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Lubricants for Marine Steam Prime Movers.

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IT is probably true to say that nothing in the operation of prime movers gives the engineer more anxiety than lubrication. Particularly is this true in marine engineering, where a lubrication failure may necessitate extensive repairs not possible to carry out while the vessel is at sea. Certainty of operation combined with as large a factor of safety as reasonable economic conditions allow, is therefore a *sine qua non* in the working of marine engines. Since even a momentary lubrication failure may result in a serious breakdown and heavy repair bills, it is essential that the correct lubricant be chosen for each particular type of engine and that the lubricant be fed in the correct quantity to the right place as uniformly and continuously as possible as long as the engine is in motion.

A full description of the various aspects of the lubrication of marine steam prime movers could only be given in an article several times the length of the present one, and even then leave many important matters unsaid. The present contribution can therefore only deal with the subject in a very general manner.

The lubrication of reciprocating steam engines may be divided into two sections: the lubrication of bearings (including valve motion, crossheads, slides, etc.) and the lubrication of steam engine cylinders and valves. Bearing lubrication in turn may be sub-divided into the type which demands oils emulsifying readily with water (the so-called marine engine oils) and the other type in which lubricants of an entirely opposite character, i.e. having a high degree of demulsibility, are required. Good demulsibility is also desirable in marine steam cylinder and valve oils in order that they may separate as rapidly and completely as possible from the condensed steam and so reduce to a minimum the amount of oil entering the boilers.

Marine Engine Oils.

These may be termed emulsifiable oils for the lubrication of the external parts (i.e. bearings and valve motion) of marine steam engines of the open crank-case type. They consist of petroleum mineral oils (of the red engine type) compounded or blended with some 5 to 25 per cent. of "blown" (i.e. artificially oxidised) vegetable or animal oil of the semi-drying type. Similar oils have in the past been extensively used by railway companies for the lubrication of the bearings and valve motion of locomotives, as the working conditions somewhat resemble those obtaining in marine engines. With a few exceptions, however, the extensive application of lubricating oils of the mineral oil-blown oil type is confined to open crank-case marine steam engines in which the bearings and other external parts are syphon-lubricated.

The main object of incorporating blown oil in marine engine oil is to cause the latter to emulsify freely when rubbed with water, with the formation of a rich and creamy lather. This is necessary in marine practice owing to the frequency with which water comes into contact with the bearings, etc. In the case of a hot bearing the cold water hose is frequently applied, or a small trickle of water is allowed to run into or on to those bearings which are inclined to run rather warm. If bearings thus exposed to water are lubricated with "straight" mineral oils (i.e. petroleum oils to which no fatty oil has been added), the water will rapidly displace the oil from the metallic surfaces and the bearing will heat; it may even seize. In view of the fact that oil wets and spreads over greasy metallic surfaces more readily than does water, it appears at first sight strange that water should be capable of displacing mineral oil in bearings. The explanation lies in the fact that owing to the supply of water being more copious than that of the fresh oil, the former exerts an erosive action on the oil film, which is then replaced by water, which has a higher surface tension than oil. Under such conditions it is essential to use a lubricating oil which, instead of being repelled by water, "makes friends" with it, i.e., is highly emulsifiable. When beaten or rubbed up with water, such emulsifiable oils break down into very minute droplets swimming in the water, which in consequence assumes a creamy appearance. If the proportion of oil is small (say 5 to 10 per cent.) the viscosity of such an emulsion may be little greater than that of water itself, yet it is capable of giving fairly satisfactory lubrication and will spread readily over the bearing surfaces. While good quality marine engine oils will emulsify readily with water, they will give more efficient and more economical lubrication if they are used without water. Owing to the physico-chemical "affinity" of marine engine oils for water, it is impossible to recover the oil from the emulsion by economic methods, and it must therefore be allowed to run to waste.

The bearings and valve motions of most marine steam engines are much more exposed to the washing action of condensed steam than the corresponding parts of open type stationary steam engines because the latter are usually horizontal, while the former are chiefly the vertical type. Again, the majority of marine steam engines run on saturated steam which becomes thoroughly wet by the time it reaches the l.p. cylinder, and since it is usually not practicable to stop the engines while the vessel is at sea, there is no opportunity for re-packing any piston rod or valve rod glands which may develop leaks. Stationary steam engine bearing oils are not therefore suitable for open type marine steam engines, as they are usually straight minerals oils not readily emulsifiable with water.

Within certain limits and in the absence of soap emulsifiers the greater the proportion of "blown" oil in a marine engine oil, the more readily does the latter emulsify with water, consequently the best quality marine oils contain up to 20 per cent. or even more of blown oil. It is not, however, desirable to exceed by much an upper limit of about 20 to 25 per cent. for the content of blown oil. This is partly because the lubricant is thereby rendered too expensive, and partly because it then has an excessive tendency to oxidise and gum with formation of sticky deposits in the bearings, syphons and oil-boxes, etc. It is also then liable to contain a relatively high percentage of free fatty acid, with consequent corrosion and soap formation troubles.

The emulsifiability of marine engine oils also depends upon the extent to which the fatty oil constituent is "blown"; up to a certain point, the more thoroughly the fatty oil is oxidised, the more readily does it emulsify with water and the more permanent is the emulsion. This is probably due to the fact that the proportion of $-OH$ groups (to which blown oils owe their emulsifiability) in the blown oil increases with the length of time that the oil is oxidised.

It is, however, important that the oxidation of the fatty oil component be not carried too far, since the miscibility of the blown oil with the mineral oil is then seriously reduced, and some of the blown oil is apt to separate out in the barrels as a thick sticky sludge.

It is rather extraordinary that even to-day oil suppliers rely solely upon the use of blown animal or vegetable oils to impart emulsifiability to marine engine oils according to principles first established many years ago, in spite of the fact that far more efficient emulsifying agents have for long been available. Thus, a considerable variety of soaps prepared by saponifying either plain or sulphonated fatty oils with soda or potash have for many years been used in the preparation of the highly emulsifiable "soluble" cutting oils used as lubricants and coolants in machine shops, and as the result of intensive scientific research the manufacture of emulsifying agents has been so greatly improved that there are now available preparations of this type which need only be added to mineral oils in comparatively small proportions to enable the addition of fatty oil to be dispensed with altogether, at any rate as far as emulsification is concerned. Thus, the addition of as little as 2 or 3 per cent. of such an agent to a mineral oil will impart to the latter a readiness to emulsify with water and a stability of the resultant emulsion at least equal to that obtainable by the addition of 20 to 25 per cent. of blown fatty oil. In this connection it is of interest to observe that some of the more recently developed "agents" are so efficient as to enable mineral oils to emulsify readily even with sea water to give very stable emulsions.

As far as the writer is aware, no accounts of syphoning tests on such mineral oil-emulsifying agent blends have yet been published, but owing to the greater resistance to oxidation and gumming which would result from the elimination of blown fatty oils from marine engine oils the matter would appear to be well worth investigating further. It is impossible to predict what effect, if any, the addition of, say, 2 or 3 per cent. of various emulsifying agents would have on the rate of syphoning of a given mineral oil, but it is, of course, very important that this should not be materially reduced, even after several hours syphoning: it would be a great mistake to judge the quality of a marine engine oil on the score of its emulsifiability alone. Again, while fatty oils, either "plain" or blown, could probably be omitted altogether from the cheapest grades of marine engine oil if the latter contained 2 or 3 per cent. of "agent", without harmful results in practice (since "straight" dark-coloured mineral oils are already used for marine engine lubrication where the cost of the lubricant is the prime consideration), it by no means follows that this would be advisable in the case of the better qualities of oil; fatty oils are at present incorporated in these to increase their "oiliness" (see later) as well as to impart emulsifiability, and it is not yet known whether any emulsifying agent of the saponified type is as efficient as fatty oils in augmenting the "oiliness" of mineral oils, especially when the fatty oils contain a moderate amount of free fatty acid. One important advantage, however, which may be found to accrue from relying on efficient emulsifying agents to give lathering properties to marine engine oils is that the fatty oil which may also be added need not necessarily be "blown", as its function will be solely to impart oiliness. As a consequence the separation troubles which now and then occur owing to the lack of miscibility of blown oils (especially when highly blown) with certain types of mineral oil should disappear entirely, practically all "unblown" fatty oils (except castor oil) being miscible with all mineral oils in all proportions.

The blown oils most commonly employed for the blending of marine engine oils are blown rape and blown fish. Blown cottonseed oil was at one time also extensively employed, but has lost favour on account of its inferior miscibility with mineral oils and its greater tendency to oxidise and gum. The blown fish oils commonly used are blown whale, blown shark, and blown cod. Blown rape oil is more expensive than the other varieties and has for many years enjoyed a great reputation as a constituent of marine engine oils. It is, however, still a disputed point among lubrication technologists whether it is superior to blown fish oils in either emulsifying power or "oiliness". It is often preferred to ordinary blown fish oils (especially in passenger vessels) owing to its having a less unpleasant odour, but the engines of many vessels appear to run without complaint on the part of the engine room staff when lubricated with engine oils containing blown fish oils. The use of deodorised blown fish oils has also largely removed the objections sometimes raised to the odour of lubricants of this type.

At one time, before viscous mineral oils of low freezing point were obtainable, it was common to incorporate a relatively high percentage of blown oil in the blend, and the fatty oil was as highly blown as possible, short of seriously reducing its miscibility with the mineral oil. The reason for this was that it enabled the oil blender to reduce the viscosity of the mineral oil component necessary to obtain a compounded oil of given body. This had the important advantage of giving a blend of reasonably low setting point. The rapid development in the manufacture of lubricating oils from wax-free crude petroleums of the naphthenic and "asphalt base" type have, however, rendered available mineral oils of moderate price which combine high viscosity with low freezing point and excellent miscibility with blown oils over a wide range of proportions. The need for incorporating relatively high percentages of highly blown oils in marine engine oils has therefore disappeared, with a corresponding marked improvement in the chemical and physical stability of the finished oil.

With marine engine oils, as with most compounded oils rich in fatty matter, it is essential to keep a sharp eye on the *acidity* of the oil. This is particularly the case with marine oils, as they usually come into contact with water, and the corrosive action of free fatty acids is much increased in the presence of moisture. Again, the blowing process tends to increase the acidity of the fatty oil component, especially if this be a fish oil, so that the latter must be carefully selected to have a low acid content when "raw". If the fatty acid content of the marine engine oil is much over 3 per cent. (as oleic) severe corrosion and pitting of any metallic surfaces with which it comes into contact may occur, and in some cases the oil may thicken and choke the syphons due to its dissolving the resultant metallic soaps. It is convenient to remember that a fatty acid content of 3 per cent. is approximately equivalent to an "acid value" or "neutralisation value" of 6 milligrams of potassium hydroxide per 1 gram of oil and that 10·5 cubic centimetres of deci-normal sodium or potassium hydroxide would be required to neutralise 10 grams of such an oil, phenol-pthalein or some organic compound of similar sensitivity being used as indicator. The acidity of lubricating oils is sometimes expressed in terms of percentage of SO_3, although modern oils extremely rarely contain more than a trace of free sulphuric acid. The total acidity of marine engine oils should not exceed about 0·4 per cent. when expressed in this scale.

While it is important to limit the percentage of free fatty acid in a marine engine oil it is a mistake to insist on an extremely low acidity: not only will this render the oil unduly expensive, but it will reduce its "oiliness" or power of adhering to metallic surfaces. This will be clear when it is remembered that free fatty acids (say 1-2 per cent.) are sometimes intentionally added to certain types of lubricating oil with the object of either increasing their "oiliness" or adhesiveness. By "oiliness" the writer understands the power of an oil to give satisfactory lubrication under adverse conditions where the opposing metallic surfaces are not completely separated by a relatively thick oil film and the lubricant cannot therefore reduce friction by virtue of its viscosity alone, as in force-fed bearings. "Oily" lubricants therefore show marked superiority over the ordinary type under conditions of heavy pressure and/or the relatively scanty oil feed, which, for economic reasons, is characteristic of "all-loss" lubrication systems. They have superior "wetting power" and ability to adhere to metallic surfaces.

