to a good thick coating of bituminous enamel.

With a view to preventing the corrosion of propeller shafts, "Cedervall's patent protective lubricating box" has been introduced, and by this means the sea water is excluded from the stern-tube. The invention consists of an annular box fitted in front of, and revolving with, the the propeller boss; it is provided with a faced packing-ring, with suitable springs to keep it in contact with the after end of the stern-tube, around which a guard plate is secured to protect the packing-box from injury by ropes, etc. Brass liners are not fitted to the shaft, which runs in metallic bearings, and is lubricated by oil forced into the stern-tube by means of a small hand-pump and pipe provided for the purpose. An air pipe is fitted to the top, and a drain pipe to the bottom of the stern-tube, each being provided with a cock fixed on the bulkhead. In many cases where this system has been adopted, when the after bearing in the stern-tube has been lined with white metal, the wear has been immoderate, and in any circumstance the renewal or relining of the bush is not so readily effected as the fitting of new lignum vitæ strips in an ordinary stern-tube.

In order to protect the propeller nut and prevent the water from getting to and corroding it, a light iron cap to cover the nut is sometimes fitted, this being jointed to the propeller boss, as shown in Fig. 78. When thus fitted, the after side of the boss requires to be faced up for the joint, and consequently leaves little or no room on which to use the ram when putting on the propeller.

To prevent the water from getting into the boss at the forward end, and so damaging the tapered portion of the shaft inside, the brass liner on the shaft is sometimes carried along until it comes to within half an inch or so from the boss, and in the intervening space an india-

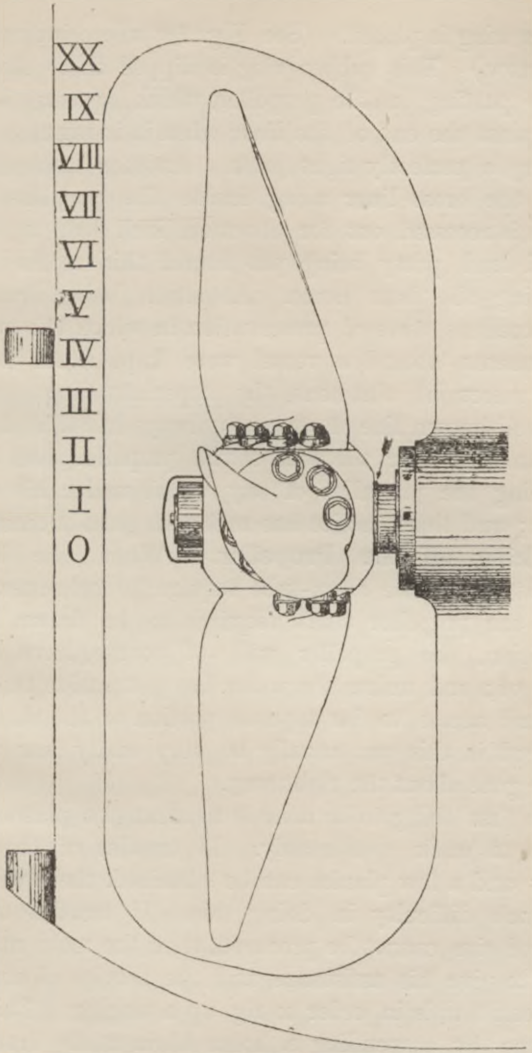


FIG. 78.—Modern Type of Propeller.

rubber ring is placed. (See Fig. 78 where indicated by an arrow.) This rubber ring is slipped on to the shaft before putting on the propeller, which squeezes it hard up against the end of the liner when it is rammed home, making a perfectly tight joint. Another method is to carry the brass liner along inside the propeller boss, which is recessed out for about an inch deep to receive it, red lead putty being put round this recess before ramming the boss home. Attention being drawn to the excellent state of preservation in which the surgical instruments aboard a vessel were kept when covered with mercurial ointment, the superintending engineer of a well-known line of steamers always has this preparation smeared over the cone of the propeller shaft before replacing the propeller of any vessel under his supervision; and this practice has met with great success.

Taking off the Propeller.—When the lignum vitæ strips in the stern-tube require to be renewed, or when the propeller shaft requires to be drawn in for inspection, the propeller will, of course, have to be taken of; and unless the water has got inside the boss, or found access to the tapered portion of the shaft and damaged it, this can usually be very easily done if the job be gone about the right way.

The first thing to be done is to arrange a platform on which to work comfortably. If trestles of the right height and a few planks can be obtained, there will not be much difficulty in doing this. If trestles of the required size cannot be procured, then the mate must be asked to give his assistance and the service of some of the deck hands in order to rig up a staging. This can be done by suspending a boom horizontally from the counter, letting it rest just abaft the rudder and two or three feet below the level of the shaft, and another boom just abaft the propeller-post and at the same height as the other, and then resting cross planks from boom to boom.

