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Marine Steam Turbine Lubrication

BY MR. A. H. MATHER (HON. TREASURER),

READ

Monday, October 14th, 1907.

CHAIRMAN: Mr. W. LAWRIE (CHAIRMAN OF COUNCIL).

CHAIRMAN : The character of the weather has been rather unkind to us, the evening being so wet, but everything considered I think the attendance is fairly good. It will not be necessary for me to offer anything in the nature of an introduction to the author of the paper to-night. He is well known to the members, his work has been of considerable value and very much appreciated. To-night he is breaking new ground and I am sure you will all be very pleased, as I am, to see Mr. Mather on the platform. I will call on him now to read his paper on "Marine Steam Turbine Lubrication."

One of the results of the progress made in the design and construction of marine steam turbines, and the consequent increase in the number of vessels fitted with turbine machinery, has been the acquirement of increased knowledge as to the

problems arising in the management and running of this class of machinery. Amongst others, the problem of lubrication has forced itself upon the notice of engineers with the usual insistence which lubrication, or the lack of it, always exhibits whenever it gets the opportunity of showing itself. Marine turbines are fitted with a system of forced lubrication, which provides for a good flow of oil through the bearings, but which might be considerably improved by attention to some matters of detail considered from the standpoint of treating the oil in such a way as to ensure the best results. I have examined a number of sets of turbine machinery, and I find that while in the majority of cases every attention has been given to the mechanical details of the lubrication system, very little thought has been given to securing the best conditions of work for the oil itself ; and it has, therefore, occurred to me that a short paper dealing with this side of the subject would be both of interest and value to the members of the Institute. I do not propose to deal with the subject of turbine lubrication from any other than the mechanical point of view, and have, therefore, confined myself to the consideration of one or two matters of detail in the arrangement and fitting up of the storage tanks and pipes, attention to which would ensure that the oil in use would receive the best treatment, and would lead to a marked improvement in the running of the jobs.

Before entering into the consideration of these details, it might be as well just to enumerate the qualities required in an oil for this class of work :—

1. It must be entirely free from saponifiable matter.
2. It must separate rapidly from any water picked up in its passage through the system.
3. It must retain its lubricating value when heated to a fairly high temperature.
4. It must retain its nature in continuous use for long periods.

In forced lubrication systems it is essential to keep the oil fully up to its standard, and to ensure this being done the two most important points to be considered are :—

1st. Its complete separation from water picked up in its passage through the system.

2nd. Its thorough filtration from grit or material substances.

The necessary installation on board a turbine ship consists

of a tank or tanks, a filter and a force pump, and it is in regard to the arrangement of these that I propose to make a few suggestions which should result in a marked improvement in the lubrication and in economy of oil. For the purposes of this paper I have prepared the diagram shown, which diagram, I may say, is based simply upon a knowledge of the properties of oil, and has been prepared with the assistance and approval of a chemist unrivalled in his intimate knowledge of oils and their proper treatment and uses. It has been recently submitted to all the prominent engineering firms throughout the kingdom, and its principles have been adopted in a number of cases with satisfactory results.

The diagram shows a complete system for the filtration and separation of oil and water, and the installation should consist of two storage or settling tanks, two filters, an oil cooler and a force pump. I have not included the force pump in the diagram, but have simply indicated its best position in the system.

The two tanks, which should be placed low down in the engine room to allow all the oil in the bearings and pipes to drain freely back by gravity, should each be of sufficient size to contain enough oil to fill the whole system outside of the tank, and have also an ample margin or capacity in the tank to keep a reserve of oil above the pump suction pipe. The tanks should be tilted, as shown in the diagram, or a pocket should be made so that the drain cock is at least 2 in. lower than any other part of the tank. The drain cock should be of large size, and means should also be provided to show clearly the amount of water in the tank. For this purpose a glass sided box placed at the lower end of the tank and having adequate protection for the glass sides, is preferable to the ordinary gauge glass, as it gives a clearer and more reliable view. An air pipe should be fitted at the highest point in the tank, and led as high as necessary. The oil return pipe from the bearings should enter the tank as near to the bottom as possible, and it is recommended that the oil be allowed to return in its heated condition in order to facilitate its separation from the water. Oil in a heated condition will also allow suspended matter to drop to the bottom more easily. In cases where a large proportion of water finds its way into the oil, as, for instance, with ordinary reciprocating marine engines fitted with forced lubrication,

where it is practically impossible to prevent a considerable quantity of water from the glands, etc., falling into the crank pits and mixing with the oil, a small heater should be provided in the return pipe to raise the temperature of the oil to about 200° F. This will result in the immediate separation of all water and foreign matter as soon as the mixture finds its way into the tank, the oil rising rapidly to the top and the residue falling to the bottom. To obtain the best results, this heater should be fitted to all forced lubrication installations, including turbine sets, although no doubt it may be urged that it is adding to the cost of the plant and increasing the space occupied where the amount available is generally very limited. The pump suction should be placed as high as possible, considering the amount of oil needed in the system, so as to allow ample space for the accumulation of water and extraneous matter to remain at the bottom without being drawn through, the opening of this pipe to be directed upwards if possible. I have shown the end of the pipe cut in a sloping direction on the upper side, but a bell mouth turned upwards would be better still. The net storage capacity of the tank is of course its capacity above this pipe opening. In the majority of installations I have examined, the inlet and outlet pipes are placed in positions the reverse of those which are here recommended, that is to say, the inlet or return pipe is led into the top of the tank, thus allowing the returning oil to fall the whole depth, thoroughly disturbing the contents and effectually preventing the separation of any of the water, and, as if this were not bad enough, the suction pipe is taken from the bottom of the tank, with, in some cases, an internal bend to carry it down to within an inch or so of the lowest point. This latter is done of course with the idea of utilizing the full capacity of the tank, but it results in keeping the turbine supplied with a mixture of oil and water. Two tanks should be supplied, and these should be used alternately at convenient intervals of perhaps two or three days, for, although the arrangement of pipes suggested allows for separation during the process of circulation, further separation is necessary to clear the oil, which can only be done by allowing it sufficient time to rest and obtain a thorough settlement.

