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Oil Fuel.

REPLY TO THE DISCUSSION WITH FURTHER OBSERVATIONS AND COMMENTS.

BY ALBERTO KEENS (Member).

It would appear that there seems to be considerable doubt as to whether oil-fired ships are more expensive to run than those fired with coal. I am strongly under the impression that when taken collectively, the oil-fired ship shows the advantage, for although on the surface, oil is more expensive to buy than coal, it appears to be burnt more efficiently, and possesses heat units greatly in excess to those of coal. It is human nature to kick against apparently high initial costs without realising that a greater primary cost may, in reality, resolve itself into a substantial saving when carefully worked out.

Taking coal at 13,000 B.T.U. and oil fuel at 18,500 B.T.U. per pound, thus allowing fair quality in each case, the oil is of nearly 43% greater thermal value, this is better appreciated when stated in tons, viz.:—

Oil per ton	=41,440,000 B.T.U.
Coal per ton	=29,120,000 B.T.U.

In actual practice however, the evaporative values are as 1 is to 1·6. Under experimental tests this value has been stated as high as 1 is to 1·95. Another factor in the favour of oil fuel is that most steam coal is of small size, and in many cases very dusty, and lends itself readily to waste, owing to it being blown about when bunkering, and falling through the bars when the furnaces are being fed.

Owing to the regular speed it is possible to maintain when using oil fuel, it is possible to save three or even more days per month with the ordinary cargo ship that steams on coal about nine knots. This represents an extra three days earning capacity to her owners, so that this value should be deducted from the cost of the fuel consumed. This, when taken in conjunction with the reduction of labour, victualling, increased cargo carrying capacity, etc., or increased radius of action cannot fail to prove the superiority of oil fuel both from a financial and practical point of view.

Another very important factor that should be taken into consideration is, that the oil companies appear to deal very fairly with their patrons; any oil that they guarantee to be of a certain thermal value is invariably superior to their claims, and the quantities are correct, at least that has been my personal experience. A ship recently took 650 tons of bunker oil at London, and the receipted quantities came within ·2 of a ton of the chief engineer's estimation. This sort of treatment is refreshing after experiencing the usual treatment associated with coal bunkering.

When either system (coal or oil) is being balanced up, we must not lose sight of the fact, that as a rule, many of the figures given are apt to be very misleading, owing to the fact that the figures are produced under ideal circumstances, *i.e.*, that is with specially tuned up engines and boilers that are used for nothing else but experimental purposes, and the tests are, as a rule, of short duration.

Performance made under actual commercial conditions by the ordinary ship in service and by the use of fuel bought in the ordinary way of business, is far more satisfactory for commercial calculations, for on every ship in active service, there always exist some defects that detract from the ultimate results; these minor and unpreventable faults that exist under practical conditions average in effect, more or less the same in every case where the usual care is bestowed, so that from a commercial standpoint of view the result of actual practice extending over a lengthy period is far more satisafctory than a test bed result can ever be.

It must not be taken by these remarks that test bed results are to be regarded as useless, far from it, they are extremely valuable for placing on record what may be achieved, and these results, to attain in actual practice, is the pinnacle of the practical engineer's ambition.

From past experience it has been proved that it is possible to get considerably closer to the results of experimental tests by the use of oil fuel than with coal.

The advance of oil fuel burning under boilers may be appreciated by the records as entered in Lloyd's Register of Shipping. These are as follows:—

Register Book.	Vessels Burning Oil Fuel under Boilers. Gross Tons.
July, 1914	1,310,209
,, 1919 ..	5,335 678
,, 1920	9,359,334
,, 1921	12,796,635

When surveying figures of this nature, two things must strike us very forcibly, viz.:—

It is a financial and commercial success,

or

A lot of money is being lost by its adoption.

By analysing the advance and progress of modern times, it would appear scarcely possible, that a scheme could assume such commercial proportions and at the same time be a failure on economic grounds.

To the engineer at sea it is very difficult to be in the possession of the different conditions and efficiencies covering a number of cases, and the standing of oil fuel cannot be put forward in the best possible light. The following, however, are the particulars that I am most conversant with. They have been taken from actual practice and refer to a ship of 8,400 tons deadweight and a war production:—

Overall thermal efficiency of engines and boilers.	Fuel used per day, tons. for all purposes, engine room.	Pounds per I.H.P. per hour.	Average speed per hour.	B.T.U. per pound of bunker oil.	Ship miles per ton of bunker oil.	Total miles covered during the trip.
12·4%	23·8	1·1	10·1	18794	10·048	4964
12·6%	22·25	1·03	9·5	18794	9·756	501
13·07%	22·0	1·05	10·069	18684	10·98	4545
13·01%	22·6	1·05	10 8	18786	11·434	2815
13·01%	22 6	1·05	12·05	18786	13·097	461
13·07%	23·3	1·048	9 58	18727	9 89	3201
13·07%	22·0	1·05	10·12	18709	11·02	3308
12·71%	22·6	10·8	8·9	18684	8·89	4689

These figures cover a period extending from last August to November, 1921, and it may be noted, that in this particular case no feed heater is fitted, although the feed is fed to the boilers at a temperature of 180° Fah. The steam is not superheated. It is perhaps to be regretted that no figures are available as to the performance of the same ship when on coal, they would have formed an interesting comparison between the two methods. The oil is burnt under forced draught conditions.

As to the consumption per I.H.P., it would appear that this has been stated to be a little higher than it actually is. The total consumption per day for all purposes has been stated in the figures given, and from this, one ton per day only has been deducted as allowance for the auxiliaries. This amount appears to be rather low. The auxiliaries are as follows :—

Steering engine, size 9ins. × 12ins., working for 24 hours per day.

Gwynne engine, size $8\frac{1}{4}$ins. × 6ins., working for 24 hours per day.

Fan engine, size $7\frac{1}{2}$ins. × 5ins., working for 24 hours per day.

Weir's oil fuel pump, $5\frac{1}{2}$ins. × 7ins. × $3\frac{1}{2}$ins., working for 24 hours per day.

Fuel heater, working for 24 hours per day.

Dynamo engine, $6\frac{1}{2}$ins. × 6ins., working for average 18 hours per day.

If it were possible to get the exact collective consumption of these auxiliaries, the main engine consumption would, in all probability fall nicely below one pound per I.H.P. per hour, together with a corresponding increase of overall thermal efficiency.

To further analyse the performance of this particular vessel :—Started voyage 27th July, 1921 ; finished voyage 26th November, 1921, or four months exactly. Quantity of oil fuel used during the four months was 2,630 tons.

This represents the total amount used for all purposes, viz. : Main engines, engine room auxiliaries, deck and cargo demands and total ports consumptions

The total distance covered by the vessel during the four months service was 24,444 nautical miles. This represents 6,111 miles per month. Without taking into consideration the stays in port, and counting *all days as running days*, this is equal to a daily average of 204 miles.

On the same basis, the fuel consumption amounts to 657·6 tons per month, thus representing a daily consumption of 21·91 tons.

The total result of this resolves itself into 9·31 nautical miles per ton of bunker oil.

In this case, heavy demands were brought upon the steam for purposes other than those connected with the engine room requirements, resulting to approximately 1·0 ton of fuel per day, so that the collective daily consumption is rather higher and the miles per ton of bunker oil somewhat lower than it might have been.