The question of the relative "oiliness" of lubricants brings us to the second reason why blown oils are incorporated in marine engine oils, namely, that the lubricating power of the latter is thereby improved to a marked degree. The bearings and external parts of open crank-case marine steam engines are lubricated on the all-loss system and not by means of a circulatory system. Consequently, in order to avoid an unduly high oil consumption, the oil feed to each bearing must be relatively sparing. At the same time bearing pressures and temperatures are fairly high and great certainty of operation is required. Such conditions demand lubricants of great "oiliness", and since ordinary distillate straight mineral oils are rather deficient in this property, while both animal and vegetable oils (especially when slightly acid) possess it in high degree, it is customary to blend a substantial proportion of fatty oil with mineral oil when it is desired to increase the lubricating power of the latter. In compounded oils of the non-marine type, unblown fatty oils are chiefly used for this purpose, but since these (with the exception of two or three which are ruled out on the score of cost) lack emulsifiability, they are not suitable for marine oils; moreover, both practical experience and scientific tests appear to show that blown or oxidised oils may have greater "oiliness" than the unblown variety. In this connection it is interesting to observe that careful researches by R. O. King and Jakeman in the well-known Jakeman lubricant testing machine at the National Physical Laboratory have proved conclusively that the lubricating power of a given oil improves to a marked degree up to a certain point if the oil undergoes *oxidation.*

It is true that these researches (accounts of which have been published in the Journal of the Royal Society and of the Institution of Petroleum Technologists during 1933 and 1934) have so far been restricted to aero-engine mineral oils and to castor oil, and that the blowing or oxidation of the oil was carried out simultaneously with its use in the testing machine itself, but there is some reason for believing that slightly blown or "pre-oxidised" rape and fish oils may be superior to the ordinary variety in oiliness.

Marine engine oils may be primarily graded on the basis of their viscosities at 140° F. Three grades of viscosity are sufficient to cover most marine requirements. Typical figures would be 160, 230 and 285 seconds Redwood at 140° F.* Each viscosity grade of oil may then be further sub-divided according to the percentage and nature of the blown oil constituent present. In addition to the viscosity at 140° F. (which should not vary by more than about ±5 per cent. from the specification figure), an upper limit should be placed upon the viscosity of the oil at 70° F. in order to ensure that the oil will not be unduly sluggish at low temperatures. This precaution will also ensure that the oil will not thin out unduly at higher temperatures. The maximum viscosity permissible at 70° F. will naturally depend upon the viscosity required at the "key" or "grading" temperature of 140° F., and while sufficiently high to admit marine engine oils in which the mineral oil component is of the normal asphalt-base type (specific gravity about 0·935 to 0·940 at 60° F.), should eliminate any "freak" hydrocarbon oils of abnormally high gravity and low viscosity index† ("Extract" lubricating oil fractions obtained as by-products from the refining of asphalt-base raw lubricating distillates by modern solvent-extraction processes might fall in this category). The placing of an upper limit on the viscosity of the oil at 70° F. (the lowest standard temperature at which the viscosities of bearing oils are normally determined) will also be an aid to ensuring that the oil will not syphon unduly slowly at low temperatures. It may not entirely ensure this, however, since, unfortunately, the rate of syphoning of various lubricating oils under a given set of conditions appears to depend largely on their chemical composition as well as upon their viscosities at the syphoning temperature. However, viscosity is a very important factor in determining the rate of syphoning, and some control should therefore be exercised upon it at lower as well as higher working temperatures.

The freezing-point (setting point) of the oil should not exceed about 30-35° F., and if, as is nowadays often the case, the mineral oil component is of the non-waxy naphthenic type, may be as low as 5-10° F. The closed flash-point is not particularly important, but should not be below about 350° F. This lower limit is imposed solely to ensure absence of contamination with more volatile petroleum products (such as gas oil) and not for

*Some oil companies supply grades of 175″, 200″ and 250″ R. at 140° F.

† Oils of low "viscosity index" have high viscosities at low temperatures for a given viscosity at say 140° F. while oils of high "viscosity index" have relatively "flat" viscosity-temperature curves.

the purpose of restricting the origin of the mineral oil to any particular type of crude. The specific gravity is also relatively unimportant, except as a means of ascertaining indirectly the specific gravity of the blown oil component in the course of a complete analysis. The specific gravity of the blown oil should not exceed about 0·99 at 60° F. The specific gravity of the mineral oil component should not exceed about 0·94 except in very heavy grades of marine engine oil, and in certain cases it is also preferable to impose a *lower* limit of about 0·91 to ensure that excessively paraffinous mineral oils have not been used, as the miscibility of these with blown oils is limited.

Opinions vary considerably as to the proportion and nature of the blown oil desirable in marine oils, but it is usually agreed that not less than 10 per cent. should be present. Many steamship companies on the other hand demand oils containing as much as 20 per cent. of blown oil, and that this should be blown rape. Generally speaking, however, for the larger reciprocating steam engines an oil containing not less than 12½ per cent. of blown fatty oil is used, the Redwood viscosity of the blend at 140° F. being of the order of 200 seconds minimum. For smaller engines lower viscosity oils are commonly used with smaller percentages (usually not less than 10 per cent.) of blown oil. For trawler work very heavy bodied oils of round about 300-310 seconds Redwood at 140° F. are generally favoured. These consist of heavy dark engine oils compounded with a cheap readily emulsifiable fat of which as much as 25 per cent. may be present.

It is difficult to lay down any hard and fast rules concerning the grades of marine engine oil required for given types of engines or sets of conditions, as these may vary so widely, but, broadly speaking, large engines and vessels navigating in hot climates need higher viscosity oils than smaller engines or vessels operating in colder climates. Only practical tests and the experience already gained in a given type of vessel with marine engine oils of known composition and properties can decide what viscosity and percentage of compound are preferable. The higher viscosity oils are usually the more economical, but oils unnecessarily viscous should not be selected as they waste power and create too much "oil-drag" in the bearings. It is a mistake to assume that a viscous oil has necessarily more friction-reducing power than a fluid oil; the contrary may be the case if the latter is richer in blown oil. It is very important that successive consignments of a given grade of oil should be as constant in viscosity as possible at 140° F., otherwise excessive variations in the rate of flow of oil through the syphons will be experienced and re-adjustment of the latter for each batch of oil is naturally inconvenient.

In addition to the tests already mentioned in previous paragraphs, the writer carries out the following tests and analyses in the complete examination of marine engine oils:—(1) Inorganic acidity (mineral acid soluble in water and reactive to methyl orange indicator). This should be, and almost invariably is, practically nil. A difficulty is encountered here owing to the permanence of the emulsion formed on shaking the oil with hot water. This can be avoided by using either strong neutral brine or slightly acidulated water of known acidity. (2) Saponification value; (3) Percentage unsaponifiable matter; (4) Percentage total fatty acids insoluble in hot water. (This is also known as the "Hehner value" and includes the fatty acids originally present as neutral blown oil glycericles). Tests 2, 3 and 4 serve to indicate the percentage of compound present, Test 2 being a rapid approximate test and Tests 3 and 4 confirmatory tests.

Blown oils have a Hehner value of about 80-85 per cent., so that the percentage of blown oil may be calculated with fair accuracy by dividing the Hehner value by 82·5.

When time permits it is advisable to determine the proportion of the isolated water-insoluble fatty acids which are insoluble in light petroleum spirit having a boiling range of about 40-60° C. (Test 5). This figure is calculated as a percentage by weight of the original blown oil and commonly varies between about 20 and 35 per cent. It is of value inasmuch as it gives some idea of the extent to which the fatty oil component has been blown and whether it has been over-blown or not oxidised sufficiently. A range of about 30-35 per cent. for blown fish oils and 25-30 per cent. for blown rape oils will be found quite satisfactory. The more highly a given fatty oil (such as rape) is blown, the higher will be the percentage of dark coloured oxidised fatty acids insoluble in petroleum ether. The oil refiner in practice judges the extent to which a given fatty oil has been blown according to its specific gravity at 60° F. and its Redwood viscosity at 200° F. or 212° F., both of which increase with the degree to which the oil is oxidised. It is not possible when examining marine engine oils to determine directly the specific gravity and viscosity of the blown oil component, since the blown oil cannot be separated as such from the mineral oil; these values can be calculated with fair accuracy if the specific gravity and viscosity of the isolated mineral oil are determined, and afford additional evidence of the extent to which the fatty oil component has been blown. The determination of the specific gravity and refractive index of the total isolated water-insoluble fatty acids derived from the blown oil is also a valuable guide. High values indicate a high degree of oxidation and *vice versâ*. The specific gravities of the free fatty acids derived from blown oils are very similar to those of the oils themselves.

The examination of the isolated mineral sometimes affords a valuable indication as to the probable *stability* of the marine engine oil on storage. Thus if the mineral oil component is of the "asphalt-base" type, i.e., has a relatively high specific gravity, steep viscosity-temperature curve and low setting point, there is less likelihood of the blown oil separating out on prolonged standing in cold weather, (especially if the percentage of blown oils is low and/or if it has not been highly blown), than if a highly paraffinic type of mineral oil has been used.

One of the problems which the analyst is most frequently called upon to solve in connection with the examination of marine engine oils is the detection of blown fish oils in samples which are reputed to contain blown rape oil only (apart from mineral oil). Until recently this was considered to be an insoluble problem, since, although the presence of *unblown* fish oils can be detected with comparative ease, the chemical changes which occur during blowing are so extensive that blown fish oils give no characteristic reactions. It is true that the presence of blown fish oils can frequently be detected by their characteristic fishy odour, but this method is hardly satisfactory for legal purposes, and frequently fails altogether if the fish oil has been deodorised by chemical treatment. Fortunately, quite simple optical methods have now been discovered whereby the presence of even small percentages of blown fish oil can be detected with absolute certainty in the great majority of cases.

No very overwhelming evidence appears to be available that blown rape oil is any more efficient than good quality blown fish oil as a compounding agent for marine engine oils, but in view of the preference shown by the majority of marine engineers for blown rape, and the considerable difference in price between blown rape oil and the blown fish oils commonly used as compounding agents, the detection of blown fish oils in marine engine oils in which blown rape is stated to be the only fatty constituent is a matter of considerable commercial importance.

No generally recognised standard tests are available for determining the separation stability of marine engine oils or their emulsifiability with water, but these should always be carried out. Very simple tests are quite sufficient for this purpose; the author tests stability by immersing two 4oz. oil sample bottles about half full of the oil to be examined in water at 32° F. and 140° F. respectively for not less than one hour and preferably for 24 hours. At the end of this period the samples should be examined for signs of separation. Good quality marine engine oils will remain perfectly clear in this test. It is difficult to devise a quantitative test for the emulsifiability of marine engine oils, but a qualitative test is certainly desirable. The practical marine engineer commonly employs a convenient rough and ready test whereby a small quantity of the oil is rubbed up on the palm of the hand with a little water and the readiness with which it forms a lather noted. The writer supplements this test with a modification of the demulsibility test for turbine oils which has been standardised by the Institution of Petroleum Technologists. In this test steam is passed into 20 cubic centimetres of the sample contained in a graduated test-tube until approximately 20cc. of condensed steam have been formed. The readiness with which emulsification occurs is noted and the tube containing the emulsion then withdrawn and immersed for an hour or more in a water-bath at 210-212° F. No sign of separation of oil and water should occur during this period. The test is sometimes modified by starting with 20ml. of sea water (or salt solution of equivalent concentration) and 20ml. of oil in the test-tube, passing in steam until 20ml. have condensed as before. This modification of the test is much more severe and the oil must therefore be regarded as satisfactory if not more than 50 per cent. of the water and/or not more than 20 per cent. of the oil separate out after the emulsion is allowed to stand for 20 minutes at 200°-203° F. In the absence of a standard I.P.T. demulsibility apparatus, shaking the oil with hot water in a stoppered bottle and then allowing the bottle to stand in a hot water bath is a useful test.

Bearing Oils for Marine Steam Engines fitted with circulatory lubrication systems. ("Circulation" or "Crankchamber" Oils).

While the requirements for oils of this type in such matters as general purity, constancy of viscosity at working temperatures of successive consignments, etc., are similar to those of marine engine oils of the type already discussed, in other respects entirely opposite properties are needed. For example, marine engine oils must emulsify readily with water, whereas for circulation oils a high degree of demulsibility is required in order to avoid the formation of troublesome deposits. Again, since the rate of feed of marine engine oils to the bearings of open crank-chamber steam engines is comparatively small, great oiliness is required, whereas for force-feed lubrication systems great oiliness is unnecessary and is, in fact, incompatible with the high degree of demulsibility and resistance to oxidation which is essential in circulation oils. The latter are used over and over again, at the same time being exposed to considerable oxidising conditions owing to atomisation at temperatures as high as 160° F. to 170° F. and over in the crank-chambers; consequently, they must not only separate rapidly from water, but must also show a minimum tendency to form petroleum acids and dark sludge-like deposits by chemical combination with atmospheric oxygen.