Two filters should be supplied to allow of one being cleaned out while the other is at work. They should consist of three

or four separate layers of brass wire gauze of, say, 24 mesh to the inch, the last or uppermost one consisting of two sheets of gauze with a sheet of cheese cloth between them. The oil should enter the filter at a point some distance above the bottom but below the layers of gauze. As the oil rises through the filter any particles of grit, dirt, etc., that may be drawn from the tank are retained in the lower part of the filter and tend to fall away from the filtering surface, which will thus remain clear for a longer period than would be the case if the oil travelled downwards, in which event all foreign matter would be retained on the filtering surface. In addition, this system of filtration would also assist in the further separation of the oil and water. For this reason sufficient capacity should be provided in the lower part of the filter, below the inlet, to collect the extraneous matter and prevent it from passing back through the pipe into the tank. A cock should be provided at the lowest point of the filter to drain this chamber.

Stop valves or cocks should be provided in the oil pipes for changing the tanks over, and, although it is not shown so in the diagram, it would be convenient to be able to use either filter in connexion with either tank, as one filter might, on occasion, require cleaning out when it is not desired to change the tanks.

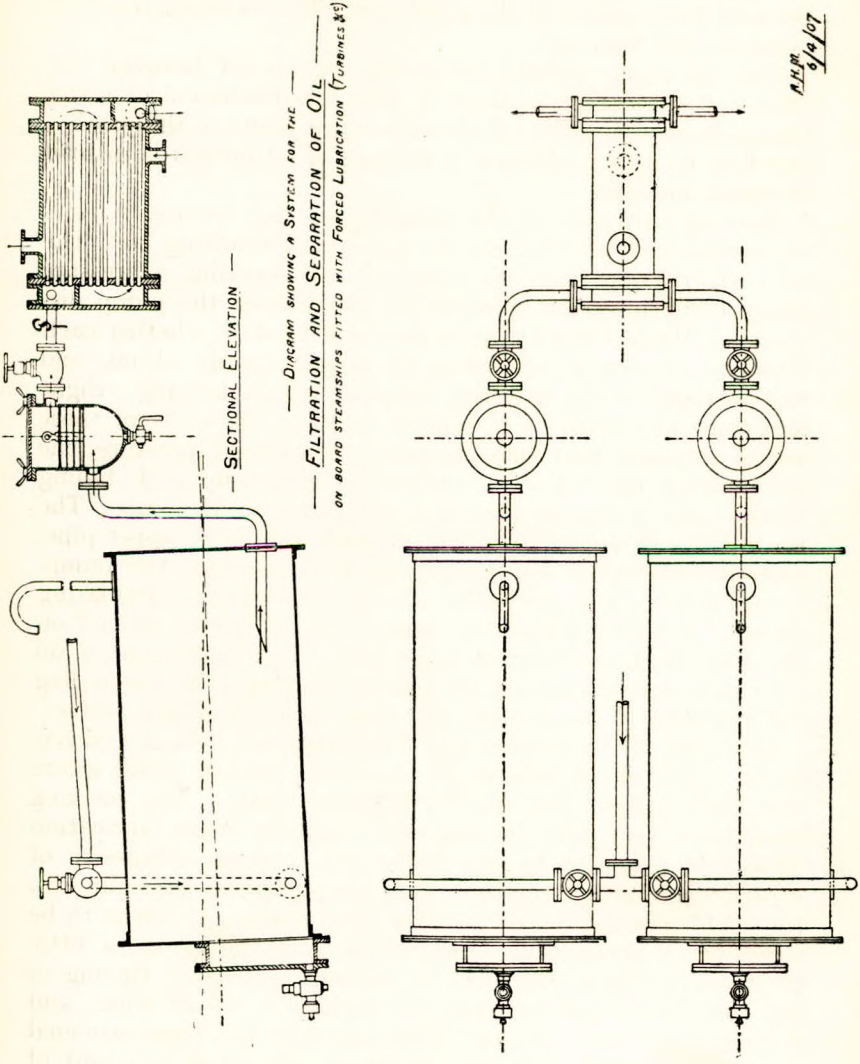
After being filtered the oil should pass through a cooler, having sufficient surface and water circulation to reduce the temperature to normal. This cooler may be of any convenient design, provided that it allows free and ample passage for the oil, and does not allow the cooling water to find its way into the oil. Probably the cheapest form to be efficient would be similar to that shown in the diagram, viz., a series of tubes with expanded ends in a casing through which the sea water can be pumped, the tubes being arranged so that the oil passing inside them is made to travel two or three times through the water. I have seen a cooling coil fitted in the bottom of the storage tank, but this has the objection that if any leaky joints occur the water gets direct access to the oil. Another method in use is a water jacket round the tank, but this is not very efficient, as only a portion of the oil comes into contact with the cooling surface, and, in the particular instance of which I am thinking, the jacket is only supplied by a half-inch pipe giving a very small circulation, although the tank holds probably 120 gallons. A cooler of

the type shown in the diagram should be so constructed that the cold water enters at the point where the oil leaves it before going to the bearings.