Meantime the after length of tunnel shafting can be removed, in readiness for drawing in the propeller shaft. Shores should be fixed between the coupling flange of the latter and the stern-tube; these ought to be of ample strength, owing to their liability to buckle should the propeller prove difficult to start, and they should be secured by chain or rope to prevent them from falling when the propeller is loosened.

The propeller nut may then be slackened back a couple of inches or so, remembering that for a right-handed propeller the thread of the nut is usually left-handed, and *vice versâ*.

The propeller boss can then be started, and an attempt should be made to do so without using a ram on it. Unless special appliances are available, a couple of long stout steel wedges, having a fine taper, should be obtained, and, having made up the distance between the boss and the propeller-post, or end of the stern-tube, with packing of iron blocks, and inserted one of the wedges from each side (having previously oiled the sides well), they can be driven up simultaneously, either with fore-hammers or light rams. An enormous strain can be obtained by the use of the wedges, and probably the boss will start without further trouble. If it cannot be started with this treatment, then a heavy ram must be tried on it, after having first put as much strain as possible on the wedges, and perhaps the boss will require to be well heated up before it will budge. The latter course is, however, attended with danger, as the boss may be cracked, or personal injury by scalding may result when the boss starts, unless one of the blades be previously taken off or other means afforded for the escape of any steam that may be generated inside the boss. If the propeller be of considerable size, it is advisable, in any case where possible, to remove the blades before slackening the boss, so as to reduce the weight to be lifted off at one time.

Having got the boss started, the weight of the propeller can then be taken by a couple of chain blocks suspended from the shackles usually placed under the counter for that purpose, and the shaft drawn in from the tunnel.

"Youngs' patient hydraulic propeller starter" supplies the long-felt want of a ready means of removing a propeller from its shaft, by a pressure equally distributed around the boss. The use of this appliance saves time and expense, obviates the burring of the gun-metal liner on the shaft, and the danger to the workmen caused by wedges, etc., falling into the dock when the propeller is started. Referring to Fig. 79, this machine is annular in form, made preferably with four segmental cylinders B, each being fitted with a ram A, of oval curvilinear shape, for bolting round the propeller shaft between the stern-tube and the propeller boss. The copper pipes and unions C, D, are for the circulation of the water pressure from the hand hydraulic pump L. The stop-cap or plug E can be used on any of the union nipples in the sides of the cylinders.

To fix the machine in place, the segmental cylinders B are first bolted together in couples, and, after placing the two parts in position, around the shaft at the back of the propeller, the coupling bolts F are inserted and tightened up; the copper pipes D are then screwed to the cylinders, and the pump L connected to the machine by the copper pipe G. Should there not be sufficient space to insert the machine behind the propeller, the shaft should be pushed outward until the necessary distance—only about four inches—is obtained.

When the machine is fixed in position, the cistern L

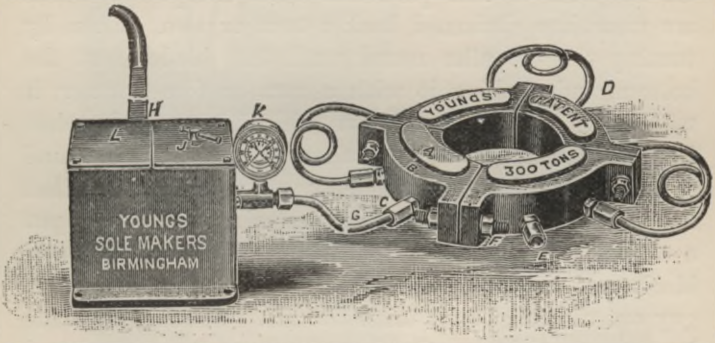


Fig. 79.—Youngs' Hydraulic Propeller Starter.

should be filled with clean fresh water and all connections made secure; take off the stop-cap or plug E, and commence to pump until the water is forced through the nipple from which the cap has been removed. All air is thus forced out of the machine, and, having replaced the stop-cap, screw up the stop-valve J, and the propeller starter is ready for work. When the maximum run-out has been attained, if it should be necessary to force the propeller still further, unscrew the stop-valve J and force back the rams A by means of wedges or with a crowbar, insert packing pieces, and pump up the machine again.

Fig. 80 is from a photograph of the propeller starter fixed in position on a shaft of 11 inches diameter. In this instance the maximum pressure exerted was 214 tons, and the propeller was started in a few minutes after the machine was in place.