Steam engine "crank-case" or "crank-chamber" oils are very similar to steam turbine oils; in fact the heavier grades of the latter are commonly used for this purpose, as the requirements of both types of oil are very similar; they may be classed together as "Circulation" oils. In order to ensure both good demulsibility and resistance to oxidation, the first essential is that the oil before use be completely free both from free organic acids and from neutral animal and vegetable oils, in other words, it must be a "straight" mineral oil. Secondly, it must either have been derived from low gravity paraffin-base crude petroleum of Pennsylvanian or similar type by normal refining methods, or, if derived from crudes of higher specific gravity, must have been treated with "selective" solvents to eliminate the more readily oxidised and emulsifiable hydrocarbons. Three or four grades of circulation oil are usually considered to suffice for covering the bearing lubrication requirements of most enclosed crank-chamber marine steam engines, whether main or auxiliary and the physical test readings for typical examples of these prepared from "Pennsylvanian" crude petroleums are given in the following table :—

		Grades of crank chamber oil.			
		1	2	3	4
Specific gravity at 60° F.		·875	·880	·883	·885
Open flash point °F. ...		410	420	430	440
Viscosity Redwood No. 1 (seconds)	at 70° F.	500	800	1200	1400
	at 140° F.	85	115	160	200/210
	at 200° F.				76
	at 212° F.	45	50	60	70
Setting point °F. ...		25/30	25/30	25/30	25/30
R.E.* value		1	2	3	3

Grade No. 1 (crank-chamber oil light) is used on most small auxiliary high-speed engines and Grade No. 2 (crank-chamber oil medium) on large slower speed engines and on auxiliary high-speed engines larger than those referred to under Grade 1. Some oil companies regard Grade 3 as a medium crank-chamber oil and Grade 4 as a heavy rather than as an extra heavy grade, there being a considerable difference of opinion as to what constitutes the ideal viscosity for a given type of engine. Crank-chamber oils, like marine engine oils of the lathering type, are in this country graded primarily according to their Redwood viscosity at 140° F. The broad rule for their selection is that the larger the engine and the higher the mean working temperature of the oil, the higher will be the viscosity (at 140° F.) required. The R.E. value (I.P.T. standard test for demulsibility) should in all cases not exceed about 2 to 3 and it is also desirable to submit samples to some form of "sludging" or "oxidation" test. This applies also to turbine oils, and the greatest step forward in the refining of circulation oils (including not only steam turbine and steam engine crank-chamber, but also Diesel engine lubricating oils) which has been made in recent years is the production of "non-sludging" oils. These were also referred to in an article by the writer under the heading of "Some Diesel Engine Lubrication Difficulties and their Remedies" in the June issue of these TRANSACTIONS, pages 169-175. Briefly, such oils are obtained by introducing into the refining process an additional stage whereby the more unstable hydrocarbons are removed by a purely physical process which in no way harms the more valuable portions of the oil. In the case of low freezing point oils, as much as 70 per cent. of the original oil may be rejected by such "solvent extraction" processes; consequently, the finished oils are more expensive than the ordinary varieties. The extra cost is often, however, fully justified owing to the greater certainty of operation which is thereby obtained and the fact that the oil need be changed less often.

The chief features of such "non-sludging" circulation oils are their resistance to oxidation (in which respect the best qualities are not surpassed even by "Grade A" transformer oils) and the extraordinary manner in which they retain their demulsibility in some cases even after many months of service. When prepared from non-paraffinic crudes they have the additional advantage of having very low setting points. The properties of some typical turbine and crank-chamber oils of this type are shown in the following table :—

		Grades of non-sludging turbine and crank-chamber oil.				
		1	2	3	4	5
Specific gravity at 60 °F.		0·904	0·905	0·905	0·906	0·908
Closed flash point °F....		350	355	355	410	425
Open flash point °F....		380	380	380	440	450
Viscosity Redwood No. 1 (secs.)	at 70° F.	590	740	1000	2000	2400
	at 140° F.	83	95	110	175	210
	at 212° F.	41	45	46	58	60
Pour test (freezing temperature) °F. ...		−5	−5	−5	+10	+15
†Asphaltic sludge formed on oxidation (B.S.I. test) %		0·23	0·20	0·16	below 1·0	below 1·0

T. C. Thomsen in his classic treatise "The Practice of Lubrication" mentions that on inspection after 20,000 miles, the white metal bearings of main marine steam engines fitted with forced oil circulation have still shown the original tool marks and that no measurable wear had taken place. It is obvious that from, at any rate, the lubrication point of view, such oiling systems possess great advantages over syphon lubrication. *Apropos* of the absence of need for high viscosity compounded oils for circulation oiling Thomsen says (loc. cit.): "One might ask why these oils, pure mineral in

* The "R.E. value" represents the resistance to emulsification of the tested oil. This is assumed to be directly proportional to the rate of emulsion separation. Thus an R.E. value of 1 is assigned to an oil which, under the conditions of the standard I.P.T. test separates completely from emulsion in one minute, 20 cubic centimetres of oil having been churned up with approximately 20 cubic centimetres of condensed steam to produce the emulsion. If complete separation of the 20c.c. of oil does not occur until two minutes have elapsed, its R.E. value is 2 and so on. The lower the R.E. value, the greater the demulsibility of the oil and therefore the better its quality from this point of view.

† The "Sludging Value" of an oil is a measure of its resistance to oxidation at moderately high temperatures. The lower the value, the more resistant the oil. In the test (which has been standardised both by the Institution of Petroleum Technologists and the British Standards Institution) 2 litres of air per hour are passed for 45 hours into 100 grams of oil maintained at 150° C. copper foil is present. At the end of this period the percentage by weight of dark asphaltic matter insoluble in aromatic-free petroleum spirit is determined and recorded as the "B.S.I. sludging value". It is one of the standard tests for transformer oils.

character and lower in viscosity than the compounded marine engine oils, can replace the latter with such great success. The answer is simply that the oil is supplied to all bearings *in abundance,* not only supplying a complete lubricating film, but also continuously *removing frictional heat* from the bearings, which therefore run *much cooler.* The bearings do not get contaminated with water, and as the revolving parts practically 'float' on a complete oil film, wear is virtually eliminated and the results are excellent from every point of view". The manner in which Thomsen explains the essential principles of force-feed lubrication could hardly be bettered, and the writer has therefore quoted it in full.

The conditions to which both turbine and crank-chamber oils are subjected in service are becoming ever more severe, and it is therefore essential that they should not only possess good demulsibility and be free from sludge-like impurities when new, but that they should retain their demulsibility and purity for as long as possible. Chemists have in the past concentrated too much on the condition of the oil when new, whereas, in the case of oils which are used over and over again, the engineer is equally concerned with the condition of the oil after it has been for some time in service.

While it is admittedly, owing to the need for arriving at an opinion in the minimum amount of time, very difficult to devise satisfactory "life" tests in the laboratory, some test of this kind has now become essential. The usual practice is to bring a known weight of the oil into contact with air or oxygen at a temperature well above any to which it would be subjected in normal service and to observe the amount of dark "asphaltic matter" or "sludge" insoluble in aromatic-free petroleum spirit which is formed in consequence. Sometimes the amount of organic acid and the amount of dark coloured saponifiable matter formed as the result of oxidation is also determined.

The test is usually performed in the presence of some metal, such as copper, which exercises a pronounced catalytic action. In order to obtain repeatable results, it is essential to work under closely standardised conditions. Comparatively high temperatures are used in order to speed up the oxidation. Unfortunately, the type of reaction occurring at these temperatures probably differs considerably from that occurring at the lower temperatures which prevail in actual service and oils are therefore not always placed in their true order of stability at the latter temperatures. Again, very small variations in the composition or surface condition of the metal (usually copper) used as a catalyst may produce big variations in the test results, and in the actual engine, the presence of additional metals, especially when in direct contact with one another, may catalyse the oxidation reactions of the oil in a different manner. However, *some* type of oxidation or "life" test is better than none at all, and in this country the transformer oil sludging test of the British Standards Institution and the continental oxidation test of the Verein der Deutschen Ingenieure are widely used, either in their original form or slightly modified as to temperature, etc. The best oils are those giving least sludge, least saponifiable matter, and least loss in demulsibility.

Modern non-sludging oils in service sometimes develop relatively high organic acidity, after a moderate period of time. Since, however, these acids are very weak, do not attack the metallic surfaces of the engine or turbine to any serious extent, and are not accompanied by sludge formation, there is no cause for alarm. Again, they do not reduce the demulsibility of the oil, in fact, curiously enough, in many cases they actually improve it.

Experience seems to show that the only cases in which turbine oils must be selected which show minimum development of acidity with period of service are with turbines in which the bearing metals are exceptionally rich in lead or zinc. These metals are attacked even by the weak oil acids, and if the white metal contains a high proportion of lead, the latter is sometimes dissolved away leaving the crystalline cubes of antimony projecting from the matrix.

With turbine oils of the low gravity Pennsylvanian or similar paraffin-base types which have not been specially refined to resist oxidation, the acidity of the oil in use must be carefully watched, samples being withdrawn and tested at regular intervals. It is often considered that the acidity should not be allowed to exceed about 0·3 per cent. as SO_3, since with oils of this type a high acidity is usually accompanied by the formation of oxidation sludge insoluble in the cold oil. By renewing part or the whole of the oil its acidity can be controlled. The inclusion of an efficient centrifuge in the system is also an aid to keeping down acidity, especially if facilities are provided for washing the oil with hot condensate water, since some of the organic acids (especially those most likely to attack the bearing-metals) are appreciably water-soluble.

As has already been pointed out, with non-sludging turbine oils of the "Edeleanuised", "Duosol" and similar "solvent extraction" types, higher limits can be allowed for acidity, but here again the limiting of acidity and removal of the more corrosive water-soluble organic acids by water-washing followed by centrifuging is advantageous.

Marine Steam Cylinder Lubricants.

The valves and cylinders of marine steam engines are often poorly lubricated. Thomsen points out that this is because, in times gone by, disastrous accidents and trouble with boilers have occurred due to the cylinder oil used for internal lubrication being carried into the boilers. It is hardly surprising that in consequence marine engineers have gone to the other extreme and reduced the supply of steam cylinder oil to the absolute minimum, confining themselves (except in the case of engines employing superheated steam) to the introduction of oil into the cylinders and valve chests solely by swabbing the piston and valve rods. This practice is naturally very wasteful and inefficient, as most of the cylinder oil is scraped off by the glands and runs to waste, very little oil getting past the packings into the cylinders and valve chests. In consequence, although marine steam engines running on saturated steam can be operated for long periods under these conditions without inconvenience or trouble (largely owing to the condensation of steam which occurs in the intermediate and low pressure cylinders), the internal friction and wear are considerably higher than when proper lubrication is employed, and much leakage of steam past the piston rings frequently takes place.

In the case of marine engines operating on superheated steam, internal lubrication by feeding steam cylinder oil to the main steam pipe or direct to the valves, cylinder and glands is essential. Provided that the correct quality of oil is selected, excessive rate of feed avoided, and an exhaust steam oil separator fitted, complete and efficient lubrication can be obtained without any risk of boiler troubles. Thomsen maintains that it would be desirable to employ the same system for marine engines using saturated steam, the best results being obtained by feeding the minimum quantity of the correct grade of oil into the main steam pipe before the engine stop valve as uniformly as possible by means of a mechanical lubricator.

An interesting possible alternative to cylinder oil for the lubrication of the cylinders of marine engines employing saturated steam is a dilute suspension of pure colloidal graphite in distilled water. "Aquadag"* has already been used for this purpose for a number of years in certain land installations where the use of the exhaust steam for various industrial, manufacturing and detergent processes renders it essential that the condensate be absolutely free from oil. As far as the writer is aware, no accounts have been published in this country of the use of aqueous *colloidal* graphite suspensions for marine steam cylinder lubrication, but there would appear to be no reason why it should not give complete satisfaction and certainly far better internal lubrication than is possible with water alone. The experiment seems well worth trying, and it is to be hoped that enterprising engineers will carry out research on these lines and publish the results.

The use of *ordinary* natural graphite (black lead) for the lubrication of steam cylinders both on land and at sea is of course by no means new—tallow and black lead, for example, used to be a favourite cylinder lubricant at sea in the days when steam pressures were low. The graphite, however, was always the natural type and was merely finely ground and not colloidal. In consequence, it could not be used in suspension in oil or water, but only in conjunction with lubricants such as tallow, which, being solid or semi-solid at ordinary temperatures, did not allow the graphite to separate out. Since tallow (unless very largely diluted with mineral steam cylinder oil) is decomposed by steam (especially at higher steam pressures) with formation of free fatty acid, it acts most destructively on all cast-iron and steel surfaces, so that the use of tallow and black lead mixtures has now almost disappeared. The use of *colloidal* graphite in suspension in water (or, in the case of engines employing superheated steam, suspended in mineral cylinder oil) is an entirely different matter and is not attended by any corrosion of the metallic surfaces with which it comes into contact.