The oil pump should preferably be placed between the filter and the cooler, as there is then less likelihood of water obtaining access to the oil through leaky joints in the cooler, any leak occurring allowing a leakage of oil outwards instead of water inwards.

Leaving this part of the installation, one or two matters connected with smaller details are worth referring to. The oil is distributed from the pump to each bearing, a pressure gauge being provided to show the pressure at the pump discharge. Means should also be provided to show whether each separate bearing is obtaining its proper supply of oil, and also to regulate the quantity supplied to each bearing. Sight feed cups are fitted to a number of jobs, but some of these are so arranged that they do away with the oil pressure, the oil entering the top of a cylindrical glass cup and falling visibly into a funnel placed lower down in the cup. The pressure is of course lost where the oil leaves the upper pipe, and the bearing is not under forced lubrication, the pump, to all intents and purposes, simply becoming a circulating pump. A better plan is to have a similar fitting placed on the drain from the bearing which will show the amount of oil which has actually passed through the bearing while permitting the pressure to be carried right up to the working surface.

One part of the turbine which is capable of giving, and has given, very serious trouble, is the steam packed gland where the shaft passes out of the turbine casing. The packing rings are a very close fit, and really require better lubrication than that provided by the wet steam, but the admission of oil here is a serious matter, as it simply passes straight into the turbine and through into the feed water. It seems to be a necessary precaution, however, to give the glands a little oil when working into port to prevent seizing or rusting of the shaft in the gland when the turbine is not at work, and I understand that in some cases a branch has been provided in the small pipe supplying steam to the gland to admit of a small quantity of oil being introduced when required, but a connexion of this kind is a risky thing, as it would be very easy for a careless or thoughtless man to put in sufficient oil to cause boiler troubles.



In conclusion, I may say that in presenting this short paper to the Institute I have done so considering that a few notes on a side issue in connexion with what is probably destined to become the premier method of ship propulsion would be

of general interest to all, and might be of service to some who have either the building or running of this class of machinery under their control, and if it is of use in showing where troubles may arise in the lubrication of turbine machinery, or in offering a suggestion which may lead to an improvement in the efficiency and economy of the lubrication system generally, I shall feel satisfied that the few ideas which have suggested themselves to me in the course of my observrations and experience have been worthy of placing on record.

CHAIRMAN : Mr. Mather has stated his views very clearly in the paper and it has been rather interesting to me as I have had nothing to do with turbines or forced lubrication. No doubt some of the members here to-night either know or have heard something of the system, and I shall be very pleased if they will criticise the paper, suggest any different method or give any fresh ideas on the subject.

Mr. J. R. RUTHVEN (Member) : I would like to congratulate Mr. Mather on the paper he has given. Several of the points mentioned appeal to me as being very good. I have no criticism to make on the subject, but I thank Mr. Mather for the paper, and I think its shortness is an additional recommendation.

Mr. F. M. TIMPSON (Member) : I have not had much experience with turbines excepting small electric engines, but I think Mr. Mather's suggestions very good and in order. Of course the quality of oil would be a point to be looked at. I think this system of cooling will be a great advantage. The paper is very clear and to the point, and I cannot see much to criticise in it ; it gives a very good idea on the subject and will prove very useful to many who have to do with these machines. I congratulate Mr. Mather on giving such a clear paper.

Mr. J. MCLAREN (Member of Council) : We are indebted to Mr. Mather for bringing such an important subject before our notice. There is one point in this arrangement of tanks

that I would like to touch upon. The inlet is shown coming to the bottom of the tank, and the oil separates there at the high temperature. A lot of debris will therefore sink to the bottom of the tank and nothing is provided for its removal. Why not have the filter at the bottom ? The oil is led off at the highest level possible, but if it were taken off at the bottom all the dirt would be caught at the filter. If the highest temperature is there that is where the filtering ought to take place in drawing off the oil.

Mr. J. HOWIE (Member) : I may be digressing somewhat from the paper, but there is one remark made I would like to call attention to in the last sentence with regard to the turbine where it is stated that it is "probably destined to become the premier method of ship propulsion." From the latest reports that I have heard, this hardly appeals to me as a sound forecast, and possibly the next time a paper is written on the subject it might be that this opinion will have been revised a little. The paper is a practical one and short, so that it can easily be grasped, which is a great consideration in these days. I should like to thank Mr. Mather and regret that I have not had an opportunity to read the paper and, coming in late, I did not hear it all read.