Taking off the Blades.—When any of the blades require to be taken off, the easiest way is to take off all the nuts of that particular blade except two, which are meantime slackened back a turn or two. Then, by turning the propeller round until that blade is at the bottom, and shaking it with a ram or fore-hammer, it will, being assisted by its own weight, become detached from the boss. If the propeller be then turned round so that the slackened blade is at the top, all that has to be done is to take off the remaining two nuts, put a shackle on the blade, and lift it off with a couple of blocks and falls hung under the counter, using the one to guy out the other as it takes the lift. Should the blade be not very tight on the boss, however, it may be lifted off at once, without going to the trouble of turning the propeller round in order to shake it.

Putting on the Blades.—The holes in the flange of the blade are usually made oval, in order to allow a variation of perhaps a couple of feet in the pitch, if required. After the blade has been set to the required pitch, slips of brass are sometimes fitted into a couple of the holes, which fill up the space not taken up by the studs, thereby preventing the blade from turning. Pieces of hard wood, cut to the required shape, will answer the purpose quite as well as the brass slips,

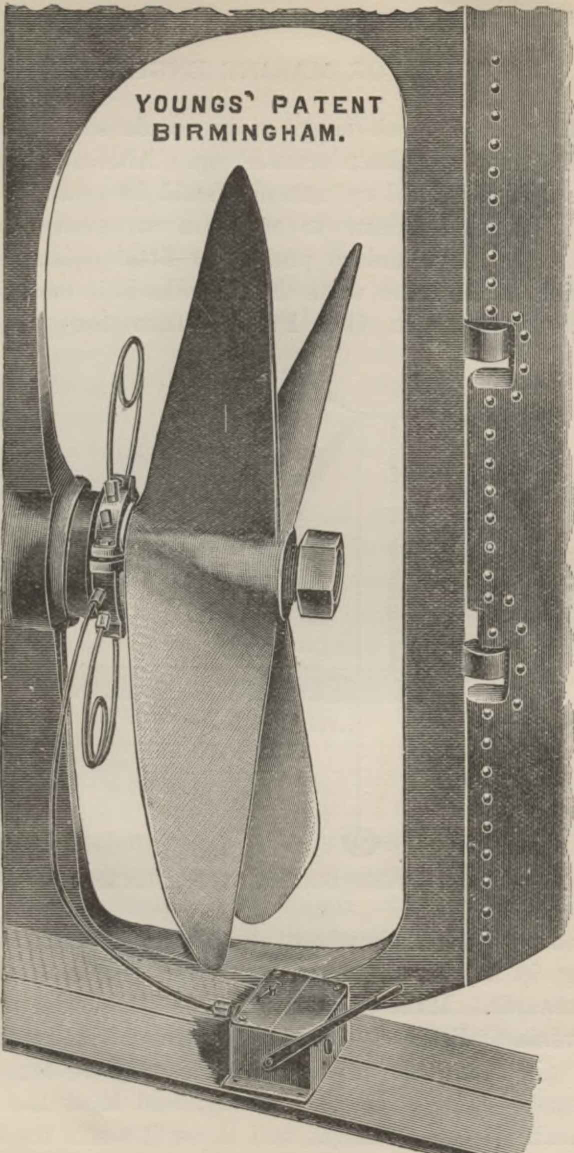


FIG. 80.—Youngs' Hydraulic Propeller Starter in Position.

for there is not much danger of the blade shifting when all the nuts have been screwed up. After all the nuts have been tightened up, cement should be placed round about them, in order to maintain an even contour about the boss, and so present as little resistance as possible to the water when the propeller is in motion.

How to take the Pitch.—Turn the propeller

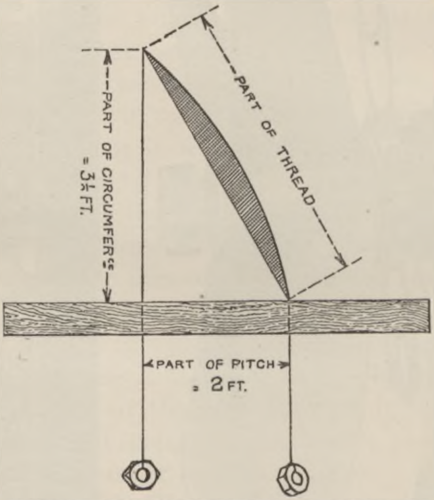


FIG. 81.—Taking the Pitch of a Propeller Blade.

round until the blade whose pitch is to be measured is lying in a horizontal position, with the face looking downwards. Make a chalk mark on the blade at any convenient distance from the centre of the boss, and the pitch at this particular place may be found as follows:—Take a piece of string, load it at the ends to make it hang straight, and throw it across the blade at place of measurement. Two sides of a right-angled triangle are thus obtained, the distance between the two parts of the string, as it hangs down, being the base, and the distance between the two edges of the blade at that place being the hypotenuse. The length of the third side may be found by calculation, or else by holding a straight-edge across from the leading edge of the blade, and keeping it parallel to the shaft, measuring the distance from it to the following edge. This third side represents part of the circumference of the screw, the base of the triangle part of the pitch, and the hypotenuse part of the thread. (See Fig. 81.) Then, as part of the circumference is to the whole of the circumference, so is part of the pitch to the whole of the pitch. For example, if the place of measurement be 5 feet radius from the centre of the boss, then the whole of the circumference will be $5 \times 2 \times 3{\cdot}1416 = 31{\cdot}416$ feet; and supposing the base and perpendicular of the right-angled triangle, as previously explained, are found to be 2 feet and $3\frac{1}{2}$ feet respectively, there is the proportion:—

As 3·5 : 31·416 :: 2 : pitch, which, when worked out, will be found to be 17·9, or nearly 18 feet.