"Aquadag" is a paste consisting of a mixture of four parts of water to one of Acheson colloidal graphite. Before being used for the lubrication of the cylinders and valves of steam engines (and pumps) it must be diluted with *pure distilled* water or at least with pure condensate from the exhaust steam until the graphite concentration has been reduced to about 0·33 per cent. The concentrated graphite paste mixes very readily with distilled water, but it is essential that the mixing should be as thorough as possible in order that the graphite may be uniformly distributed throughout the liquid. Provided that only pure distilled water has been used for diluting the Aquadag and that the vessel in which the mixing is carried out is perfectly clean, the graphite should remain in suspension indefinitely with minimum settling out of any particles. Ten gallons of the diluted Aquadag may be prepared at a time. The vessel containing the mixture should be kept stoppered, and any funnels, spouted jugs, etc., used for transferring the liquid from the storage vessel to the lubricators should be kept perfectly clean.

A special lubricator must be provided, since in the ordinary hydrostatic sight feed lubricator the water resulting from condensation comes into contact with the lubricant, and in both this type of lubricant and the mechanical reciprocating plunger type the sight feed glass is of the bottom feed type filled with water and arranged for oil to travel upwards through the latter in separate drops. It is obvious that this arrangement would not work with lubricants having an aqueous basis since these would mix freely both with the water resulting from condensation and with that in the normal type of "upward flow" sight feed lubricator. For those who prefer the simple lubricators of the hydrostatic type, an instrument specially designed for use in conjunction with aqueous colloidal graphite lubricants and known as the "Johnston" Aquadag lubricator is already available. As far as the writer is aware, few *mechanical* lubricators suitable for lubricants of this type have as yet been marketed,

*A proprietary product manufactured by Messrs. G. Acheson, Ltd.

but it would be quite a simple matter to modify the design of any of the well-known mechanical oil lubricators already available so as to render them perfectly suitable for aqueous lubricants.

In the Johnston lubricator the aqueous graphite liquid is separated from any condensed steam by means of a layer of oily liquid such as paraffin. The sight-feed glass is also filled with paraffin (or with a "white" mineral oil of the transformer oil or medicinal paraffin type); in other respects the working of the Johnston lubricator is similar to that of the ordinary hydrostatic type.

The consumption of graphited water will naturally vary widely with the type and size of engine, but a fair approximate figure would be one third of one gram or 0·0005 part of lubricant (containing 0·33 per cent. of graphite) per b.h.p. hour. For example, a 2,500 h.p. engine would require one gallon of graphite water about every six hours. This figure is of about the same order of magnitude as is normally obtained with oil lubrication. Thomsen, for example (loc. cit.), gives the following figures for the consumption of cylinder oil in vertical steam engines:

Below 400 h.p. 0·15 - 0·6 grams per b.h.p.
Above „ „ 0·05 - 0·4 „ „ „

The consumption in most ships' propulsion engines would approach the lower figure.

The figures for the consumption of graphited water are of interest, not only because they form a basis for arriving at the probable cost of such lubrication*, but because the graphite content of the condensate can be calculated. It will be found that this is extremely small—less than 1 part in 10,000,000. Water containing this amount is quite untinted and it is doubtful whether the graphite could be estimated at all by ordinary methods of chemical analysis. It will be evident that the amount of graphite entering the boiler itself would be very small, even after prolonged runs; moreover, since graphite-containing compounds are commonly added to land boilers for the purpose of reducing the formation of scale, it is probable that even if the amount of graphite entering the boilers was several parts per million no harm would be done.

It is claimed that in the operation of steam engines used in process work a saving in the cost of lubrication is effected when Aquadag is used in place of cylinder oil, quite apart from the considerable economies resulting from the availability of the condensed steam and the reduction in friction and wear. The main advantage, however, lies in the fact that the condensate is oil-free.

The beneficial results accruing from the use of diluted Aquadag for the cylinder lubrication of steam engines and steam pumps were described in an interesting paper read by Mr. E. W. Johnston in 1916 before the Birmingham Association of Mechanical Engineers. Extracts from this are quoted in T. C. Thomsen's well-known treatise "The Practice of Lubrication" on pp. 150 - 154 of the 2nd (1926) edition. Mr. Johnston recorded that after a six months' running test the greatest wear at any point of the valve and cylinder was found not to exceed one-thousandth of an inch, and that it was particularly noticed that the walls of the high pressure cylinder and piston rings were in faultless condition, having mirror-like surfaces. At the time that Mr. Johnston read his paper, the entire steam plant of which he was in charge had been working with Aquadag as the sole cylinder lubricant for almost five years, being in daily use.

While aqueous colloidal graphite lubricants give satisfactory cylinder lubrication in engines designed to work with saturated steam at pressures up to about 250lb. per sq. in., they must not be used with superheated steam. Under the latter conditions there is always a tendency for the superheat of the steam to evaporate the water in the lubricant near the point where it enters the feed pipe. As a result the graphite is not properly distributed and the lubricator outlet becomes choked. For superheated steam the colloidal graphite must be introduced in an oil medium, "Oildag" (a suspension of about 10 per cent. by weight of Acheson colloidal graphite in pure mineral lubricating oil) diluted with high grade "straight" mineral cylinder oil of appropriate viscosity down to about 0·35 per cent. graphite content being admirably suited for this purpose. As the exhaust steam will now contain a small proportion of oil, it is necessary to pass it through an efficient oil separator, but the addition of colloidal graphite to the cylinder oil gives the dual advantage of enabling the oil feed to be reduced (after about three or four weeks), by as much as 33 per cent. to 50 per cent., at the same time giving less friction and wear. The reduction of the oil feed reduces not only the cost of lubrication but also the amount of oil carried into the boiler.

Here again, as far as the writer is aware, no accounts have been published concerning the application of colloidally-graphited oils for marine steam cylinder lubrication, although such lubricants are already used with success for this purpose in quite a number of land installations; in fact, cases are known here and there where (probably owing to abnormally high local pressures, due to lack of alignment of the piston rods and cylinders) it has been found impossible to lubricate the steam engine cylinders satisfactorily, even with the best quality heavily compounded cylinder oils (applied through modern mechanical lubricators) unless a small proportion of colloidal graphite is incorporated in the oil.

It is most important that the graphite used for the lubrication of steam cylinders (whether suspended in oil or in water) should be both free from abrasive matter and *colloidal*,—not merely finely ground. Colloidal graphite may be defined as graphite which is so finely divided that it does not

*Approximately 0·0016d. per b.h.p./hour.

sink in the liquid in which it is suspended, although having over twice the specific gravity of the liquid. No other type of graphite possesses this property, which is due partly to the particles of colloidal graphite being so extremely small that they are of the same order of magnitude as the molecules of the suspension liquid itself and therefore prevented from sinking by the continual bombardment of these molecules, all of which are in active spontaneous motion, and partly to the fact that the particles all carry electrical charges of the same sign and therefore mutually repel one another. The extreme fineness of division of colloidal graphite particles has the dual advantage of keeping the graphite in suspension in liquids (provided they are free from electrolytes) for an indefinite time, even at very high dilutions, and of increasing the affinity of the graphite for metallic surfaces and hence its lubrication efficiency.

The best colloidal graphite is usually considered to be that manufactured by the Acheson process. This material possesses the important advantage, from the lubrication point of view, of being remarkably pure (the purity of Acheson lubricating graphite is said to be over 99·5 per cent.) and entirely free from harmful abrasive substances such as quartz. Few natural graphites approach this degree of purity, and many of them contain up to 10 per cent. of mineral matter or even more. As much of this consists of highly abrasive crystalline quartz, it is very important to ensure that the graphite be practically free from silica and that it contains only the minimum amount of abrasive ash.

Many experiments have been made with ordinary flake graphite and oil for the internal lubrication of steam engines employing superheated steam. While in many cases satisfactory results have been obtained, a great many failures have also been reported when ordinary natural graphites were used, although none with lubricants containing pure colloidal graphite. The failures with flake graphite have been due to its use in excessive amounts, to the use of coarse or impure graphite, or to the breakdown of the mechanical stirrers which are essential in the lubricators unless the graphite is colloidal.

It is most important that the oil or water used for diluting concentrated colloidal graphite preparations should be sufficiently pure, since the colloidal character of the graphite will otherwise be destroyed and the graphite may settle out completely on standing. While even this sedimented graphite is much more finely divided than the most finely ground ordinary graphites commercially obtainable, and is readily redistributed throughout the liquid by slight stirring, such precipitation of graphite is obviously undesirable unless mechanical stirrers are fitted. The oil or water should be absolutely free from electrolytes (i.e., water-soluble mineral acids, alkalis and salts). Ordinary water, however soft, should never be used for diluting Aquadag, and artificially softened boiler water is particularly objectionable. If pure distilled water is not available clean condensate from the exhaust steam may be used. Usually the cylinder oils which separate most readily from hot water are also those which have the best graphite suspension properties, since the good demulsibility of oils is largely due to their freedom from organic acids and electrolytes. From the point of view of marine steam cylinder lubrication this is fortunate, since for this purpose oils which separate readily from water are required. Since lubricating oils (including steam cylinder oils) vary in their graphite suspension properties, it is advisable to consult the manufacturers of colloidal graphite products before deciding what type of oil they should be mixed with. It is a good plan to submit, say, pint samples of the oils it is proposed to use.

Marine Steam Cylinder Oils.

These are usually of the so-called "Dark Steam-refined" type, ranging in viscosity from about 130 to 170 seconds Redwood at 200° F. Steam cylinder oils are commonly rated according to their fire test, but it is more satisfactory to grade them according to their viscosity at 200° F. or 212° F. Occasionally their viscosities are also determined at 140° F. and 250° F. The low gravity Pennsylvanian or similar paraffin-base types of cylinder oil are decidedly preferable for marine lubrication to the high gravity "Western" cylinder oils, as they separate more readily from the condensed exhaust steam (a very important point) and are freer from dissolved asphaltic and tarry substances which frequently cause troublesome deposits in cylinders employing highly superheated steam. The "hard asphalt" or "asphaltene" content of the dark cylinder oils should not exceed 0·3 per cent. and in the case of filtered cylinder oils should be absent altogether. Marine steam cylinder oils are seldom tested for demulsibility, yet it is most important to ensure that this should be as low as possible. Naturally one cannot demand (especially with dark cylinder oils) the same rapidity of separation from hot water as is common with good quality turbine and crank-chamber oils, but the I.P.T. demulsibility test is of value. Some of the best quality cylinder oils give R.E. values as low as 4—5 in this test.

Although the majority of the cylinder oils used in marine work are dark, it is often advantageous to use the "filtered" or "amber" type. When used "straight" they separate more readily and completely from the boiler feed water than the dark type, and their extra cost per gallon is offset by the fact that they can be fed more sparingly to the cylinders. When lightly compounded (i.e. containing about 4 per cent. of fatty oil) the consumption may be further reduced, so that some lubrication specialists recommend that such oils be used in preference to straight oils where an efficient oil separator is used. Additional oil economy is thus obtained, and although even lightly compounded oils often separate less readily from hot water than straight oils, the amount of oil entering the boiler may be reduced when the former type are used because the effect of the reduction in the amount of oil in the exhaust steam may outweigh the reduced demulsibility of the oil. In all cases the oil must be used very sparingly and on no account must heavily compounded cylinder oils be employed, or trouble will be experienced with oil entering the boilers. In addition to the tests already referred to, cylinder oils should be examined for specific gravity, colour by reflected light and by transmitted light (in the latter case after heavy dilution with paraffin oil), and hard asphalt content. These are all tests for purity; the lower the figures obtained, the purer the oil. Flash and fire points are relatively unimportant except as an aid to identifying the origin of the oil and for the detection of accidental contamination with low-flashing oils (very rare). The consumer should satisfy himself that mineral acids are absent (inorganic acidity nil) and that organic acidity (petroleum and/or fatty acids) is low. The Cold Test (setting point or freezing point) is usually determined and should not be too high, otherwise the oil will be difficult to handle in cold weather. A high cold test also indicates an excessive paraffin wax content, which is undesirable, as wax may be regarded as an impurity of little or no lubricating value. Cylinder oils for marine work should always be examined to determine whether they contain fatty matter (compound). This must either be absent or strictly limited in amount (depending upon whether or not an efficient oil separator is fitted). Since fatty oils are more expensive than dark cylinder oils, cheap dark cylinder oils are not likely to contain fatty matter, but there is always a possibility that the oil supplier may accidentally deliver a heavily compounded cylinder oil. This should always be rejected for marine work. In cases where a lightly compounded cylinder oil has been specified, the nature as well as the amount of compound should be determined. "Acidless" tallow oil constitutes a satisfactory fatty constituent.