CHAIRMAN : I know it is rather difficult to criticise if one has had no experience with this particular method of lubrication, but there are some points which will appeal to members. Of course fast running engines require a somewhat different lubrication from the slow, but as Mr. Mather says, he has confined himself entirely to the mechanical part of the subject. It would be interesting to know, in a general way, the difference between the lubricants required now and what was required in reciprocating engines. I remember when in the cotton mills, with the spindles running at 4,000 revolutions per minute, we did not give the oil much consideration. I do not know what they did use but I suppose it would be something of the nature of the oil used now. As to the pressure I must admit my ignorance of the subject as I have had nothing to do with it, but I think something might be said as to what pressure can be maintained in the pump or pipe. Another thing which might be mentioned is in connexion with the continued use of the oil, how long the engineer is safe in running the same oil

through the bearings. I do not know what steps have been taken to find out how long the same oil is used or whether a proportion of it is changed during the twenty-four hours. Mr. Mather mentions that he has been assisted in this matter by a chemist. I think that was a very good idea. I fancy that that is the best way of arriving at the best methods, for the practical man to put his knowledge alongside of that of the chemist, and it appears to me that by this means we will arrive at the most satisfactory results. I do not know that there are many more points, but some of the members will have had time to think them out, and it is open now for any one to ask questions or to pass remark.

Mr. J. G. ROBERTSON (Member) : I should like to thank Mr. Mather for his paper. Coming in rather late I have not had time to go through it carefully, but I really do not see the necessity for fitting a filter in connexion with turbines. When the oil is supplied to the tanks it is pure, and where the necessary grit and dirt to be filtered comes from I fail to understand. In the case of the *Kingfisher*, which ran the whole of the season last year, I have seen a sample of the oil taken from that boat, and it was equally as good after the season's running as at the beginning, there was no dirt in the oil at all. I do not see that the filtration process is necessary where a suitable oil is supplied. As for the cooling of the oil, this might be done, as I understand the best way to tell the temperature of the bearings is by the heat of the return, that is, after the oil has passed through the bearings to the tank.

Mr. F. M. TIMPSON (Member) : I understand Messrs. Parsons and Co. recommend filtration and the drawing off of so much of the oil. That is general practice. Mr. Robertson thinks that there is no occasion for the filter; from my general experience I have found that there is.

Mr. J. CLARK (Companion) : I suppose that wherever forced lubrication is in use, whether in turbines or in other engines, some such method as Mr. Mather has described is adopted for dealing with the oil requiring to be filtered. Where it picks up the dirt or grit it is hard to say, sometimes in emptying a cask of oil the dirt falls into the vessel. I notice Mr. Mather refers to the fact that he is only dealing with lubrication from

the mechanical point of view, but I understand that in turbines it is only mechanical forced lubrication that is used, other methods being of no use on account of centrifugal action. I think the author might have given us a few more particulars about the class of oil that is most suitable. He refers to oil getting into the boilers and doing harm, but there are certain kinds of oil that might get into the boilers in small quantities without doing any harm.

I think the plan for gauging the oil by means of lunettes is a good one, because as a rule gauge glasses fill up in a very short time. The matter of heating the oil is almost a necessity, and many filters are arranged to put hot water in the oil in order to make the deposits separate out more quickly. With regard to this particular pipe system of cooling, I do not know whether it is a good system or not. It seems to me that it might be far better to deal with the oil away from the system altogether. I do not know whether this method of cooling the oil has been tried or not. He does not say much about the cooling surface. I think in a small cooler the water would be more equally diffused throughout by having more inlets and outlets, as the more you have the better the action of the cooling water. The water does not diffuse through a cooler of any size, it generally goes through from the inlet to the outlet in a straight line, and the more straight lines there are it is generally found to work better. I think, with the others who have spoken, that the paper has been a very good one and I have to thank Mr. Mather.

CHAIRMAN : Another point that might be dealt with is the temperature of the oil. Can Mr. Mather give the temperature it gets up to ? Then there is the question as to what part of a particular bearing the oil is introduced into, whether in the centre in grooves, or whether into the top, side, or bottom of the bearing. There is a variety of information which might be furnished by those who have experience. I think the proper place to admit the oil is in the bottom of the bearing. I do not know the practice in turbines but I should think that is the best place, or at any rate not at the top. I have seen it put in at various parts, and it would be useful to know some of these points.

Mr. G. W. NEWALL (Member) : I should like to know whether the weight of the moving rotor of the turbine is the same when

running at high speed as when standing. What I mean is, if you have a shaft running at a high speed, whether the fact of the steam rushing through the vanes tends to raise the weight of the rotor off the bearings, or whether the weight is all on the bottom of the bearing, or whether it is alternating between the bottom and top and more or less swinging in space. Another point I would like to raise is the question of the relative amounts of oil used in turbines compared with reciprocating engines, say triple-expansion or quadruple-expansion. Is the one much heavier on the use of oil than the other ?

Another question is whether solid grease forced through the bearings would be preferable to oil, as there are some very good greases on the market for lubrication and most of it can be forced. We use a great deal of it in the works ; nearly all our heavy machinery has for a lubricant a thick grease something like butter, which is forced under great pressure, through the bearings, and where, possibly, 3*s*. a week would be spent in oil, I do not think it costs more than 1*d*. or 1½*d*. now. It is used over and over again, in the form of a very thick paste. I do not know whether such grease would be useful in turbines or not.

Mr. W. R. Watson (Visitor) : I am afraid I cannot say much on the subject. I have had a little bit to do with turbines on land work, but have had no experience with marine turbines. I would suggest that the filter might be eliminated and a gravity filter used instead so that it would throw slightly less work on the oil pump. If a few gallons were taken out every day nearly the same result would be obtained by putting it through a gravity filter. With regard to the question, Mr. Chairman, as to where the oil enters the bearings, I think, as a general rule it enters at the bottom and flows up and out at the ends. The bearing, as a rule, is supplied in two halves ; the oil would enter, say, in the centre and work along the bearings and out at the ends.