This method of calculating the general efficiency is, to the engineering mind, a little out of order and not of a very technical nature. It is, however, most expressive to the shipowner as representing the result in pounds, shillings and pence. Figures of this nature eventually find their way into his private *vade mecum*, and until such time that these figures regarding the oil fuel burning ship are capable of showing an overwhelming advantage over and above those of coal, shipowners will not show any great desire to make the drastic change. Many go ahead shipowners have already recognised the superiority of oil as a medium of producing steam, and at the present time some of the largest and fastest ships in the world are successfully using oil.

Tradition takes a lot of living down, but it is difficult to conceive the reason why some owners are satisfied to continue in the old coal burning rut, when there are such good economic and practical grounds for converting to oil fuel.

Whilst on the look out for conditions that may exist on ships, it came to my knowledge that the consumption of a certain ship of 2,262 registered tonnage and 382 W.H.P., was 17 tons of oil fuel per day, or ·84 pounds per I.H.P. per hour. This particular ship had two main boilers using forced draught and under a working pressure of 180 lbs. per square inch.

In another case, a ship on voyage from America to Queenstown and having two main boilers under forced draught and 180 lbs. per square inch working pressure, used only 17 tons of oil fuel per day or ·898 pounds per I.H.P. per hour. This ship was of 3,062 registered tonnage and 425 W.H.P.

These consumptions, which have been taken from the official logs books, appear to be very highly satisfactory, more especially so, when it is noted that they were made under commercial conditions. The two performances point to a high state of efficiency, and it may be interesting to note that both these vessels were fitted with the Smith-Zulver patent system of oil fuel burning.

The "get steam at any cost" principle that was referred to, does not appear to be a very laudable one, and there are not many commercial concerns that could continue on that basis; there is no doubt that this has seemed to be the case to a certain extent, especially during the recent war when a dependable speed was an asset, under ordinary circumstances however, it would appear to be the outcome of following the line of least resistence. The fault lay to a great extent with the owner of the ship, for oil fuel systems are often fitted apparently without due consideration. Lightning virgin conversions from coal to oil burning does not, as a rule, produce the desired effect, and after a time the particular party concerned converts back to coal, a disappointed man, with a kick against oil fuel like the proverbial steer.

Should due consideration however be paid to the choosing of a reputable system that is in keeping with the general conditions, the accruing result will give entire satisfaction in all directions. The fault does not always lay at the door of the owner however, for some engineers are apt to lose sight of many small, but essential details that contribute to the general efficiency and low maintenance costs.

Should it be possible to get a combination of high ideals from both parties the advance of oil fuel burning under boilers, would show a great and rapid advance, and would in a short time become the general order of the day. From past records, embracing both large and small units, the oil system has proved both efficient and economical.

Taking the figures of Lloyd's register into consideration, it would appear that we are getting a certain combination between engineers and shipowners, and there is no doubt, in due course, oil will assume its rightful position, as the Twentieth Century fuel.

Various methods of burning oil fuel have been discussed from time to time, viz.: Pressure system, air injection system and steam injection system.

The pressure burner system appears to be preferred for use on board ship as it lends itself readily to the conditions that prevail at sea. The combustion under this system appears to be extremely satisfactory, and it would appear possible to burn more oil in a given time than by either of the other methods. It may be stated that this arrangement gives the highest thermal efficiency. The pressure system in conjunction with forced draught appears to be the ideal method of working. The fuel oil pressures may vary considerably according to the nature of the plant used, and may be noted as low as 15 pounds and as high as 150 pounds or thereabouts.

Atomising with hot air. Most of the burners that are used in conjunction with hot air have also some mechanical device to assist the breaking up of the oil. The combustion is far more rapid and local than with the steam burners, and the temperature produced is higher. By the use of this system it is possible to produce a particularly high local temperature which makes this arrangement extremely valuable under certain conditions. For use at sea however, it does not appear to possess any particular feature of recommendation.

Atomising by steam. The steam jet system has several points that bears in its favour, unfortunately, so far as sea is concerned, its evils outbalance its advantages. Simplicity is the keynote of this system. The space occupied or the cost as compared with the other systems does not show any material advantage. For some reason that does not appear to be very clear, steam possesses the virtue of having a greater power of atomising oil than air, no matter how the air is applied, although curiously enough it is not the most efficient. Steam in itself is not a combustible commodity, nor will it support combustion.

It has been advanced in certain quarters that this system is capable of producing greater heating power, owing to the fact that through the dissociation of the hydrogen and oxygen of the steam used, and the subsequent ignition in the furnace, greater heat units are available. It should be kept in mind, however, that the heat that is absorbed in breaking up the component elements of the steam, corresponds approximately with the heat that is given off by the combustion of the resultant hydrogen and oxygen, so that the advantage on this score appears to be nil. Moreover, approximately 5% of the total steam available is consumed absolutely during the transaction. The most important feature will ban this system for ever, so far as general use at sea is concerned. Again, owing to the steam not being a supporter of combustion, the burning of the oil does not take place so rapidly as it otherwise might do, so that there is always a possibility of unburnt gases escaping from the funnel, and a quantity of heat units being lost. Under certain conditions, however, this system certainly has distinct advantages. For use at sea however, it does not appear to have any especial advantage or recommendation, and for obvious reasons it would appear to be last to come in for consideration for maritime use.

The three systems compared, so far as steam consumption is concerned, is as follows:—

The steam pulverising system uses about 5% of the total steam available. This steam is lost absolutely, and ample evaporators must be fitted to make up these losses, in isolated cases the consumption has been noted as high as 10%.

The hot air system absorbs about 4% of the total steam generated, but this figure may be increased according to the efficiency of the compressor. The steam in this case is not lost, as it is condensed and fed back to the boilers in the usual manner.

The pressure system apparently heads the list, so far as ships are concerned, and consumes the least steam, approximately 2% (and has been stated as low as 1·5%) of the total steam produced being required for the entire working of the plant. The two items requiring steam being the pressure pump and the fuel heater. The steam used is afterwards condensed and used for boiler feed.

The evaporative value of the systems are as follows:—

Pressure system:	80% of the theoretical maximum.			
Hot air system:	78%	,,	,,	,,
Steam system:	73%	,,	,,	,,

These figures include the amount of steam required to operate the particular plants.

It was pointed out during the discussion that oil-fired boilers seemed to depreciate at a considerably faster rate than the coal-fired boilers. In time past, there has certainly been very rapid depreciation in certain cases, but we must not lose sight of the fact that oil fuel is a comparatively new thing, and that experience is a very relentless teacher; also that the oil-fired boiler works considerably harder than the boiler on coal. With the past experience at our command, the life of an oil-fired boiler should not prove any shorter, *pro rata*, than a similiar boiler on coal. Actually, the oil-fired boiler should show a very beneficial effect, owing to the pressure and temperature being so regular, and the heat being distributed so very evenly throughout the entire length and surface of the furnace. We must not lose sight of the fact that the water circulation is more active, and the temperature variation at various parts of the boiler does not show the variation of the coal-fired boiler. In view of these very satisfactory conditions it is difficult to conceive that there should be any doubt as to the length of life of the oil-fired boiler, providing it is properly handled and the system is in keeping with the conditions.

It may be stated that various burners may be supplied that are suitable for any class of boiler. By using the wrong type of burner considerable damage may be done to a boiler in a very short time. Some burners produce a very short flame, others on the other hand produce a long flame. There are several burners between these two extremes.

Obviously, the using of a burner that produced a long flame would soon result in extensive damage to a marine multitubular boiler, so that to get the best results as regards combustion, economical fuel consumption, long life of the boiler, coupled with low maintenance costs, great care should be taken to get the burner that is best suited to the conditions.