The following table gives some of the properties of a few typical steam cylinder oils suitable for marine use. There is naturally some difference of opinion as to the grade of oil suitable for a given range of steam pressures and temperatures, but the figures may be taken as a rough guide :—

	Low Viscosity.		Medium Visc'y.	
	Dark.	Filtered.	Dark.	Filtered.
Specific gravity at 60° F.	·895/910	·890-5	·895/910	·896
Flash Point P.M. apparatus — Closed °F.	470/490	500	500/510	490
Flash Point P.M. apparatus — Open °F.	510/30	540	540/550	530
Fire Point °F.	590/610	600	625/635	610
Setting Point	30/45	30/45	30/45	35/45
Viscosity Red. 1 at 200° F.	130	130	165	165
Hard Asphalt %	not over 0·3	nil	not over 0·3	nil
Conradson Carbon Residue	2/3	—	3/4	—

The 130 viscosity oils are generally considered suitable for steam pressures up to about 100lb. per sq. inch and the 165 viscosity oils for pressures up to about 150lb. per sq. inch. Some oil companies advocate this viscosity for pressures up to 200lb. per sq. inch, others use 190/210 viscosity range for pressures over 150lb. and a 160/190 range for pressures of 100-150lb. Again, while some lubrication technologists consider that cylinder oils of viscosity below 210 should be used for saturated steam only, others advocate the 130 oil for steam temperatures up to 525° F. and the 165 oil for steam temperatures in excess of this. At such high temperatures the viscosities of all cylinder oils, however viscous at 200° F., will be very low, and their lubricating power will probably depend upon their adhesiveness to the metallic frictional surfaces rather than upon their viscosity, hence the wide variations in the 200° F. viscosity recommended for given steam pressures and temperatures.

Modern Developments.

These may be briefly summarised as follows: (1) Marked improvements have been made in the stability of marine engine bearing oils of the emulsifiable type due to the introduction of mineral oils more miscible with blown oils than those formerly used. (2) Improvements in the deodorisation of fish oils enable the refiner to supply cheap grades of marine engine oil which, although containing blown fish oil, are free from offensive odour. (3) Little if any change has occurred in the quality of dark cylinder oils, but the filtered variety have had their cold tests improved to a marked degree owing to the introduction of more efficient dewaxing methods. (4) The former supremacy of low gravity paraffin-base circulation oils (i.e., crank chamber and steam turbine oils) purified by the older refining methods is now being seriously threatened by the rapid development of the more modern "Edeleanuised", and other solvent-purified "non-sludging" circulation oils. These have the very important advantage of being more chemically stable, inasmuch as they resist oxidation to a very marked degree. In consequence a charge of such oil will run in a steam turbine or steam engine crank-chamber for lengthy periods without appreciable loss of demulsibility or formation of sludge-like deposits.

Possible Future Developments.

Prophecy concerning technical matters is almost invariably rash, and not least so in the field of lubrication. A brief summary of certain suggestions made in earlier portions of this article may, however, be of some interest.

(1) Lathering properties may in future be imparted to marine engine oils by the addition of small percentages of highly efficient modern emulsifying agents (probably as soda soaps) instead of by the incorporation of relatively high percentages of blown fatty oils, as the latter are comparatively inefficient for the purpose.

(2) Steam engine cylinders and valves running in saturated steam may be lubricated by means of modified mechanical lubricators feeding a very dilute suspension of colloidal graphite in water instead of the present inefficient method of swabbing the rods with cylinder oil.

(3) Superheated steam cylinders may be lubricated with cylinder oils containing a small percentage of colloidal graphite instead of with plain cylinder oil. The present tendency in the marine engineering world to install exhaust steam turbines and thereby increase the thermal efficiency of the power unit to something more nearly approaching that of the Diesel engine has necessitated the use of superheated instead of saturated steam to avoid the choking of the turbine with condensate. This in turn has necessitated the proper internal lubrication of the steam engine with modern mechanical lubricators providing small but very uniform feeds of cylinder oil to atomisers in the steam pipes and/or direct to the cylinders and valve chests. For this purpose much better qualities of cylinder oil are required than suffice for the older method of "swabbing the rods", and in view of the importance of reducing oil consumption to a minimum, combined with the difficulty of providing satisfactory lubrication with plain oil where really high steam temperatures are employed, it is not unlikely that the addition of colloidal graphite to the cylinder oil may become quite common practice.

(4) The old fashioned low gravity paraffin base steam turbine and crank chamber oils will be entirely displaced by "non-sludging" turbine oils refined by "selective solvent extraction" processes from a much wider variety of types of crude petroleum. These may, however, later on include the paraffin-base Pennsylvanian type if there should be a demand for oils showing minimum change in viscosity with temperature and minimum development of acidity in use as well as great resistance to oxidation.

In conclusion the writer would like to record his great indebtedness to his fellow lubrication technologists in the oil industry, many of whom are in daily contact with marine lubrication problems. Such knowledge concerning lubrication and lubricants as he may possess is very largely due to their friendly and enthusiastic co-operation with himself in solving lubrication problems and their readiness at all times freely to impart information and to discuss various aspects of this fascinating branch of applied science. Without such hearty collaboration, this article could not have been written.

"Some Diesel Engine Lubrication Difficulties and their Remedies"

An Explanatory Note.

With reference to the above paper by Mr. Alan Wolf, which appeared on pages 169 to 175 of the June, 1934, TRANSACTIONS, it has been pointed out to the author that his comments might be inferred to mean that the use of colloidal graphite lubricants in *all* Diesel engines might cause sludge formation due to emulsification with water. The author wishes to make it quite clear that his remarks in this connection were only intended to apply to Diesel engines in which abnormal leakage of water into the crank-chamber occurred.

An Oil Fuel Burner of Variable Output, with Notes on the Theory and Principles Involved, and some Results.

By S. O. GRANT, (Student).

THE employment of oil fuel burners for marine purposes being confined chiefly to the pressure jet or mechanical atomizing type, developments in this class of burner will be followed with interest by marine engineers.

The pressure jet burner, whilst having considerable advantages over other types, has the inherent disadvantage of requiring the size of burner to be changed when any appreciable change of output is required. In order to reduce to a minimum the inconvenience of changing burners, the manufacturers have so designed their equipment that the working burner may be shut down, a spare burner inserted and the furnace relighted in a very short time. There are cases, however, when changing burners is very inconvenient, such as when manœuvring a merchant vessel in or out of port or on naval vessels, tugs, and whalers where changes in power may be frequent, calling for instant response from the stokehold. There are also many industrial cases which could be cited. Furthermore, a wide flexibility is required with all burners arranged for automatic control, either of the progressively operated type or those arranged for a high-low regulation.

Manufacturers and inventors have spent a good deal of time in trying to evolve a pressure jet burner with a variable output. Among those who have wrestled with this problem is M. Pillard, of Marseilles, who has been actively connected with the design and manufacture of oil burners in France since 1919. M. Pillard has evolved a theoretical study of mechanical atomization which, in itself, is a subject on which there is little information. From conclusions drawn from his mathematical reasoning he has evolved a pressure jet burner of variable output which he calls a "D.X." burner. He has thus the two-fold satisfaction of putting forward a theory of the phenomena of mechanical atomization and of producing a practical burner in a very simple form, solely by mathematical reasoning The burner has been applied with considerable success to marine boilers (without any modification to the existing plant), to industrial boilers, and to glass and other industrial furnaces. It has proved an ideal burner for locomotives and has been installed on several engines in France, where these burners are being handled by Messrs. Pillard Frères et Cie, of Marseilles, who are the French licensees of Messrs. Todd Oil Burners, Ltd., of London. To the latter firm, who are introducing the "D.X." burner into this and certain other European countries, the writer is indebted for enabling him to submit the following translation of M. Pillard's Theoretical Study, his description of the burner and the results of trials.

Theory of Mechanical Atomisation.

Our object is to equate the movements of the liquid in order that we may study each of the variables—output, pressure, diameter of the burner nozzle, cross section of the tangential channels, etc. —and thus determine their respective influences.

In order to evolve these equations from first principles, we shall consider that the liquid is submitted to two motions, firstly in the vortex in passing from the tangential channels to the centre of the chamber, and secondly, a transversal motion in passing from the centre of the chamber across the "tip" or expansion orifice.

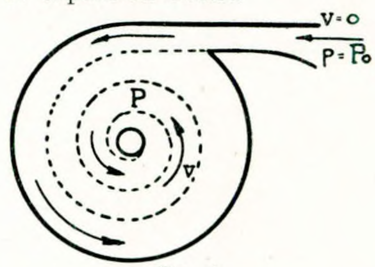


FIG. 1.

1st. In the vortex chamber we will assume that the flow of the liquid is continuous and that its path is a spiral to the centre of the chamber. The flow therefrom being continuous and free from eddies is governed by Bernouilli's theorem: Piezometric height+static pressure+dynamic pressure=Constant.

Neglecting the piezometric height we have:

$$p+\frac{v^2}{2g}=\text{Constant} \qquad \text{(a)}$$

Thus at any point in the vortex chamber where the static pressure is p and the velocity v

$$p+\frac{v^2\,\delta}{2g}=P_0+0=P_0 \qquad \text{(b)}$$

because we can ignore the velocity of the fluid which is very small previous to its entry into the tangential passages.

From this equation can be deduced that:

(1) The speed increases towards the centre of the chamber (since the pressure diminishes).

(a) p=static pressure at any point.
v=linear velocity at the point considered.
(b) P_0=supply pressure at the inlet to the tangential channels.
δ=density of the liquid.

(2) The maximum value for the velocity at the centre is $v=\sqrt{2g\frac{P_0}{\delta}}$ that is to say the velocity due to the total supply pressure.

On the other hand, the successive layers of fluid in rotation one upon the other, cause a pressure from the centrifugal force. In order to calculate the pressure derived from the centrifugal force, imagine a section of fluid in rotation. The centrifugal force on an element of Section s and thickness dr is equal to:

$$f_c=\frac{s\,dr\times\delta}{g}\times\frac{v^2}{r} \qquad \text{(c)}$$

The pressure resulting from the centrifugal force is

$$dp=\frac{s\,dr\times\delta}{sg}\times\frac{v^2}{r}=\frac{\delta}{g}v^2\frac{dr}{r}$$

and the pressure at any point is:

$$p=\int_{ro}^{r}\frac{\delta}{g}v^2\frac{dr}{r}=\frac{\delta}{g}\int_{ro}^{r}v^2\frac{dr}{r} \qquad \text{(d)}$$

With the transversal flow we can assume that

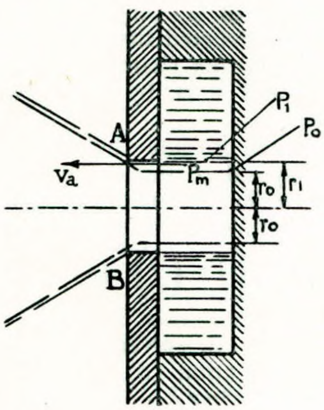


FIG. 2.

a static pressure p_m causes a stream in the form of a film of annular section of which the surface will be

$$\pi(r_1{}^2-r_0{}^2) \qquad \text{(e)}$$

In order to simplify the calculations we can assume that the mean pressure p_m is equal to the mean of the pressure at the radii r_0 and r_1.

$$p_m=\frac{p_1+p_0}{2}=\frac{p_1}{2} \qquad \text{(f)}$$

since the pressure in r_0 is nothing.

On the other hand, as with all streams of fluid in the form of a fine film, the thickness of the film is diminished in the neighbourhood of the orifice *A.B.*

We have assumed that this contraction will be about 25 per cent.

Therefore we may say that the output is equal to:

$$Q=0{\cdot}75\,v_a\times\pi\,(r_1{}^2-r_0{}^2) \qquad \text{(g)}$$

Principal Equations.