Chairman : I had in my mind the idea of the shafting being very much lighter than in the reciprocating engine, but of course having the whole thing so nicely balanced would alter the conditions. The only reason I had for mentioning the point was to get full information on it. I will now call upon Mr. Mather to reply to the discussion.

Mr. MATHER : I am very pleased with the reception the paper has met at your hands. Evidently the subject matter had been looked into beforehand and several members had some practical experience with forced lubrication to guide them in their remarks.

Mr. McLaren referred to the inlet pipe being taken to the bottom of the tank. The idea in view is when the oil arrives at that point and opens into the tank, separation immediately takes place. The oil, of course, being lighter, would rise and leave the water and foreign matter behind. I have made provision for this to be removed by draining it off at the lowest point and in the lowest corner of the tank there is the large drain cock. This should be attended to periodically and the water drained away, and if this is done, any trouble caused by the water and dirt gathering in the tank is obviated.

Mr. MCLAREN : That leaves the filter very little to do. If the whole of the water, grit and dirt goes to the bottom, the tank forms a filter in itself.

Mr. MATHER : The action of separation in the tank means that you help to free the oil from the bulk of the foreign materials, while the filter completes the operation and puts the oil into perfect condition. The point of highest temperature is where the separation takes place, the warm oil rising clear of the water. If the filter were at the bottom of the tank the water would be more likely to get through it and the oil would be more difficult to filter.

It would also be more difficult to clear the filter surfaces than in a separate filter. There are no special fittings in the tank itself for cooling. Mr. Robertson mentioned in his remarks that the temperature of the oil coming back from the bearings in some cases was fairly high. This is quite correct although in many sets of engines there is a water jacket fitted to the bearings, which helps to keep the temperature down. It seems to me that the oil should be allowed to come back as hot as possible as, if no cooling is allowed until it gets back to this point, it naturally reduces the amount of work in the filter. The oil invariably gathers a certain amount of grit and as a precaution the filter is necessary under any circumstances, perhaps as an extra safeguard. After the bearings have been running some time there is bound to be a certain

amount of grit produced and means are required for taking these metallic portions out of the oil.

Mr. Howie referred to my description of the steam turbine as being probably destined to become the premier method of ship propulsion and questioned whether it should be described as such. That, of course, remains to be seen. I said "probably," and in view of the *Lusitania's* last voyage I do not think we can say yet that the remark is unjustified.

The Chairman's comment that in the old days "oil was oil" and not much consideration was given to the question of fitness for its duty, generally any kind of oil was considered good enough. It seems to me they did not think there was any difference in the oils excepting perhaps that it was vegetable oil in one case and mineral in another, but as long as it was oil it could be used for any kind of lubrication.

With regard to the length of time which the oil may be kept in a system of forced lubrication such as is fitted with the turbine, there seems to be no reason, as long as the oil is not ill-treated, or badly charged with water and dirt, why the same oil should not be used for very long periods. As a matter of fact it is being done. One ship that I know of ran the whole voyage to India and back using the same oil in the system the whole time. If time is allowed for settlement and regular alternate use is made of the tanks, by merely making up for losses and leakages the same oil may be used for a very long time.

With regard to our Chairman's remark as to the chemist and the engineer working together, the fact of an engineer having to handle the machinery which is being lubricated gives him the opportunity of ascertaining the action and condition under which the oil is to work, and if he puts those conditions and actions before a man who has studied the subject from a chemical point of view, the chemist will tell him if he is giving the oil a fair chance. It is possible to have a good system and a good lubricant, but if one or two points are neglected, such as this little point of changing the tanks alternately, the full value of the oil is not obtained. Probably the engineer does not know the conditions which will give the best results, but it is the chemist's business to know these things, and the experience of a chemist in a case of this kind is of great assistance to the engineer. The question of writing this paper was really brought up after a conversation on the

subject with the gentleman mentioned in the paper and, in conjunction with that gentleman was written in the way of a correction on what, it was found, was being done in the majority of cases for marine installations.

Mr. Robertson made a remark about grit in the oil. I have already touched on that matter and, as I said, it seems to me to be quite necessary to have a filter in the system as a safeguard. I think it is proof that such a thing is necessary when, in every case, without exception I believe, a filter has been fitted in the system, and in some cases it has been found very necessary indeed.

The two tanks, I may say, have been used in nearly all ships fitted with turbines, but the difficulty in many cases is, that although the two tanks are there, there is a doubt as to the best way in which to run them. Sometimes one of the tanks is used during the whole of the passage to the outward port and the other used for the return voyage. The only chance that the oil gets for perfect settlement in these cases, is when the ship is standing in one of the ports on the way out or back. If the tanks are used systematically and alternately, being changed regularly every two or three days the oil gets the opportunity of being regularly cleared of water and will be kept in good condition.

A reference was made to the amount of water which might be left in the oil. Some oils will carry a greater proportion of water than others and will hold it a longer time in suspension. It is always best to separate this water as soon as possible, as the efficiency of the lubrication is greatly reduced by the water in suspension.