The depreciation that usually takes place in oil-fired boilers makes itself apparent in the combustion chambers, and affects the lower tubes and saddle seams, sometimes the stays are affected. These invariably leak badly in the first instance, and later on, the plates crack usually from the rivet holes to the edge of the plate. When good practice is followed as regards the fuel system, this fault invariably points to the fact that cold air has been freely and frequently admitted into the furnaces shortly after shutting off the oil, and before the plates have had time to be equalised in temperature. The cold air striking the extremely hot surfaces of the plates causes severe stresses to be set up, and the plates in a very short time appear to lose their nature. It is an undoubted fact that boilers when handled with care do not develop this fault. Cases are on record where it has been necessary to renew furnaces in practically new boilers, on the other hand, with suitable plant and careful handling, boilers have run for several years without requiring even a caulking tool being used on them, and are in appearance, as new. There is no doubt that the oil-fired boiler must be handled with thought and care, for the intense heat under which they work renders it impossible for them to stand the criminal usage that some coal-fired boilers are called upon to stand.

With regard to this matter, it will perhaps be of interest to state the condition of the boilers—from which the data given upon another sheet was taken—on being opened up after six months continuous working. These boilers are over three years old, and have been used continuously under oil fuel.

Density on starting: Fresh. Density after six months service: 4-$5\frac{1}{2}$-$4\frac{1}{2}$ ounces.

The scale on the furnaces was about 1/32nd thick all round, being slightly thicker at the top than the bottom.

The tube plates, tubes and combustion chambers were covered with a protective scale, the thickness of an eggshell, and required no cleaning. The shell plates still retain their new bloom.

The fire sides did not show the slightest trace of salt or leakage in any of the back ends, and the combustion chamber plates were not buckled in any shape or form. The stay nuts are as new and do not show the slightest signs of being burnt. The boilers were cleaned, washed out and put into action without any further expense.

From the foregoing remarks it may be gathered that the only ways that an oil-fired boiler can suffer rapid or unusual depreciation, or can even have a shorter life, *pro rata*, than the coal-fired boiler is: By careless and thoughtless handling. By using arrangement that is unsuitable to the conditions, or, by working a boiler above its rated capacity. This last mentioned condition is rather elastic, for with suitable arrangements and fittings, careful handling and attention, a boiler may be worked for considerable periods of time at its *fullest* capacity without showing any signs of distress.

It was pointed out during the discussion that it did not seem possible to increase or decrease the combustion chamber temperatures except by increasing or decreasing the amount of fuel burnt. This statement should be received provisionally, for although perfectly true under each separate condition, it is apt to be very misleading if taken literally, for under varying conditions, but maintaining the same steam pressure, the temperatures of the combustion chambers may vary considerably. The combustion chambers, being a vital and vulnerable part of the boilers, by virtue of having joints, stays and tubes, sharp edges of plates that lend themselves readily for absorbing and conducting heat *or cold* should come in for special consideration as regards any means for their protection, and from our present standpoint even two or three degrees reduction of temperature is a good step in the right direction.

It will be appreciated that steel at high temperatures is extremely sensitive. The higher the temperature, the more sensitive it becomes to any variation that may take place, and the more it deteriorates when subject to any *rapid* variation. The heat under oil fuel is intense, hence the desirability of reducing the combustion chamber temperatures so far as reasonably possible.

The condition, in which the least temperature of the combustion chambers exists, is that, where a burner is used that produces a very short flame, in such a case the combustion takes place in the front of the furnace and the heat of combustion is partly dissipated by radiation and convection whilst passing through the remaining portion of the furnace, so that when it enters the combustion chamber the gases are reduced in temperature quite an appreciable amount, and by the time the gases have passed through the tubes and reached the funnel, the temperature should be in the vicinity of 500° Fah.

By the use of different burners giving various length flames, the heat of the combustion chambers is proportionately increased until a burner is used whereby the flame may actually play direct on to the backplate and we are getting combustion in the chamber itself. Obviously, the combustion chamber local temperatures in such a case are considerably above those necessary for a given amount of oil burnt, hence the desirability of a burner that produces a short flame. It has been stated that serious backend troubles have been experienced whilst using oil fuel, this undoubtedly has been so, and the above may answer the cause of quite a number of them.

On the use of firebricks in the furnaces and combustion chambers, the discussion was rather disappointing and the points raised were few. It was mentioned that in the White system no firebricks were used. This is true, where the bearer and back bridge plates are removed under *any* system, the back bridge plate, when left in, must be covered with firebricks all over to prevent it from being burned away. The front bearer plate, if left in, must also be protected from the intense heat. it is usual also, to build a wall up to the under side of this plate to prevent it from sagging, observing that a sufficient opening must be left to enable a sufficient quantity of air being admitted when necessary, and also, to enable a rake to be introduced to draw out any residue that may collect in the bottom of the furnace. This opening also serves for observation purposes. As stated before, the question of brickwork is a point upon which there is a great diversity of opinion amongst engineers, it may, or may not be an advantage, according to circumstances.

The measuring tanks that were referred to, in connection with the bunkers, presumably two in number, would certainly be an advantage, and would facilitate the rapid and accurate calculation of fuel consumption, except on rare occasions, these are not ordinarily fitted, the ordinary bunker, is, from the shipowners' point of view, quite sufficient to arrive at the practical consumption. The total collective result of the fuel paid for, is, to the owner, more expressive than pounds per I.H.P. per hour.

As to the danger of stokehold fires. The fires that may occur in the stokehold under exceptional circumstances assume in certain cases, considerable proportions, and may become unmanagable. In the vast proportion of cases the fires are traceable to the lack of care or knowledge of those in charge, or, to the inefficient plant used. Up to the present time there does not appear to be a thoroughly efficient or trustworthy method known of coping with extensive ship fires, although, there are certain methods that have proved very efficacious in the case of minor fires.

All large things have a small beginning, and the best way of preventing fires of any magnitude is to be prepared, and to be in a position to attack the first suspicion. With a clean stokehold the chance of fire is very remote. With well-appointed stokeholds, careful attendants and efficient plant, the danger of fire is not considered to be above the normal.

As to the possibility of a fire or explosion *inside* the fuel pipes from the pressure pumps, it would appear that a condition of this nature was impossible. In certain cases of neglect, burners have been noticed to be red hot, caused by the burner getting partly choked and being allowed to continue until the burner got red hot and finally choked up altogether; in such cases no ill-effects have been produced, except, that the burner has been so badly carbonised as to be ruined.

It has been stated, and correctly so, that many of the gauge glasses fitted to the observation tanks for assistance in detecting oil leakage, fail to fulfil the duties for which they are fitted. A badly fitted or ill-placed gauge glass is worse than useless. The best place in my opinion to fit a glass, although I have never seen one in practice, is, direct on to the return pipe from the heating coils and *before* the observation tank. By fitting a glass in this position and with a slight rake, the condensed water must pass through the glass before it enters the observation tank and any leak, however slight, would be instantly apparent by observation only.

In some cases it may be noticed that steam is issuing from the observation tank, this points to a very badly managed arrangement, the latent heat of the steam that should be transferred to the oil in the heater being dissipated in the return pipes and observation tank, much to the discomfort of the persons on watch. In some cases, an effort is made to prevent the wastage of steam in this direction by fitting steam traps on the return line and in close proximity to the heaters.