Considering once more the general equation giving the pressure at any point of the vortex chamber:

$$dp=\frac{\delta}{g}v^2\frac{dr}{r} \qquad (1)$$

also Bernouilli's general equation:

$$p+\frac{v^2\delta}{2g}=P_0 \qquad (2)$$

we obtain:

$$\frac{dp}{P_0-p}=2\frac{dr}{r}$$

Integrating we obtain

$$P_0-p=\frac{P_0r_0{}^2}{r}$$

or

$$p=P_0\left[1-\left(\frac{r_0}{r}\right)^2\right] \qquad (3)$$

From equations 2 and 3 we obtain also that:

$$\frac{v^2\delta}{2g}=P_0\left(\frac{r_0}{r}\right)^2$$

$$v=\frac{r_0}{r}\sqrt{\frac{2g\,P_0}{\delta}} \qquad (4)$$

The tangential velocity at radius r_1 is then

$$v_1=\frac{r_0}{r_1}\sqrt{\frac{2g\,P_0}{\delta}}\text{ or at } r_0: v_0=\sqrt{\frac{2g\,P_0}{\delta}}$$

The mean tangential velocity at the outlet is then:

$$v_m=\frac{v_1+v_0}{2}=\frac{\sqrt{\frac{2g\,P_0}{\delta}}\left[\frac{r_0}{r_1}+1\right]}{2}=\sqrt{\frac{2g\,P_0}{\delta}}\times\frac{r_0+r_1}{2r_1} \qquad (5)$$

Further, at the admission, that is to say at the outlets of the tangential channels

$$v_R=\frac{r_0}{R}\sqrt{\frac{2g\,P_0}{\delta}}$$

and if S is the section of these channels which are supposed to be designed so as to give a maximum speed of entry into the chamber, the output is equal to:

$$Q=v_R S=\frac{r_0}{R}\sqrt{\frac{2g\,P_0}{\delta}}\times S$$

$$Q=r_0\sqrt{\frac{2g\,P_0}{\delta}}\times\frac{S}{R} \qquad (6)$$

In reconsidering the transversal flow, the output, which is obviously equal to that calculated above, is equal to $Q={\cdot}75v_a\times\pi(r_1{}^2-r_0{}^2)$ as we have already seen, and with

$$v_a=\sqrt{\frac{2g\,p_m}{\delta}}=\sqrt{2g\frac{p_1}{2\delta}}$$

(c) r = radius of the stream.
(d) r_0 = interior radius of the ring of liquid.
(e) r_1 = radius of the burner tip.
(f) p_1 = static pressure at the radius r_1.
p_0 = static pressure at the radius r_0.

(g) v_a = velocity in the direction of the axis.
Q = output in volume.
The metric system having been used throughout, the value of g is therefore 9·81 metres per second.

it becomes :

$$Q=1\cdot66(r_1^2-r_0^2)\sqrt{\frac{2g\,p_1}{\delta}}$$

and from equation (3)

$$p_1=P_0\left[1-\left(\frac{r_0}{r_1}\right)^2\right]$$

$$Q=1\cdot66(r_1^2-r_0^2)\sqrt{\frac{2g\,P_0(r_1^2-r_0^2)}{\delta\times r_1^2}}$$

or :

$$Q=\frac{1\cdot66}{r_1}\sqrt{\frac{2g\,P_0}{\delta}}(r_1^2-r_0^2)^{3/2} \qquad (7)$$

If we equate the two output expressions 6 and 7, we obtain a general equation in the following form :

$$\frac{Q}{\sqrt{P_0/\delta}}=4\cdot43r_0\frac{S}{R}=\frac{7\cdot36}{r_1}\times(r_1^2-r_0^2)^{3/2} \quad (8)$$

where acceleration in metres/sec./sec.=9·82.

These equations may easily be tabulated in graphic form expressing $\frac{Q}{\sqrt{P_0/\delta}}$ as a function of r_0 by a polar function of $\frac{S}{R}$ and also $\frac{Q}{\sqrt{P_0/\delta}}$ as a function of r_0 by a polar function of r_1.

The readings from the curves of these two variables give for each value of r_1 and $\frac{S}{R}$ the unit of output $\frac{Q}{\sqrt{P_0/\delta}}$, also the radius (interior) r_0 gives by r_1-r_0, the thickness of the film, that is to say an idea of the quality of the atomization.

It is interesting to note that given a burner of known characteristics the output Q is proportional to the square root of the pressure :

$$Q=k\sqrt{P_0}$$

from which can be seen exactly the variations in output that it is possible to achieve with a mechanical atomising burner of the ordinary type.

If we suppose that the minimum pressure necessary in order to obtain good atomisation is, for example, 6 kilos/cm², the variation in output will be in a ratio of :

1·29 by increasing the pressure from 6-10 kilos/cm².
1·41 „ „ „ „ „ 6-12 „
1·58 „ „ „ „ „ 6-15 „
1·73 „ „ „ „ „ 6-18 „

It is evident that these variations are insufficient in the majority of cases, and for that reason other means of augmenting them must be found.

The Characteristics of the Burner.

In order to follow clearly the influence of the variables : r_1 and $\frac{S}{R}$ their curves are plotted from the general equation. By examining this graph (Fig. 3) it is easy to note, for example, that if the unit of output $\frac{Q}{\sqrt{P_0/\delta}}$ remains constant at ·078 with $\frac{S}{R}$=·0002 and r_1=·001 (a burner tip of 20/10ths), by keeping the same burner tip we can increase the value of the unit of output from ·078 to ·455 by simply increasing $\frac{S}{R}$ from ·0002 to ·002.

Thus by merely altering the ratio $\frac{S}{R}$ we can increase the output in a ratio of 1 to 6 without changing the burner tip, even without altering the pressure; that is to say, without any other means of variation.

It is evident that if we vary $\frac{S}{R}$ and P_0 simultaneously, we will obtain an even greater variation. This is what has been obtained with the "D.X." burner.

The "D.X." Burner.

The burner is so designed that any variation in the oil supply pressure alters the ratio $\frac{S}{R}$ or more exactly the value of S because R remains constant. This is achieved in a very simple way. The atomizer is so constructed that the pressure on the back face of the vortex chamber alters the section S of the tangential slots, by increasing the depth of the chamber.

In order to appreciate the motive power we have at our disposal to move the piston, we will refer to the formula (3) for the pressure in a point of the vortex chamber situated on any radius

$$p=P_0\left[1-\left(\frac{r_0}{r}\right)^2\right]$$

and note that the total force on a ring of thickness dr is equal to $df=p\times2\pi rdr$.

Thus after equation (3)

$$df=P_0\times2\pi rdr\left(\frac{r^2-r_0^2}{r^2}\right)=2\pi P_0\left(\frac{r^2-r_0^2}{r}\right)dr.$$

from which we get the total force on the piston to be

$$f=\int_{r_0}^{R}2\pi P_0\left(\frac{r^2-r_0^2}{r}\right)dr$$

$$\therefore f=2\pi P_0\left[\frac{R^2}{2}-r_0^2\left(\frac{1}{2}+\log_e\left(\frac{R}{r_0}\right)\right)\right] \quad (9)$$

The second part of this formula is a very small quantity in comparison with the first part, and we can therefore say that f is in the neighbourhood of

$$2\pi P_0\times\frac{R^2}{2}=\pi R^2\times P_0$$

which is the same thing as saying that f will vary directly with Po and that the values of f are appreciable and can be balanced by ordinary means.

Take for example in the standard "D.X" burner where r_1=0·001, R=0·006 and $\frac{S}{R}$ varies from ·0002 to ·002; we have

f=6 K 06 where P=6kgs./cm².
f=12 K 96 where P=12kgs./cm².

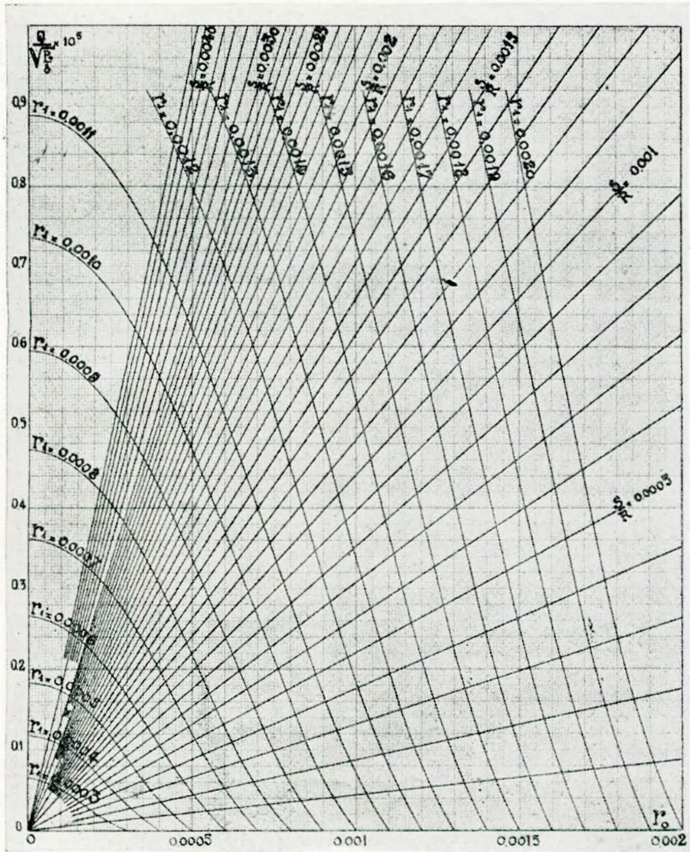


FIG. 3.

It remains, therefore, in order to design a "D.X." burner capable of having

$$\frac{S}{R} = \cdot 0002 \text{ with } P_0 = 6\text{kgs.}$$

$$\frac{S}{R} = \cdot 002 \text{ with } P_0 = 12\text{kgs.}$$

to obtain a spring with the necessary resilience to uncover a section S ten times as great when the force increases from 6 K 06 to 12 K 96. We have then evolved a burner of which the theoretical variation in output will be

$$\lambda = \frac{\cdot 078\sqrt{6}}{.455\sqrt{12}} = \frac{1}{8\cdot 2}$$

In practice it is useless to seek variations in output as great as this because of the combustion difficulties which it would be necessary to overcome. We can only affirm that variations of from 1/5 to 1/6 have been actually achieved.

The Advantages of the D.X. Burner.

With this burner the required variations in output are obtained without any modification to an existing installation of the ordinary mechanical atomizing type. As these burners can always be dismantled, all that is then required is to replace the burners having the ordinary type of atomizer and tip with the "D.X." type, a transformation which can be carried out in a few minutes.

Any variation in output is carried out simply by varying the oil supply pressure, a manœuvre which has previously permitted only

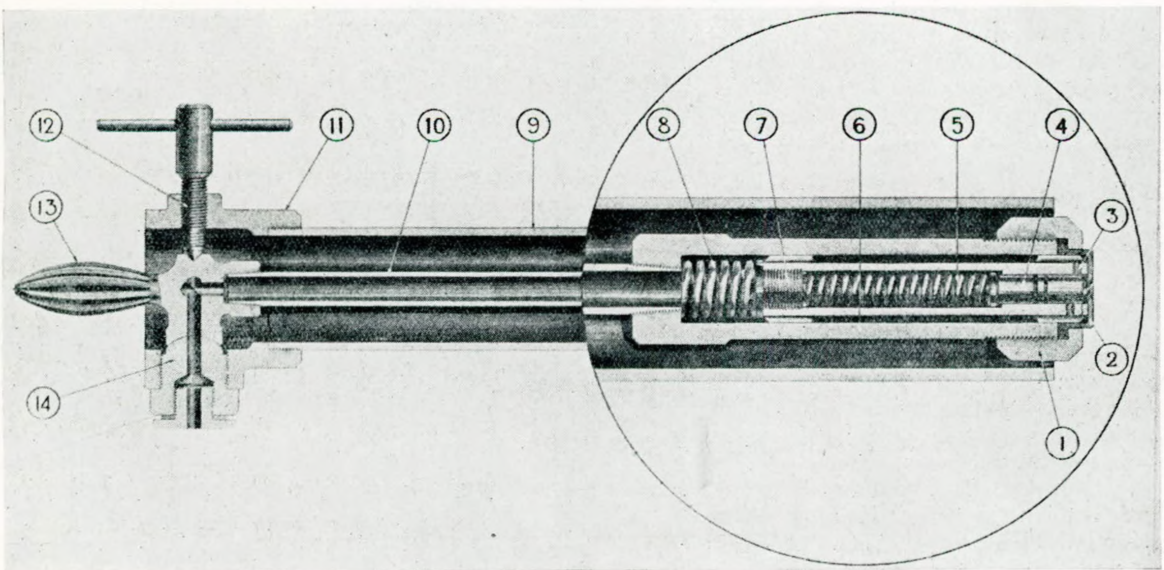


FIG. 4.—Section of the Burner.