Mr. Clark referred to forced lubrication generally. As to his remarks regarding dirt the same statements that I have previously made apply in this case also—the dirt does gather wherever it comes from. I do not think ring lubrication has ever been fitted to a marine turbine at all; they have all been on the pressure system with the oil pumped around. In most cases oil is a very good thing to keep out of the boilers, it does not much matter what kind it is. The heater I mentioned in connexion with the suggestion to add to the heat of the oil in the return pipe is, I may say, an adaptation of the method of separating oil from water in use in a number of factories in this country where a large quantity of water gets in with the oil, and I make the suggestion in the paper with special

reference to reciprocating marine engines fitted with forced lubrication to the principal bearings, main bearings, crank pins, crossheads and eccentric straps, with the crank pits open and connected together so that the oil all drains to a pocket to which the force pump suction is led. It is found with these engines to be of the greatest importance to keep the water out, and the treatment of the oil becomes a serious matter. Separate settling tanks are used into which the oil is periodically withdrawn from service and when the heater is added to the system the separation is much more rapid and much more complete.

In reference to Mr. Clark's remarks with regard to the cooling water passing through the cooler, I agree that in a general way where there is one inlet and one outlet the water would pass straight through and cool some of the pipes and leave the others untouched, but with a system of baffles the water is split up and a better circulation obtained. Such points are of importance and require to be attended to. The same difficulty would arise with a surface condenser unless the water was properly baffled.

Mr. Newall referred to the weight on the bearings when the turbine is running at a high speed. I think it seems to be quite certain that when the turbine is running the weight on the bearings is very much lighter than when at rest. When at rest the whole weight is on the bearing, whereas when it is running, the action of the steam itself assists the shaft and helps to keep it supported. I think the appearance of the bearings, which generally show very little wear on any part when opened up for inspection after a long voyage, proves that the weight is not excessive.

A question was raised as to the quantity of oil used with the turbine as compared with that used with the reciprocating engine. I should not like to give figures for a comparative statement, but it will be seen that in a system of this kind, where practically the only losses are those due to leakage, it would amount to a very small figure compared with that of the reciprocating engine.

I am afraid the suggestion of grease for lubrication of this class of work would be a difficult matter to arrange. I do not know what means there are in the machines referred to by Mr. Newall for collecting this grease from the bearings, if it is to be forced through continuously the collection alone would be a difficult matter.

Mr. NEWALL : It is pumped continuously all the time the machine is running.

Mr. MATHER : It would not be such a simple matter as with the oil.

Mr. Watson referred to a separate gravity filter. I think that would give very good and efficient filtration, more particularly on land plants. It would do very well for marine installations also, but would not be so convenient as when the whole thing is self-contained, and it would necessitate extra work in the way of handling.

With regard to the supply of oil to the bearings, the bearings are very complicated in their oil passages. The oil is supplied under pressure from the pump and finds its own way through so that there is a complete supply to every portion of the bearing. There are special arrangements made whereby the oil gets into every portion not only of the supporting, but of the thrust bearings as well. The forced lubrication system in the turbine bearings is a very complete one.

CHAIRMAN : You have heard Mr. Mather's reply to the remarks that have been passed and I think he has dealt very fully with them. If any other point has occurred to any one there is still time to discuss it.

Mr. W. HOWELL (Associate) : With regard to the cooler in connexion with this system, the author speaks in the paper of having seen a cooling pipe fitted in the bottom of the storage tank, but he objected to that on account of the leakages that might occur. I think that in this cooler which he describes there would be a greater possibility of leakage. The pressure on the oil would be liable to start the tubes where there are so many of them. While the pressure is on the oil the water could not get back through a leakage, but suppose you get into port and the oil pumps are stopped before the circulating water is shut off, if a leak of any kind occurred, the water would escape back and you would get a great quantity of water with the oil in the cooler, whereas in the other case, where there was only one inlet and one outlet, there would be no chance of leakage at all compared with the one described by the author.

Mr. NEWALL : Mr. Mather made a remark which is not quite

clear to me. He mentioned the case of a ship going out to India and bringing back the same oil. That appears to me rather to savour of perpetual motion with regard to oil. Say that a ship takes away 500 gallons of oil and brings back 490 gallons. Has it lost nothing beyond the small amount allowed for leakages ? If we fill up our system with oil and use it from Liverpool or London to New York and back, what is lost in the running ? The oil cannot be as good when it comes back, something must pay for use. Of course the oil does come back, perhaps in almost the same quantity, but what is it like in quality ? We cannot make use of anything in nature without an expenditure.

There was another point occurred to me. Can Mr. Mather tell us if there is any experience of a real hot bearing on a turbine. Most of us have had some kind of an experience with a hot bearing on reciprocating engines. Of course the bearings on the turbine are liable to become heated, but what do they do when there is a real hot bearing, one they can smell at the other end of the ship ? I remember in my first sea-going days as a junior it was my humble duty to let the crank-pin ends together, and in those days we took the hot bearing as a matter of course. The second engineer would come down before we started and would say to me " Now which bearing are we going to get hot this time ? " and we would scratch our heads and point out one that had been hot last time and say that a certain other one ought to be hot next. They were hot bearings in those days and I should like to hear whether they have any similar experiences with the turbines.