The Pitchometer.—The pitch may be found much more correctly, and without requiring to make any calculation whatever, by means of the pitchometer, of which Fig. 82 is an illustration. The pitch of a blade is found as follows:—Place the blade as before in a horizontal position, but with the face looking upwards. Disconnect the rod A A with the spirit-level attached, and hold it up against the after side of the propeller boss where faced up—or anywhere at right-angles to the axis of the propeller—and adjust the spirit-level, jamming it in position by the thumb-screw at the side. Connect again to the rest of the instrument, and rest it across the face of the blade at the particular part to be measured, as shown in the illustration, the

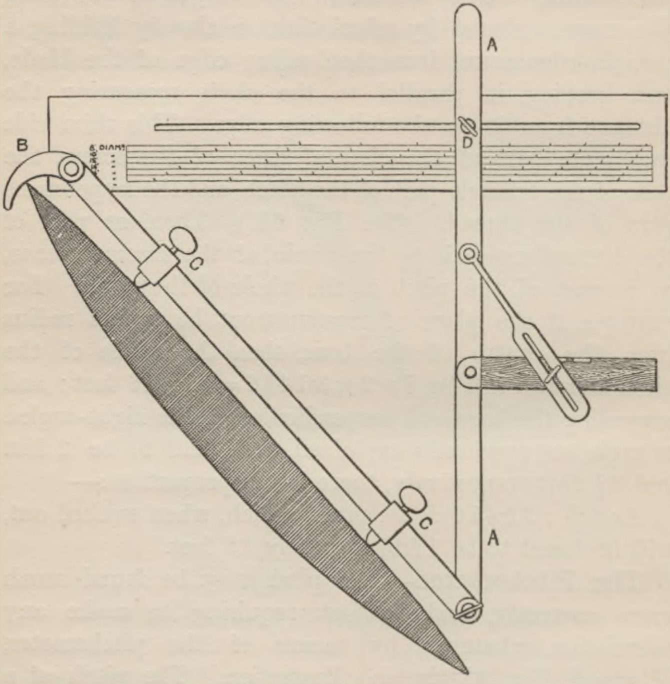


FIG. 82.—Pitchometer.

hook B catching the leading edge and holding up the weight, C C being adjustable points intended to make the instrument lie evenly across the slightly rounded surface of the blade. Adjust the rod A A until found to be in the correct position according to the spirit-level, jamming it afterwards with the thumb-screw D. The pitch can then be read off the graduated scale where the side of the rod A A crosses the line for the diameter corresponding to that for the place on the blade at which the measurement is taken.

Conclusion.—The successful management of steamship machinery is based upon close observation, and the measure of success attained will be in proportion to the exercise of this faculty. The habitual observance of slight and apparently insignificant irregularities may be the means of averting many disastrous failures. But, while there is nothing like personal experience for making an indelible impression upon one's memory, this alone is not sufficient; for if an engineer were never to investigate the causes of any failures, excepting those with which he was immediately connected, he could scarcely be considered thoroughly competent to undertake the responsibility of managing the machinery of high-class passenger steamers, or indeed any class of machinery. Any records of instances where failure has occurred through the faulty treatment of others should be studied, and a mental note made of the same. By so doing, self-reliance and precision of judgment will be acquired.

An engineer should bear the same relation to the engines placed under his charge as a doctor bears to his patients. He should be able to prescribe the treatment best calculated to maintain them in a healthy condition; and, when they happen to suffer from any malady, should be competent to make a diagnosis of the case, and able to suggest appropiate remedies for their recovery to health; for the origin of breakdown or failure of any description, whether in the case of engines or patients, is within reach of intelligent investigation.

This little book has been written in order to help young engineers to more fully realise their responsibilities, and assist them with their daily work. The management of steamship machinery is a very extensive subject, and this book might easily have been made three or four times its present size, but that would have involved much additional expense; meanwhile, it is merely intended to form a concise and handy guide to some of the more important matters that demand the attention of marine engineers, and is published at such a cheap price as to make it easily procurable by all. Should it be the means of smoothing the way of any engineer, or helping him to a clearer understanding of his duties, in however slight a degree, then its publication will not have been altogether in vain.

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