(1) Nut.
(2) Tip.
(3) Atomiser.
(4) Atomiser Piston.
(5) Atomiser Spring.
(6) Body.
(7) Atomiser Bushing
(8) Atomiser Retaining Spring.
(9) Jacket-tube.
(10) Burner Tube.
(11) Jacket Tube Housing.
(12) Housing Screw.
(13) Handle.
(14) Union Bushing.

slight variations with the ordinary type of burner. Therefore, by a single operation, the output of all the burners in an entire battery of boilers can be instantly varied.

Further, it should be noted that the output of the pumps is never in excess of the output of the burners; thus their power consumption is strictly limited and wear kept at a minimum.

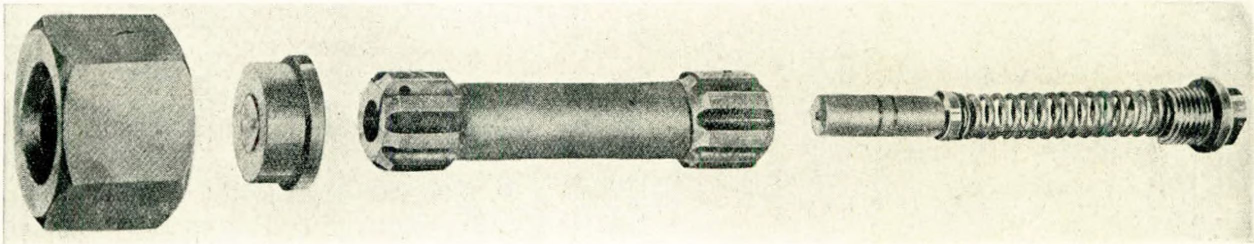


Fig. 5.—Atomiser, Tip and Nut.

Results of Trials.

The preceding figures will no doubt be under suspicion as being more or less exaggerated if not backed with actual results obtained under working conditions. The following records fill this gap by explaining a result obtained on two industrial boilers, one equipped with ordinary burners and the other with the "D.X." type.

The two boilers were coupled in parallel and the total steam consumption was more or less constant at about 38 tons of steam per hour. The aim of the trial being to test the variation in output that could be obtained with the D.X. burners, a variation in the oil consumption of one boiler was made by extinguishing certain burners, while at the same time the oil pressure was raised to the other boiler equipped with the D.X. burners, keeping the number of burners in use constant.

It was thus possible, within the limits of the installation, to observe the variation of output obtained from that boiler by simply varying the oil pressure.

The boilers were equipped with steam meters of the automatic type, from the records of which can be examined the variations in load as shown in the adjoining reproduction (Fig. 6).

It will be observed from these records that at 10h. 20m. the output of boiler (1) (equipped with the D.X. burners) was less than 10 tons, and at 11h. 15m. the output was 31 tons. These two outputs were obtained without extinguishing or re-lighting any of the burners. In a comparison it will be noted that in order to obtain the same difference of output from boiler (3), 28 tons at 10h. 20m. and 7 tons at 11h. 15m., it was necessary to extinguish six burners out of seven.

These results speak for themselves and it only remains to be added that the maximum oil pressure to the D.X. burners never exceeded 11 kilos/cm², because at that power the boiler had already exceeded by one ton its maximum load of 30 tons. It would only have been necessary to raise the pressure to 12 or 13 kilos in order to have generated 50 to 60 tons of steam, had the boiler been large enough. The practical ratio of outputs would have been more than 6 to 1, confirming the theoretical conclusions on all points.

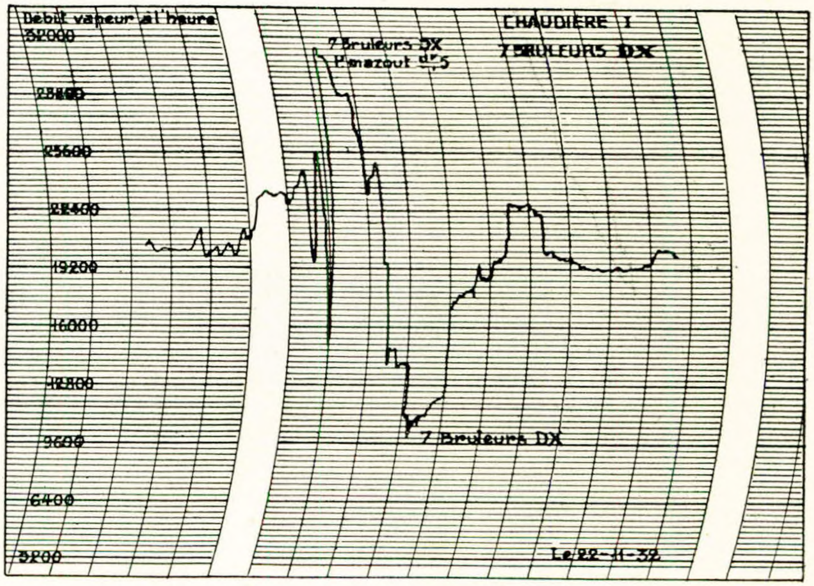


Fig. 6.—No. 1 Boiler—DX Burners—Steam Output.

Inauguration of The Institute of Marine Engineers Guild of Benevolence.

Minutes of Proceedings of the Extraordinary General Meeting held on Thursday, August 2nd, 1934, at 6 p.m. at The Institute Premises.

An Extraordinary General Meeting of The Institute was held on Thursday, August 2nd, 1934, in accordance with the following notice:—

9th July, 1934.

NOTICE IS HEREBY GIVEN that an Extraordinary General Meeting of The Institute will be held at The Institute Premises on Thursday, the second day of August, 1934, at 6 o'clock p.m., for the purpose of considering and, if deemed desirable, passing (with or without modification) the following Special Resolutions:—

(1) That The Institute of Marine Engineers Guild of Benevolence be and is hereby formed and established.
(2) That the Rules of the above-named Guild of Benevolence shall be as set forth in the copy attached hereto.
(3) That The Institute of Marine Engineers Benevolent Fund be wound up voluntarily, and that the assets thereof be transferred to the above-named Guild of Benevolence.

B. C. Curling,
Secretary.

The President, John H. Silley, Esq., O.B.E., occupied the chair, and was supported by Messrs. J. Hamilton Gibson, O.B.E., M.Eng. (Chairman of Council), A. Robertson, C.C. (Honorary Treasurer) and the Secretary.

Messages expressing regret for their unavoidable absence were received from Messrs. G. Adams, J. Carnaghan, R. T. Clarke, T. A. Crompton, J. M. Dewar, J. B. Harvey, S. N. Kent, A. E. Laslett and Robert Leslie.

The Chairman, having called upon the Secretary to read the notice convening the meeting, said that that Extraordinary General Meeting to which the Members had been called that evening was for the specific purpose of submitting for their approval the formation of a Guild of Benevolence in connection with the Institute.

He first wished to congratulate the sponsors of this very necessary scheme. On assuming the office of President nothing had given him greater pleasure than to learn that the Council were making a move in this direction. He frankly admitted that they were launching this scheme at possibly the most difficult time in British shipping, but it was gratifying to him to know that notwithstanding the difficult time through which shipowners were passing, they were showing great practical sympathy with the Council's efforts to assist brother engineers in distress. The Secretary had from time to time informed him of the many serious cases coming before him of men who, in the past, had shown great resource and ability and through no fault of their own were in very dire straits.

They were only just issuing their appeal, but a few days ago he had approached a few of the leading shipping and allied interests and he was most gratified by the response that they had made. He was pleased to say that the list had been started by a contribution through the Chairman of the P. & O. Company, the Hon. Alexander Shaw, who, on behalf of the P. & O. Group, had promised them £2,500. He had also received promises of £1,000 from Lord Inverforth (Past President), the head of Andrew Weir & Company, and £1,000 from Lord Essendon on behalf of the Furness Withy Group. The previous evening he had had the pleasure of calling upon one who, and indeed whose family also, had always shown a great interest in The Institute. He referred to Lord Weir. They all remembered him as one of their esteemed Past-Presidents. He was more than delighted to tell them that Lord Weir had promised them a handsome donation totalling £6,000, being £2,000 from the late James Weir's Trustees, £1,000 from the firm of G. & J. Weir, Ltd., £1,000 from Lord Weir himself, £1,000 from Mr. J. R. Richmond, and £1,000 from Mr. J. G. Weir. This was a most magnificent send-off for them. He heartily thanked these gentlemen for their great generosity. (Loud and prolonged applause).

They were appealing to all their Past-Presidents and the shipping and allied interests generally, and he felt sure that the great example set by those he had just mentioned would act as an incentive to others to follow. He had emphasized in the appeal he was issuing that the Members of The Institute intended to do their part. He earnestly appealed to every Member of The Institute who was in a position to do so, to become an annual subscriber. That would be the greatest encouragement they could give their Council, not only in administering this Guild, but in approaching others to help them.

At no time in their history was the plight of the Mercantile Marine more serious than it was to-day. Notwithstanding this fact, the shipowners had already shown their practical sympathy by the handsome donations he had already mentioned.

Coming now to the agenda before the meeting, he did not propose to prolong the business by recounting there and then the developments by which the Guild had come into being. With their approval he would ask the Secretary to prepare a *resume of those developments for publication with the report of the meeting. He would like, however, to place on record their indebtedness to Messrs. A. E. Crighton (Vice-President) and J. B. Wilkie (a recent Member of Council) for having given this idea of a Benevolent Guild the final urge towards realisation. Such a scheme had been

* *See page* 217.

first suggested by their Honorary Treasurer, Mr. A. Robertson, some time ago, and had been discussed on various informal occasions during recent years, but the final stage in which the scheme had been practically formulated dated from the 1933 Golf Competition, when in their speeches after the prize distribution, Messrs. Crighton and Wilkie put forward a concrete suggestion for the consideration of the Social Events Committee and the Council, resulting eventually in this Guild of Benevolence which they had met to inaugurate. (Applause).

He voiced their keen regret at the absence through illness of Mr. George Adams, who had officiated for several years past as Chairman of the Benevolent Fund Committee, and latterly as Chairman of the Special Joint Committee which had worked long and arduously in the formation of this Guild. He would ask the Secretary to convey to Mr. George Adams from the meeting their best wishes for his early and complete recovery. (Applause).

Submitting the Special Resolutions to the meeting, the President emphasized that the scheme they were launching was "national" in its scope and that it would presumably be the policy of the Council to administer it on a national basis (subject to the provisos in the Rules giving precedence to Members of the Guild) by co-operating with any other organisations which might be working on similar lines for the benefit of marine engineers.

The following Special Resolutions were then put consecutively to the meeting by the Chairman, and each in turn was declared unanimously carried on a show of hands:—

(1) That The Institute of Marine Engineers Guild of Benevolence be and is hereby formed and established. (Proposed by the Chairman, seconded by the Chairman of Council).

(2) That the Rules of the above-named Guild of Benevolence shall be as set forth in the copy attached hereto. (Proposed by the Chairman, seconded by Mr. R. Rainie).

(3) That The Institute of Marine Engineers Benevolent Fund be wound up voluntarily, and that the assets thereof be transferred to the above-named Guild of Benevolence. (Proposed by the Chairman of Council, seconded by the Honorary Treasurer).

In connection with (3) the Honorary Treasurer read the following statement of the assets of the existing Benevolent Fund:—

Benevolent Fund:—Assets at August 2nd, 1934.

CAPITAL ACCOUNT.

INVESTMENTS.

		£ s. d.
£1,937 London, Midland & Scottish Railway 4 per cent. Preference Stock as valued at 31st January, 1925 ... ... (Market value 2nd August, 1934, £1,515 14s.).		1,564 2 6
£500 New South Wales 4 per cent. 1942/62, as valued 31st January, 1925 ... (Market value 2nd August, 1934, £505 12s. 6d.).		426 17 6
£150 3½ per cent. War Loan as valued 31st January, 1925, *less* Bonus ...	£150 14 1	
£100 3½ per cent. War Loan at cost	102 9 9	
		253 3 10
(Market value 2nd August, 1934, £259 16s. 3d.).		
£103 4½ per cent. Conversion Stock, 1940/44, as valued 31st January, 1925	£100 0 1	
£300 4½ per cent. Conversion Stock, 1940/44, at cost	301 13 9	
		401 13 10
(Market value 2nd August, 1934, £446 19s. 2d.).		
		£2,645 17 8

LIFE SUBSCRIPTIONS NOT YET INVESTED.