As pointed out, the heating coils around the suction pipes in the bunkers are not, in certain cases, sufficient, and that further heating surface is required. When the bunkers are carried in double bottom tanks, or oil is carried as cargo, it is imperative that ample heating surface should be fitted to allow the oil to be kept in an efficient state for pumping and the pipes are led all over the bottom of the tank. These pipes are as a rule of ample size (usually about 2ins. diameter). With the side or cross bunkers, however, the coil around the suction pipe appears to be sufficient, owing to the slow rate that the oil is handled. Up to the present time (feeding from the cross bunker) I have never had the necessity of using even this, the oil in use being of ·95 to ·97 specific gravity. Some engineers make a practice of heating the oil in cold weather as they maintain that it facilitates the handling, and obviates any possibility of the pumps refusing action. When looking out for low consumption and efficiency, the heating coils in the bunkers are never used except as a forced measure. The steam required and the fuel to produce it is rather a heavy factor. When one considers that one ton of oil at 18,500 B.T.U. per pound, when burnt under a boiler at maximum efficiency, viz., 80%, gives off sufficent heat to raise the temperature of 1,000 tons of water *at the boiler* 14·8° Fah., and the subsequent radiation and condensation of the steam in passing from the boilers and through the pipes to the tank, reduce the heat available at the tank down to a comparatively low figure. Owing to the properties possessed by oil fuel it readily absorbs heat but we do not want to lose sight of the fact, that it is also susceptible to cold. The wetted surface of the tank has a very great bearing on the heating consumption. This on economic grounds, makes it inadvisable to put the heating coils in action except under exceptional circumstances.

Coming back to the pipes themselves, it would be advisable to have them without joints if possible, as this is often a practical impossibility, special care must be taken to ensure a perfectly tight union. There are two methods in constant use that gives good results, that is with iron or steel pipes. In one case, the ends of the pipes are screwed with a gas thread on the outside, flanges are screwed to fit them, and the pipe ends are then expanded into them with a tube expander, the pipes are then jointed together with suitable jointing material and a trustworthy connection is the result. The other method consists of screwing the pipes as above and fitting a screwed sleeve so that each pipe screws half-way in, lock nuts are then fitted at each end of the sleeve with a grummet. The former joint appears to be the best, but is more expensive.

It should be noted, that the deterioration of these heating pipes in the oil tanks takes place on the *inside* owing to the fact that when not in use, the pipes contain a considerable amount of water and air that lends itself readily for the corrosive action that the pipe is subject to. The oil does not seem to have any adverse effect on the material, and it often happens that a pipe that is thin and in places worn through, appears to be quite new on the outside.

When a number of tanks are being heated at the same time, it is advisable to have some simple method of testing each individual tank service as it leaves the tank. An ordinary drain test cock fitted to the exhaust line appears to be the simplest way of doing this, and an arrangement of this description greatly facilitates detection of invidual tank leak leakage, and is successfully used in practice.

With regard to the appearance of a furnace doing good work. The accepted opinion, so far as the present marine boiler is concerned, is, that a short flame of large cross section is to be desired, and that it should flare close to the end of the burner, preferably about one inch from the nozzle.

When observing the flame from behind the burner, nothing can be seen except the start of the flame, and this is extended into an incandescent mass of brilliant whiteness through which it is impossible to see; there is no signs of smoke or vapour. When looking through the ashpit sight holes, a clear view of the back ends, or the bridge plates if they are left in, is obtained. The lower edge of the flame is throwing off a number of small incandescent stars; these stars are apparently the residue that is incombustible, this is so light that it passes off together with the gases of combustion from the funnel unnoticed, and does not, as might be reasonably expected, collect in the bottom of the furnaces. In a case of personal knowledge, one vessel having nine furnaces has not had a rake put into any of them for six months. The corrugations at the bottom of the furnaces had slowly filled up nearly level with the heavier residue that had collected during that time, so that it may be taken that should the furnace be doing good work they will run from one docking to another without requiring any cleaning. This also applies to the combustion chambers. The boiler tubes of this particular vessel also ran for three months without requiring to be swept, and without apparently losing any efficiency. It will be noted that this condition was maintained under the use of heavy oil fuel, having a gravity of ·95 to ·97. The furnaces of a marine boiler doing good work may therefore be recognised by the short white flame, flaring close to the end of the nozzle, and without any signs of smoke or vapour.

With regard to the funnel gases in a case where good work is being done. With satisfactory combustion the CO_2 recorder should show approximately 12·5% carbon-dioxide; should, however, an excess of air be fed to the furnaces, the percentage will fall and the percentage of free oxygen will increase.

It would perhaps be of general interest to enumerate the various conditions that existed in the instance of the furnaces just quoted. It may be stated that only one burner per furnace was used. The temperature of the oil appears to be rather low for the specific gravities, but are the temperatures as read off the thermometers in use. The total result was smokeless combustion without residue.

*A sample of the deposit that had accumulated in the furnace bottoms will be shown for inspection and examination, the nature, thickness, etc., may give rise to a discussion of an interesting character. It will be kept in mind, that the thickness, which is shown to be about ⅛th solid at the bottom of the corrugations, is the collection of over six months without disturbance.

To my mind, this deposit is not created whilst the furnace is actually in action but is caused on first starting up or restarting, in this condition there is always a small amount of comparatively cool oil in the branch pipes that does not fire immediately on entering the furnace, but falls into the corrugations at the bottom of the furnace. This small amount of oil is carbonised by the following oil firing and producing the necessary heat for this purpose. The actual deposit in the furnaces and combus-

* Sample may be inspected in the Reading Room at the Institute.

tion chambers that is produced whilst the furnaces are in regular action and giving good service consists of light dust which may be blown from the funnel by a few minutes extra forced draught supply.

I.H.P.	Specific Gravity of fuel.	Fuel pump pressure.	Furnace front fuel temperature.	Air press at fan casing.	Size of nozzles in use,	Kind of fuel oil used,
1940	·959	60 lbs.	200F.	1·375″	·059	Mexican
1830	·951	55 lbs.	205F.	1·375″	·059	Mexican
1920	·961	60 lbs.	215F.	1″ to $1\frac{1}{4}$″	·059	Mexican
2000	·964	70 lbs.	220F.	1″ to $1\frac{1}{4}$″	·059	Venezuela
1870	·968	58 lbs.	225F.	1·25″	·059	Venezuela
2400	·970	70 lbs.	230F	1·5″	·063	Venezuela

The following figures may be useful as a starting base for the satisfactory burning of oil fuel of any origin. It will be recognised that these figures are not given as a definite guide, for the temperatures required may vary in either direction depending upon the origin, viscosity, and nature of the system used, etc., but by taking the particulars given, as a starting base, the exact temperature may soon be arrived at. This temperature is such—when taken in conjunction with the other factors that bears directly or indirectly on ideal burning—that it is readily recognised by the absence of smoke and residue. The oil pressure must be regulated according to the number of burners in use and the pressure of steam required.

Specific gravity of the oil used.	Temperature required to burn it efficiently.
·87 to ·89	140 to 150 degrees Fah.
·89 to ·91	150 to 160 ,, ,,
·91 to ·935	160 to 170 ,, ,,
·935 to ·946	170 to 200 ,, ,,
·946 to ·96	200 to 240 ,, ,,
·96 to ·97	240 to 270 ,, ,,
·97 to ·99	270 to 300 ,, ,,

For economy and smokeless combustion, it is essential that the air that enters the furnaces should be previously heated to as high a temperature as possible. Should it be possible to heat the air by the aid of the waste gases of combustion, this condition is obtained without any extra cost and incidently the efficiency is increased and the funnel temperatures are reduced. This condition is readily effected in cases where forced draught is used.

Natural draught, however, offers a little more difficulty in this direction, but, with up-to-date and well-designed furnace fronts, a similiar effect is obtained, although not to the same extent as with the forced draught front. Under experimental tests it has been found possible under natural draught conditions, to supply air to the furnaces at a temperature of slightly over 200° Fah.