Mr. J. HOWIE : I had a little difficulty some time ago with a reciprocating engine in which forced lubrication was used. Some one said that a saving would be effected by putting in small pipes. One-eighth pipes were put in and in this case they did not work at all. The oil will not travel through small pipes, that is if they are too small, and if the attempt is made to force it through there will not be sufficient lubrication for the work.

Another thought suggested by the Chairman's remarks is in connexion with the quality of the oil. In the former part of the paper the author says that one of the qualities required in the oil is " that it must retain its lubricating value when heated to a fairly high temperature," and Mr. Farenden has been noting quietly as to the saving that would take place if one

could have the same oil at the end of the season as at the beginning, as would be the case if the oil could be used over and over again. Of course, one is a little dubious about some of these statements regarding the oil retaining its quality, but there is a very good way of testing the value of oil by getting a vessel, conical at one end with a hole just large enough to allow a needle to pass through, and about two inches in diameter at the other. The oil is poured into this vessel and allowed to drop through, and there would then be from forty to sixty seconds between each drop at 212° Fahr. according to the kind of oil used; it must have lost in value if quicker in its passage through. Engineers, as a rule, are kept pretty busy and do not waste much time over little experiments of this kind, the usual thing is to put the fingers in the oil. Of course one can tell pretty well the temperature in that way, but I do not know whether it would do to ascertain the quality. Some one in the engine room might do a little experiment of the kind I have described.

With regard to wear on the turbines, I very much doubt that the weight on the bearings is decreased when the turbine is in motion. It would not be advisable to take any notice of any possible decrease, I should always take into consideration its weight when standing and would not allow for any decrease of weight from the running. The equilibrium of the pressure on the motor must be fairly constant throughout, and this being the case we can suppose the turbine to be the most elaborate engine for giving a turning movement as a rotor at the present time. I would not like to let the opinion go forth that there is a decrease in pressure after starting and therefore allowance ought to be made for same.

I believe it is a common practice to put the oil in from the bottom, in forced lubrication, and it seems to me there must be a very high pressure required to get the oil in in this way. It is an entire departure from the old style, where the oil is let in at the top, the shaft itself taking it round and gradually forcing it through the system. Yet we have to consider the impossibility of retaining the oil when forced in on the slack side under the present system of open ended bearings, and its chances in this case of never reaching the tight side or bottom as in the case of heavy shafting. I suppose that the quality of the oil will have something to do with the difficulties experienced in forced lubrication, caused by the thinness of the film in a poor

quality not being able to support the weight of the rotor. Of course that is a question to be settled by the experts; there are so many different kinds and it is hard to say which is the best quality to be used.

Mr. G. W. NEWALL: I do not quite agree with the last speaker in his statement that there is no decrease in pressure on the bearings when the turbine is running on account of the equilibrium being maintained. The source of supply from the boiler is by means of a pipe and branch piece which is not annular, and the exhaust branch from the turbine also is not annular. The inlet of steam strikes right against the opposite side of the casing and is thus distorted out of line; in consequence the rotor is not in equilibrium. If the steam could be put in an annular space and the exhaust also in an annular space then the rotor would be in equilibrium, but the two openings cannot be in the same direct line, there are sure to be differences in the line of pressure between the inlet and outlet, and that little difference in pressure more or less tends to lift the rotor, by the action of the resultant forces. The steam enters at about right angles to the shaft, and, taking the shortest line to the exhaust, it must tend to put a side pressure on, and that pressure, I think, upsets the equilibrium theory.

Mr. HOWELL: With reference to the remarks upon the wearing on the bearings, there is an instance given in this week's *Mechanical World*, in which a turbine was opened up after working for a year and the tool marks were seen on the surface of the bearings. That, I think, is almost a proof that there can be no practical wear.

Mr. TIMPSON: I may say that I saw a turbine opened up after three years running and the tool marks were found on the bearings, there was no perceptible wear.

Mr. A. G. RAINEY (Member): Mr. Mather touched upon the importance of separating the oil from the water. I have had nothing to do with turbines, but in the reciprocating engine, when the bearings are rather heated it is sometimes the practice to cool them down by putting clean, fresh water in along with the oil, and in many cases where the mixture of fresh water and oil is used the bearings are found to run much cooler

than with the oil alone. It forms a thick mixture, rather like cream.

CHAIRMAN : I remember a patent being brought out some years ago for running in oil mixed with water, Mitchell's patent it was called, but it did not add to the lubricating quality of the oil—in my opinion it rather detracted from it.

Mr. J. MCLAREN : There are ships running out of Liverpool at the present time with Henderson's lubricating apparatus for adding water to the oil, and it effects a saving.

CHAIRMAN : Perhaps Mr. McLaren has heard of the *Virginian* ; she was fitted with the patent I referred to and it was said that she made a great saving in oil. I happened to be on a vessel called the *Brooklyn* at the time, which indicated probably within 20 to 30 H.P. of the *Virginian*. The managing director of the Dominion Company, who owned the *Brooklyn* put forward the Leyland boat, the *Virginian*, as an example of the saving that could be effected by using Mitchell's patent. I said " Tell me how much they use to begin with," and it turned out that they used about nine gallons a day on that boat without the patent, and after fitting it the consumption was reduced to something like four to four and a half gallons, while we were using about three on the *Brooklyn*.

Mr. MCLAREN : There are ships to-day equal to the *Virginian* using two and a half gallons.