It must be kept in mind that the higher the temperature of the air supplied to the furnace the higher the efficiency of the boiler.

Combustion, from a chemical point of view, is the intimate and complete combination of the carbon and hydrogen of the oil with the oxygen of the air. When the result of burning the fuel oil carbon is carbon-dioxide (CO_2) the combustion is perfect; should any carbon monoxide (CO) be formed at the same time it points to the fact that the oil is not being burnt to the best possible advantage. The hydrogen in the oil is consumed to the best advantage when combined with sufficient oxygen to produce H_2O.

It is usually accepted that theoretically, approximately 14 pounds of air or 200 cubic feet of air is necessary for complete combustion per pound of oil. Unfortunately, it is not always possible in practice to get within 1,000 miles of the pinnacle of theoretical perfection, and in this particular instance, the air required in practice for satisfactory combustion is about 25% greater than the theoretical amount. Careful regulation therefore is necessary to control the air that enters the furnaces as it is of vital importance to economy, any excess of air that is supplied to the furnaces exerts a considerable cooling effect to the furnace generally, owing to the fact that the air must be heated to the temperature of the furnace before any heating effect of the fuel may be utilised for steam generation.

Several remarks have been made as to the boiler design suitable for oil fuel. For some time past I have had the opinion that the present marine multitubular boiler that is designed to burn coal, or, designed under the present proportions, to burn oil, is not entirely suitable for the oil burning conditions, and may not, and in some cases cannot, give satisfactory results as to combustion, especially so, when worked at the fullest capacity. It will be recognised that only in very rare cases, is it possible when burning coal, to keep a full head of steam when the main engines are opened up full, and in almost every case without exception is it possible to keep a full head of steam when additional calls are made upon the boilers beyond the main engine requirements.

When using oil fuel, however, the boilers will meet any reasonable calls that may be made upon them, for more heat units may be released in a given time and the boilers work harder. This apparently, is where the difficulty creeps in, for in many cases when boilers are converted from coal to oil burning, they will, up to a certain point, give most excellent results. When that point is passed the smoke appears, and the smoke gets denser as the quantity of oil burnt increases, and it is impossible to stop or prevent this smoke.

From these results, it would appear, that in all probability (if the present type of marine boiler is retained) the future oil burning boiler will be slightly longer than the present practice. The extra space thus got will be utilised as extra depth of the combustion chamber. In short, the combustion chambers and furnaces will be made as large as conveniently possible. The tubes may perhaps remain about the same length. This arrangement would give the extra combustion space that appears to be desired.

Under this arrangement more tube area may be found to be necessary, also, an increase of smokebox and cross section funnel area may be an advantage. However, whatever the design or proportions of the future marine boiler may be, there is no doubt that it will be the outcome of various and possibly extensive experiments in order to keep up with the created conditions, for there is no doubt that the present boiler does not appear to be ideal for the conditions of practically—within reason—unlimited power.

It has been noted that apparently it is invariably possible to burn heavy viscosity oil fuel of low B.T.U. to slightly better advantage than the better quality oil fuel. On the face of it, it does not appear possible to get a higher efficiency out of one than the other, *pro rata*, especially so, noting that from an observation point of view, both oils are being burnt under ideal circumstances. From this it would appear that human observation is not quite so keen as it is usually supposed to be.

However, this statement as to extra efficiency does appear to have foundation in practice and perhaps the boiler construction previously under review may have some bearing on the subject, observing, that the low grade fuel may have, say 17,000 B.T.U. against 18,500 of the better quality, with its attendant greater volume of products of combustion.

By the kind permission of the Smith's Dock Company I am able to reproduce the results of tests made at their well equipped works. This company has facilities for carrying out extensive tests with oil fuel. There is no doubt that the experiments and energies of reputable firms of this description has gone a long way towards solving the difficulties that have from time to time beset the paths of oil burning engineers.

The following figures, which was produced at their works, are well worthy of thought:—

INFORMATION ON LIQUID FUEL.

The following analyses of five varieties of liquid fuel will show the variations in the oils obtained from different countries:—

	Borneo Oil Fuel.	Texas Oil Fuel.	Californian Oil Fuel.	Roumanian Oil Fuel.	Mexican Oil Fuel.
Carbon	86.74	86.30	84.43	87.11	84.10
Hydrogen	10.67	12.22	10.99	11.87	12.29
Sulphur	.03	1.33	.59	.16	2.95
Nitrogen	.05	.06	.65	.15	—
Oxygen ... / Water ... / Ash	2.51	.09	3.34	.71	0.66
Calorific Value in B.T.U.'s ...	18,830	18,400	18,806	19,320	18,862
Specific Gravity at 60° Fah. ...	.9628	.922	.962	.935	.940
Flash Point ...	225° Fah.	160° Fah.	228° Fah.	244° Fah.	192.2° Fah.
Ignition Point ..	294° Fah.	215° Fah.	258° Fah.	298° Fah.	244.4° Fah.

I trust that these replies to the discussion my paper gave rise to, together with the various comments may prove to be of interest, and to our younger members I would add: To the engineer that aspires to the superior knowledge and successful operation in respect to oil fuel, he must be prepared to exchange both time and labour for experience; order and cleanliness of habits must be his religion, and he must use and sharpen his powers of observation and deduction Although the ideal burning of liquid fuel is so delightfully simple under certain conditions, the satisfactory solution of many of the varied faults that may arise or may exist in certain cases, may only be arrived at by the engineer who has bought the experience.

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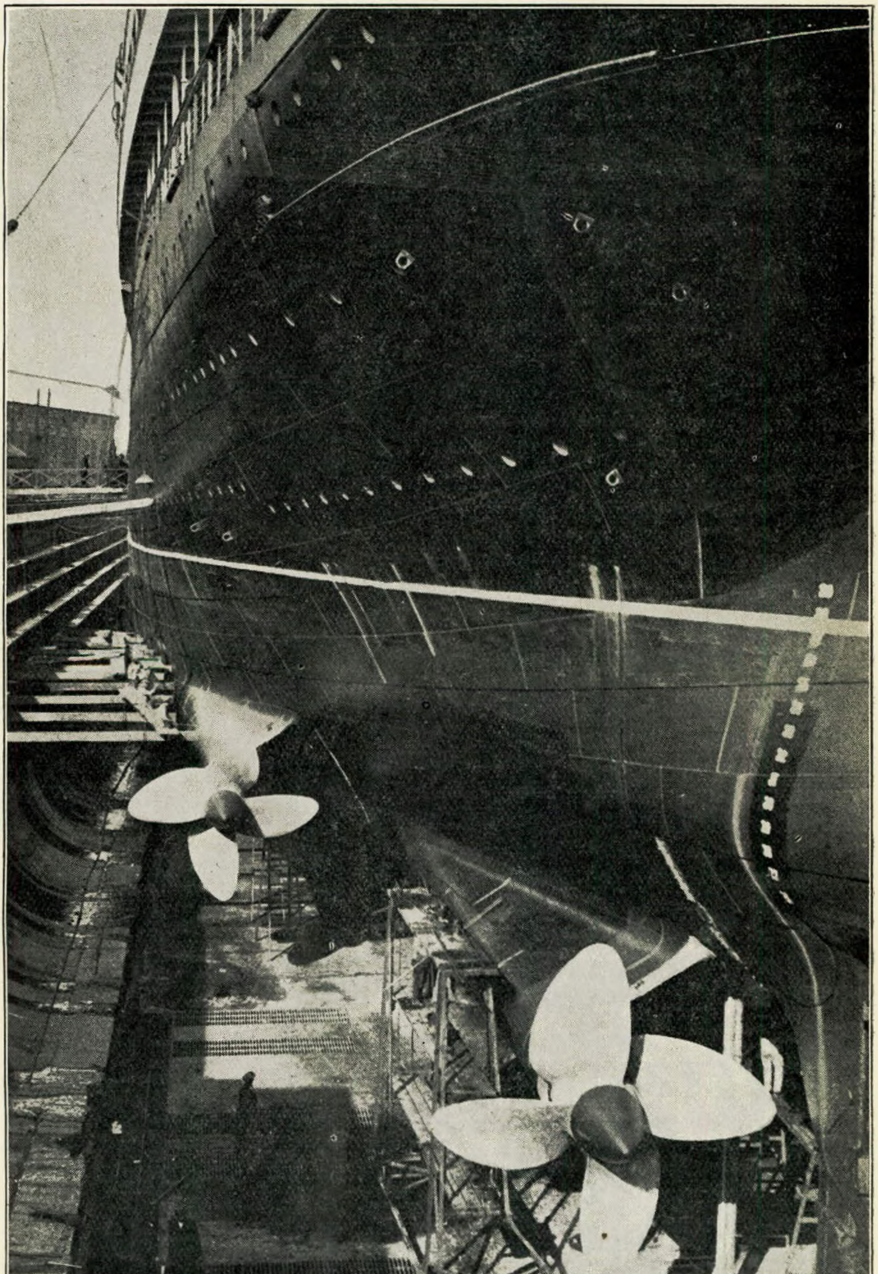
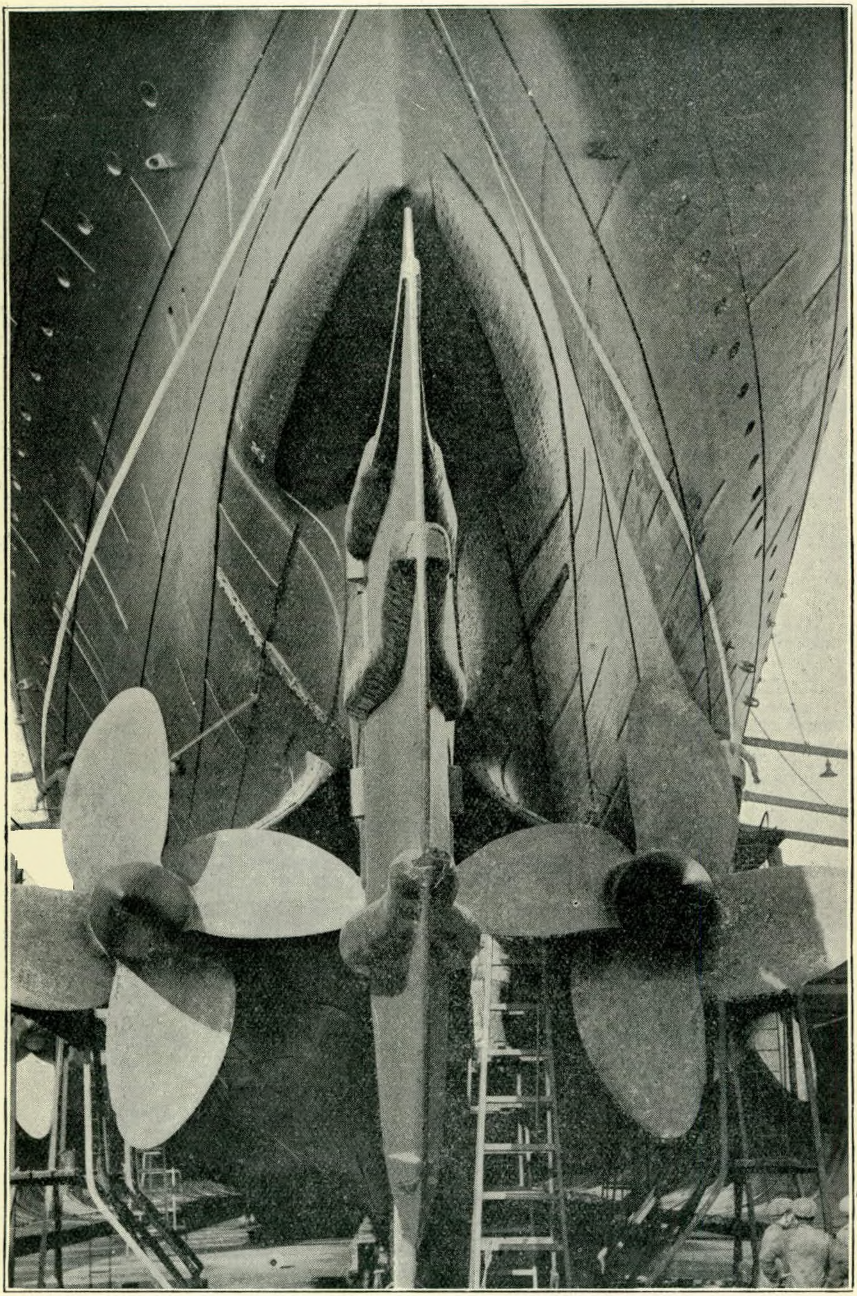
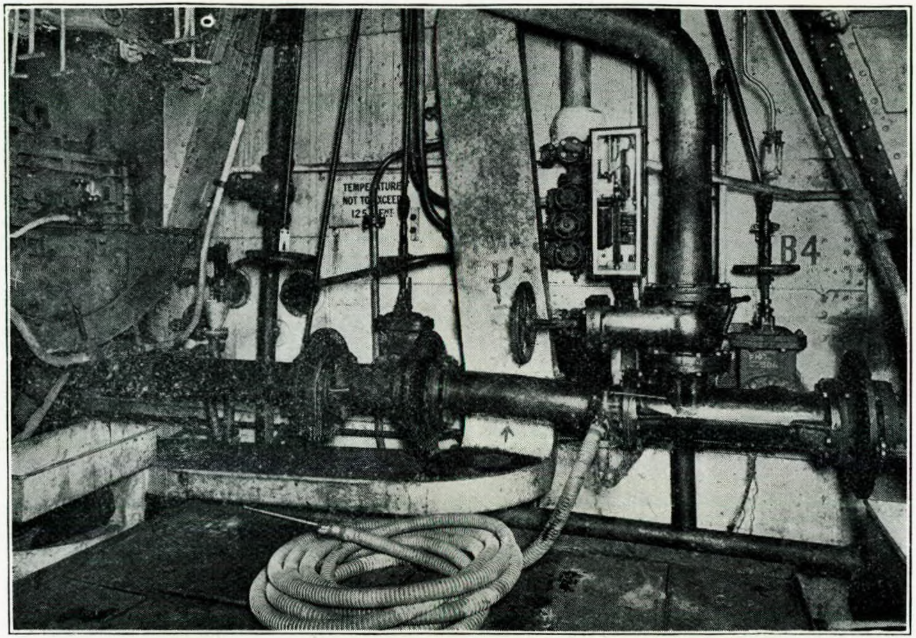
The illustrations which follow are reproduced by the courtesy of *The Shipbuilding and Shipping Record*—*Mauretania* in dry dock, and of *The Marine Engineer and Naval Architect*—the fuel installation in the *Mauretania*.