CHAIRMAN : That is the amount they were using then at any rate. However we are on the subject of turbines just now, and if none of the members have anything further to add to the discussion, I will ask Mr. Mather to make a further reply before bringing the meeting to a close.

Mr. HOWIE : I do not know whether it is a fair question or not, but in connexion with the saving of oil, I would like to know the comparative amounts used, or how much is passed through the turbines as compared with the reciprocating engines of similar power ? I am not pressing for an answer, as I know information of this kind is not always ready at hand.

Mr. MATHER : There are just one or two further points I would like to reply to. Mr. Howell referred to the possibility of leakage with this type of cooler. With any kind of cooler fitted with tubes there is a possibility of leakage, but there is no greater possibility with the expanded tubes than with the jointed. The expanded ends would, I think, give perfectly satisfactory results, as there is no very great range of temperature at that point. There is not such a big difference of temperature as in a surface condenser for instance. When there are many tubes like this it is better than the coil, as there is a better chance of thoroughly splitting the oil up and getting more value from the circulating water. That is the comparison I made in the body of the paper.

Mr. Newall and others referred to the small quantity of oil required to make up. Naturally the oil loses in quality to some extent as it goes around, but there are leakages to make up, and the fresh oil added to make up for these leakages is quite sufficient to maintain the lubricating value, provided such means are adopted as are recommended in the paper to give the oil the best opportunity to retain or recover its natural condition. If it is not kept passing through the system too long, if it is allowed time to settle, and the other precautions are taken, they will all help to prevent the necessity for adding a greater quantity of fresh oil to the system than is required simply to make up for losses. The *Kingfisher* has been referred to, and I believe that that ship ran practically the whole season with a ridiculously small addition to make up.

Mr. Howie remarked upon the use of small pipes in a forced lubrication system. The amount of flow through a pipe depends upon the pressure and the friction between the fluid and the inner surface of the pipe and with small pipes the friction is quite sufficient to prevent any flow at all. An increase in the length of a small pipe makes itself felt in a most decided manner and may be sufficient to stop the flow entirely where there was only a small flow to commence with. Other questions asked might perhaps be better answered if we could have a word or two from a gentleman who has actually had charge of this kind of machinery. The condition of the bearings after continued work, the details of the lubrication of the bearings, the position of the inlet pipes, the amount of oil used and the length of time it is in use, and other points of that kind, might be touched upon with advantage.

Reference was made to a mixture of oil and water acting better in some circumstances than oil alone. In the lubrication of reciprocating engines in the majority of cases the oil is of such a nature that it will mix, to a certain extent, with the water and form a lather, but in the case of turbines, with forced lubrication, any symptom of the formation of lather is a bad feature. If the oil mixes with the water in such a manner it eventually gets so thick that it will not go through the system. This is one of the points referred to at the commencement of the paper where it is stated that the oil for this class of work "must be entirely free from saponifiable matter," the oil would get so thick that it would choke up the passages.

CHAIRMAN : If there are no further remarks to make, we will bring this discussion, which has been a very interesting one, to a close. It has given me a very good idea, as I suppose it has to the other members present, of the method of lubricating the turbine, and I think Mr. Mather has dealt with the various points that have arisen in a very clear and concise manner. So far as I can see the points that he has brought forward in his system, the feeding, the tanks and the filtering and other matters described in his paper and in the drawing, are very good indeed, and I am sure it has helped many of us to see the thing a little clearer than before. With regard to the turbine superseding the reciprocating engine, I think it is generally admitted by engineers that turbines have come to stay, but that does not, I think, imply that we have got turbines to that state of perfection that we may ultimately expect them to come to. There is no doubt that very great improvements have been made in the turbine since it came into general use, and I do not see why there should not be further improvements which will bring the turbine even more to the front than it is now. All engineers have a warm side to anything in the way of improvements and there is no doubt that in many ways the turbine is an improvement over the reciprocating engine. I am sure we will all watch its progress with interest and it will not be the fault of engineers if it is not a success.

Mr. J. R. RUTHVEN (Member) : I have pleasure in moving a hearty vote of thanks to Mr. Mather. In many ways it is a model paper and well worthy of the remarks passed upon it.

Mr. NEWALL : I have very great pleasure in seconding this

motion, and in doing so I may say, although I have heard a whisper of a certain amount of pessimism with regard to the future of the turbine, I think it is a most wonderful achievement and am proud to have lived in the day when we have seen the removal of 80 or 90 of the moving parts of our modern engines, and an engine with only one moving part in their place. All those various parts have been brought down to one single piece and we cannot have less than one, which I think is a great achievement, and any paper which deals with or bears upon a, subject of this kind, that many of us may have to become familiar with in the future, is well worthy of us taking up in the heartiest manner possible, and on these grounds I heartily second this vote of thanks.

Mr. MATHER : I have much pleasure in accepting your vote of thanks. Considering the night we have had I am very pleased indeed that the members have turned out in the way that they have, and the amount of support and discussion brought out by the paper is a great compliment to myself in addition to the vote of thanks you have passed.

CHAIRMAN : Before bringing the meeting to a close I think it would be well if any of the members who have any ideas on the subject and have not expressed them to-night would send in a communication to the Honorary Secretary and let their communication be printed along with the paper. That, I think, would be a better plan than asking for another night's discussion.

Mr. P. BOYD proposed and Mr. HOWELL seconded a vote of thanks to the Chairman, after which the proceedings terminated.