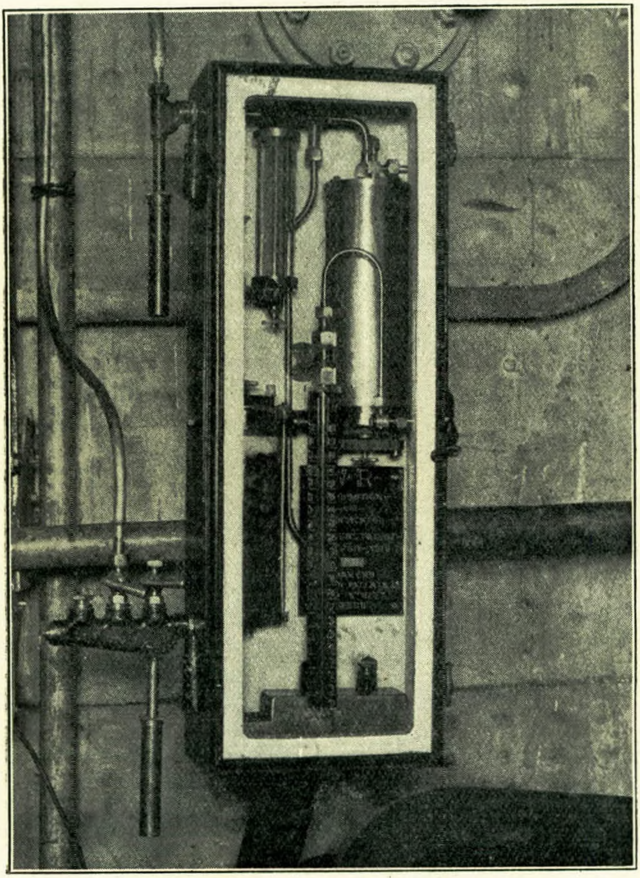
" Mauretania " in Dry Dock at Southampton preparatory to leaving on her first voyage after being fitted with Oil Fuel Burning Installation. Reproduced by the courtesy of *The Shipbuilding and Shipping Record.*



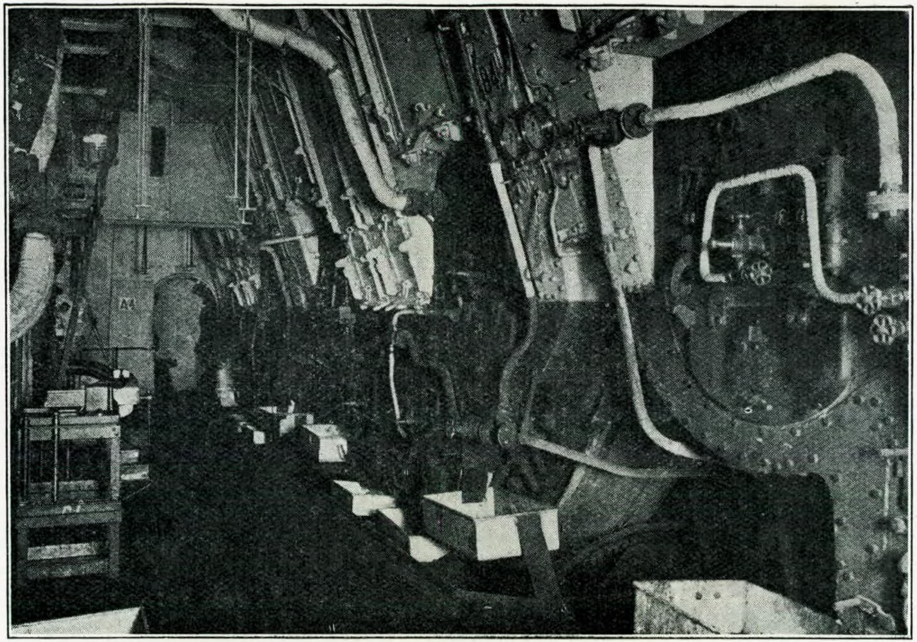
Stern View of the "Mauretania" in Dry Dock, showing the Rudder, two of the Propellers and the run of the Stern Plating. Reproduced by courtesy of *The Shipbuilding and Shipping Record.*



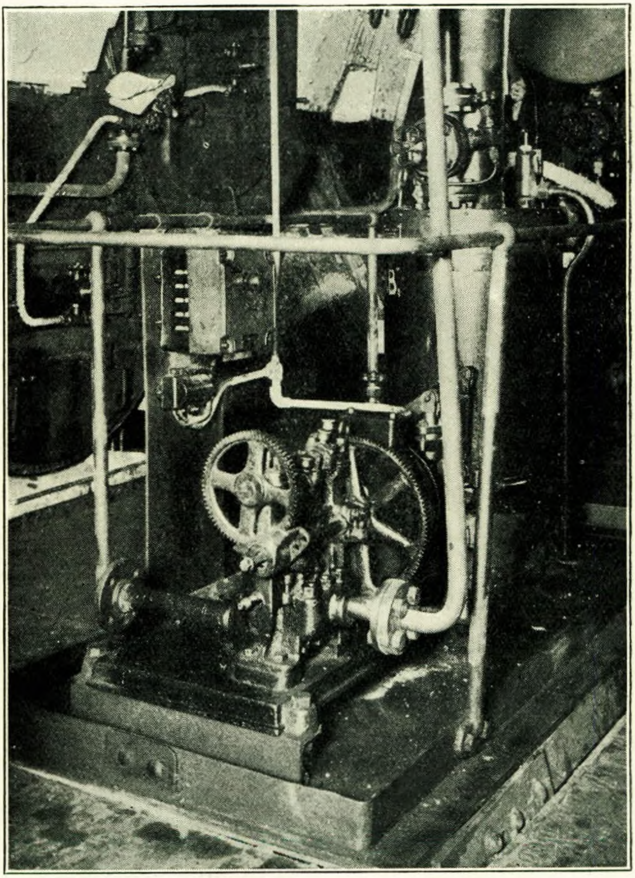
No. 4 Centre Stokehold showing Filling Main, Bellows, Expansion Piece, Hot Salt Water Hose, Ventilating Duct, Sluice Valve Extension Rods.



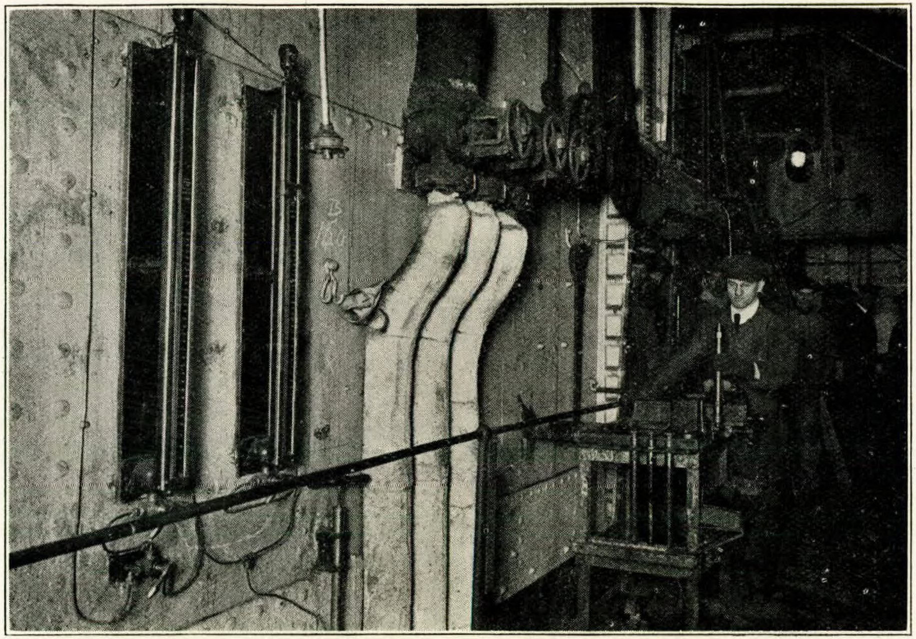
"W.R." CO_2 Recorder, No. 3. Stokehold, Centre Section.



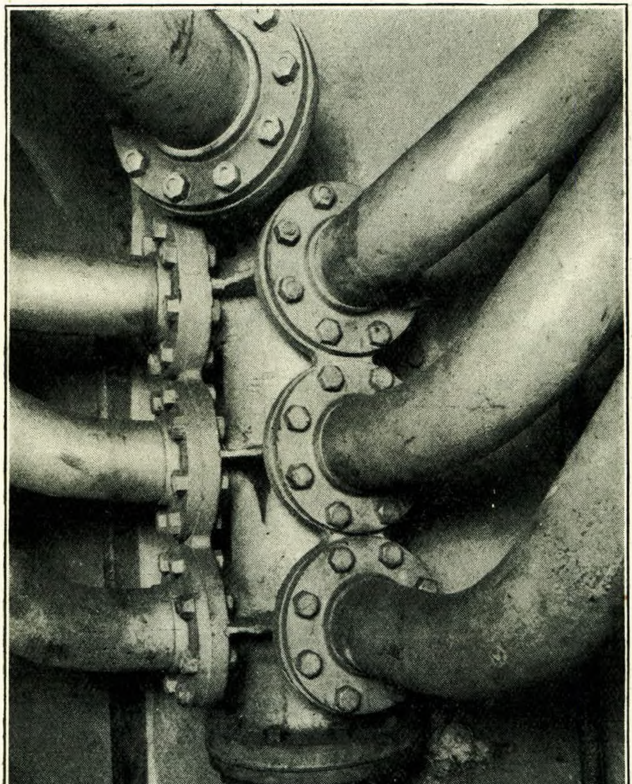
No. 4 Stokehold Forward Single-end Section, showing Furnace Fittings and Drip Trays.



Emergency Starting Set, No. 4 Stokehold, Centre Section.



No. 2 Stokehold Forward, Single-end, showing Pneumercator Gauges and Equilibrating Hand-pump, also Balmer Vice for Burners.



Overflow Junction Piece and Air Escape to Funnel Casing.

Review of Books added to Library.

Burning Liquid Fuel (*Wm. N. Best*) (*U.P.C. Book Co., New York*).—This is an opportune treatise on a subject which is very prominent at present, and the opinions and practice laid down are those of an engineer with a long and varied experience of the subject. Many useful tables are included amongst a wealth of practical information. It is noted that the American practice of placing decimal points on a level with the bottom of the figures has led to some errors, as on page 34 where the points are printed as commas, the proper place for decimal points is at half height of the figures, thus avoiding confusion with punctuation in the script. It is to be regretted that so small a portion of this authoritative work is devoted to marine practice, and that with types of boilers unfamiliar to the British Marine Engineer, but the information given covers a very wide field, and will be of value to those in charge of works plant in which the use of oil fuel is contemplated.

A Manual of Marine Meteorology (*Wm. Allingham*) (*C. Griffin & Co., Ltd.*)—This work on a subject which has an inexhaustable fascination and interest, put into convenient form a mass of information on atmospheric and climatic conditions and their causes. It is of course well known that much of the theory on the subject is speculative, and Polar exploration still has for one of its objects the solution of these mysteries of weather and storms, but even though the theories held may be disproved by later discoveries, the subject, dealing as it does with the elemental forces of nature, is full of interest, although with the departure of the sailing ship, weather lore is of less moment than formerly it was. A few typographical errors are noted, for instance, on page 47 the temperature at a place in Siberia is given as 56°, obviously—56° is intended, and in the same paragraph it is said that "absolute zero is variously stated as anything between 270° F. and 500° F. below the freezing point of fresh water." We are not so hazy on the subject as the figures quoted would imply, for Charles and Gay Lussac put us on the right track, and the absolute zero of 461° F. or—273° C. has since been verified by actual accomplishment at Leyden University. Apart from this small matter, however, the subject is dealt with in a fresh and vivid manner, and the book is recommended to the study of all who are interested in the phenomena of weather and conditions arising therefrom.

We have been honoured by the receipt of a volume of the Transactions of the Society of Engineers for 1921. This will be of great interest to members, and the wide range of subjects dealt with will supply something of interest and value to all.

The "Shell" Marketing Co., Ltd., have very kindly sent us a handsome souvenir volume commemorating their achievements and progress, with much useful information on the subject of petroleum and its products, and the storage, sale, and distribution of this commodity which has now become so necessary to all of us.

THE COCHRAN BOOK OF OIL FIRING (*W. K. Wilson*).—A very useful book on the subject. Typical installations are described, and excellent instructions and hints are given regarding the practical burning of fuel oil.

MODERN WORKSHOP PRACTICE (*Ernest Pull*).—This text book deals with its subject in a very comprehensive manner. In 24 chapters it describes all the tools and machines used in a modern workshop, and the methods of operating them. Gear-cutting and gear-hobbing machines are dealt with.

THE JOURNAL OF THE INSTITUTE OF METALS (Vol. XXVI.).—We have again been favoured by the above Institute with the latest volume of their Journal. It contains 12 valuable papers dealing with various sections of the non-ferrous metal industry. One of the most interesting of its contents is the paper by Dr. Bengough, on the corrosion and protection of condenser tubes. Dr. Bengough has been investigating the problem under the auspices of the Corrosion Research Committee for nearly 10 years, and the paper undoubtedly represents the most authoritative expression of opinion on the subject that can be given at the present time.

N.B.—In connection with the formal opening of the new home for the Royal Merchant Seamen's Orphanage, on Saturday, May 27th, the arrangement is being made to meet visitors at Reading Station, G.W.R., about 2.15, when conveyances will be ready to drive to the home, which is a fine building.

The invitation to the Conference of the Institution of British Foundrymen, at Birmingham, includes admission to the International Foundry Trades Exhibition. It is suggested that Thursday, June 21st, or Friday, June 22nd, are the most suitable days to attend.

Election of Members.

Members elected at a meeting of the Council held on Monday, May 8th, 1922:—

Members.

Frederick John Cargill, 62, Edge Grove, Fairfield, Liverpool.

William George Norman Henderson, 4, Prospect Terrace, Grove Road, Ventnor, Isle of Wight.

Neil Matheson Macaulay, Ardencaple Villa, Oban, Scotland.

Robert Llewellyn Pughe, Messrs. Hayward Tyler and Co., Ltd., 99, Queen Victoria Street, E.C.4.

Sydney William Raworth, "Ingleside," Foggy Furze, West Hartlepool, Durham.

James Shepherd, 10A, Bishop Lane, Hull.

Charles Willis, 19, Bedford Row, London, W.C.1.

Alexander Garland Wilson, "St. Edmonds," Gaudin Street, Kilbirnie, Wellington, New Zealand.

George Francis O'Riordan, "Brathay," Chestnut Avenue, Hessle, East Yorks.

Associate Members.

Frank Mitchell, 119, Queens Place, Thorne's Lane, Wakefield, Yorks.

Frederick George Baden Wynn, 31, Devon Street. Barrow-in-Furness.

Associates.

Cyril Sadler Poole, 61, King Edward Street, Shotton, near Chester.

Graduate.

Marshall John Smith, H.M.S. *Fisgard*, Portsmouth.

Horace Edward Catlin, 134, Maidstone Road, New Southgate, N.11.

Douglas Robert Palmer, 66, The Drive, Ilford, Essex.