	£ s. d.
H. A. J. Silley	25 0 0
C. W. Conoley	25 0 0
	£50 0 0

REVENUE ACCOUNT

	£ s. d.
Balance at Bank	192 1 7
Cash in hand	1 13 0
	£193 14 7
Less the two above mentioned Life Membership subscriptions to be invested for Capital Account	50 0 0
	£143 14 7

A proposal was next moved by the Honorary Treasurer, seconded by Mr. J. Hawthorn, and carried unanimously, that the undermentioned subscribers to the former Benevolent Fund who had paid their subscriptions as from January 1st, 1934, be enrolled as Subscribing Members of the Guild for the remainder of the present year:—

MEMBERS OF COUNCIL AND VICE-PRESIDENTS (PAST AND PRESENT): Messrs. G. Adams, T. A. Bennett, Jas. Brown, Jas. Carnaghan, A. E. Crighton, A. Cross, J. M. Dewar, S. F. Dorey, J. R. Douglas, J. Hamilton Gibson, W. A. Graham, J. Harbottle, J. B. Harvey, W. D. Heck, J. Houston, H. S. Humphreys, Summers Hunter, Junr., R. S. Kennedy, S. N. Kent, A. E. Laslett, R. Leslie, J. H. Mackirdy, W. McAusland, J. J. McKenzie, A. H. Mather, R. Rainie, A. Robertson, W. L. Roxburgh, E. F. Spanner, A. F. C. Timpson, H. J. Vose, J. B. Wilkie, W. J. Willett-Bruce, and R. T. Wilson.

MEMBERS: Messrs. W. H. Bailey, W. Balsillie, W. J. Blomfield, W. W. Buckton, J. Burghardt, J. L. Coates, T. A. Crompton, B. C. Curling, A. Girdwood, D. Jenkins, Jas. Main, E. E. Mees, E. A. Roberts, J. Stewart, W. A. Tait, A. Taylor and F. W. Youldon.

Messrs. H. A. J. Silley and C. W. Conoley were enrolled as Life Members of the Guild, their applications and life membership subscriptions having been received prior to the meeting.

The Chairman next invited applications for enrolment from Members present, and as a result the following were enrolled :—

LIFE MEMBERS : Messrs. A. E. Crighton, R. M. Gillies, R. S. Kennedy, Capt. B. Warwick and A. E. Whiteside.

SUBSCRIBING MEMBERS : Messrs. F. O. Beckett, W. J. Ellwood, F. A. Hunter, E. B. Irwin, A. Jobling, E. H. Jones, H. G. Jones, W. McLaren, K. A. Saunders, H. M. St. Yves, G. R. Unthank, and Eng. Rear-Admiral W. M. Whayman.

The Chairman intimated that this concluded the business of the Extraordinary General Meeting, and that he would ask those already enrolled as Members to stay and thus constitute the first Annual General Meeting of the Guild of Benevolence. The names of the Members present at this first meeting were as follows :—Messrs. F. O. Beckett, A. E. Crighton, B. C. Curling, W. J. Ellwood, J. Hamilton Gibson, F. A. Hunter, E. B. Irwin, A. Jobling, E. H. Jones, H. G. Jones, R. S. Kennedy, W. McLaren, R. Rainie, A. Robertson, K. A. Saunders, J. H. Silley, H. M. St. Yves, A. F. C. Timpson, G. R. Unthank, H. J. Vose, Capt. B. Warwick, Eng. Rear-Admiral W. M. Whayman, Messrs. A. E. Whiteside and R. T. Wilson.

The Chairman then invited nominations for Chairmanship and Membership of the first General Committee of the Guild. Mr. George Adams was unanimously elected as Chairman, on the proposal of Mr. J. Hamilton Gibson, seconded by Mr. A. E. Crighton. The following were unanimously elected Members of the Committee, on the proposal of the Chairman, seconded by the Honorary Treasurer :—

Members of Council : R. Rainie (third year of office), J. Hamilton Gibson (second year), and R. M. Gillies (first year).

Vice-Presidents : J. Carnaghan, A. E. Crighton, and R. S. Kennedy.

Members : T. A. Crompton, Capt. B. Warwick, and F. W. Youldon.

It was also unanimously resolved, on the proposal of the Chairman, seconded by the Honorary Treasurer, that Messrs. West and Drake be appointed official Auditors, that Messrs. J. B. Harvey and H. J. Vose be appointed Honorary Auditors, and that Mr. W. E. Archer be appointed Honorary Solicitor to the Guild.

On the suggestion of the Honorary Treasurer it was agreed that the accounting period should be the calendar year, i.e., the same as The Institute's accounting period.

It was also decided that the first meeting of the General Committee be held on Friday, August 10th, 1934, at 5.30 p.m.

In conclusion, a vote of thanks to the Chairman was proposed in felicitous terms by Mr. J. Hamilton Gibson (Chairman of Council), seconded by Mr. G. J. Wells (Vice-President) and carried unanimously with loud and prolonged applause. The Chairman made an appreciative reply and the meeting terminated.

How The Guild of Benevolence Originated.

The following résumé will give Members, and particularly those who have joined The Institute recently, an outline of the circumstances and events which have led to the formation of the new Guild.

From the foundation of The Institute in 1889 till well into the present century, although the idea of benevolent activities was always present in the minds of the early Members of Council, the task of building up and strengthening the main financial structure of The Institute necessarily pre-occupied those responsible for the administration of The Institute's affairs in those days, at times becoming the paramount issue and demanding concentrated attention on the part of the Council and Treasurer in order to maintain a secure financial position.

Then, in 1912, came the "Titanic" disaster. The epic heroism of the engineers who, to a man, remained at their posts till the end inspired the whole world. A public fund composed of shilling subscriptions was started by the "Daily Chronicle" for the relief of widows and children of those heroic men, and evoked an immediate response from sympathisers all over the country. The promoters decided to entrust the distribution of the sum raised, amounting to approximately £2,600, to The Institute. The bulk of the money was invested in the name of The "Titanic" Engineering Staff Memorial Benevolent Fund, and from the income derived therefrom relief was administered to dependants of the dead heroes, mainly in providing for the maintenance and education of some of the youngest children.

As in the course of time these children grew up and became self-supporting, and in the absence of further claims from the widows, the scope of the Fund was widened early in 1931 to include any necessitous widows and children of deceased marine engineers, and the Fund was re-named "The Institue of Marine Engineers Benevolent Fund".

The intervention of the War had prevented any substantial enlargement of the capital by donations or of the revenue from subscriptions, and the only increments to the Fund since its formation have been legacies left by the late W. Murdoch and D. F. Robertson, and several grants of £100 made by the Council from the proceeds of The Institute's Social Events. The following table, which is reprinted from the latest Annual Report of The Institute, shows at a glance the modest extent of the activities to which the Benevolent Fund Committee have been confined.

The unprecedented depression of recent years, which has been particularly severe in its effects on

BENEVOLENT FUND.	31st Jan., 1925.	31st Jan., 1926.	31st Dec., 1926 (11 months)	31st Dec., 1927.	31st Dec., 1928.	31st Dec., 1929.	31st Dec., 1930.	31st Dec., 1931.	31st Dec. 1932.	31st Dec., 1933.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Revenue Interest	83 17 9	91 6 8	81 2 8	92 15 9	92 15 8	92 15 10	93 8 0	94 8 8	83 0 0	85 9 4
Donations ...	20 6 5	31 3 0	11 15 4	35 10 9	56 10 8	18 2 6	12 13 2	28 16 6	46 6 0	71 8 9
Income Tax recovered	24 3 8	—	30 10 6	21 6 6	31 1 6	21 6 4	20 14 4	21 18 8	20 14 11	19 10 7
Total Receipts ...	128 7 10	172 9 8	123 8 6	149 13 0	180 7 10	132 4 8	126 15 6	145 3 10	150 0 11	123 9 8
" " (without donations)	108 1 5	141 6 8	111 13 2	114 2 3	123 17 2	114 2 2	114 2 4	116 7 4	103 14 11	104 19 11
Expenditure ...	144 1 0	171 13 4	124 2 0	152 14 4	188 16 0	132 4 8	126 15 6	125 1 0	165 6 4	120 7 0
Investments ...	2,243 4 2	2,340 17 2	2,340 17 2	2,340 17 2	2,340 17 2	2,340 17 2	2,340 17 2	2,544 17 11	2,543 7 11	2,645 17 8
Cash and Deposit A/c. ...	6 16 11	7 13 3	6 19 9	3 18 5	4 9 9 (debit)	8 11	1 11 1	21 13 11	7 18 6	9 11 2

the shipping and shipbuilding industries, has emphasized the need of a substantial fund from which relief might be granted not only to dependants of deceased marine engineers, but to living marine engineers who may be stricken by adversity in the form of prolonged unemployment or illness, of whom there have been and still are many among the membership of The Institute.

As has been previously mentioned, the case for the formation of such an organisation as the new Guild has been urged on frequent occasions by our Honorary Treasurer, Mr. A. Robertson, but it was not until June of last year that his suggestion in substance was pressed home by Messrs. A. E. Crighton and J. B. Wilkie in their speeches after the prize distribution at the Annual Golf Competition. They urged that a Benevolent Scheme be formed on a contributory basis on similar lines to the scheme administered by the Liverpool Marine Engineers' and Naval Architects' Guild. Their proposal was given careful consideration at a special meeting of the Social Events Committee on June 29th, 1933, presided over by Mr. A. Robertson (Convener), and attended by Messrs. A. E. Crighton, T. A. Crompton, J. B. Harvey, J. J. McKenzie, R. Rainie, A. F. C. Timpson and the Secretary. As a result of their deliberations the Committee unanimously resolved to recommend the proposal to the Council and to urge its early adoption.

On the 3rd July, 1933, the Committee's recommendation was discussed by the Council and referred to the Benevolent Fund Committee for their consideration, with the assistance of co-opted members.

Subsequently the Council at their meeting on September 4th, 1933, had under consideration the following resolution, which had been unanimously passed by the Benevolent Fund Committee at a meeting held on 11th August, 1933: "That this Committee, having carefully considered the recommendations of the Social Events Committee, are in unanimous agreement with the proposals for the extension of the Benevolent Fund, and further recommend that the Council should form a representative Committee to draft rules and regulations of the proposed scheme for the consideration of the Council". The above recommendation was unanimously adopted by the Council, and a Special Joint Committee, consisting of the members of the Social Events, Finance and Benevolent Fund Committees, was appointed to draft rules and regulations of the proposed scheme under the Convenership of Mr. George Adams.

On February 5th, 1934, the Council received and considered the following recommendations which had been put forward by the Special Joint Committee:—

(*a*) that the proposed scheme be carried into effect as soon as possible;

(*b*) that the title of the new association be

"The Institute of Marine Engineers Guild" (carried by a majority vote of 7 to 4. The minority had favoured a proposal that the title be "The Institute of Marine Engineers Benevolent Fund". In view of this difference of opinion the ultimate decision on this point had been left to the Council);

(*c*) that the proposed scheme should be founded on a voluntary contributory basis;

(*d*) that the following members be appointed as a Sub-Committee to draft the constitution and rules of the scheme for the consideration of the Council: Mr. George Adams (Convener), Messrs. J. Carnaghan, J. B. Harvey, A. Jobling, R. S. Kennedy, A. E. Laslett, A. F. C. Timpson, A. E. Whiteside and the Honorary Treasurer.

A suggestion by Mr. J. B. Wilkie, that the proposed scheme should be kept quite separate from The Institute activities and that the Chairman, who should be a Member of The Institute, should act independently of The Institute Council and Committees, had been referred with the foregoing recommendations to the Council for consideration.

The Council unaimously resolved that recommendations (*a*), (*c*) and (*d*), together with Mr. Wilkie's suggestion be approved and adopted; with regard to recommendation (*b*), the question of the title of the new organisation was specially discussed and it was eventually resolved unanimously that the title be "The Institute of Marine Engineers Guild of Benevolence".

Later, on the 7th May, 1934, the Council received and considered draft Rules submitted by the Special Joint Committee. These Rules were remitted for consideration by individual Members of Council with a view to further consideration at the next meeting, to which the President was invited in view of his keen interest in the proposed scheme.

At the next meeting of the Council on the 4th June, 1934, the President was present and promised his fullest support and active co-operation in approaching the shipowning interests on behalf of the Guild. The draft Rules were adopted after sundry amendments, and subject to the approval of The Institute's Honorary Solicitor.

The Council, at their meeting on 2nd July, 1934, finally adopted the Rules which had been further amended as a result of suggestions by the Honorary Solicitor in order to rectify certain omissions or possible ambiguities in the original draft. It was resolved that an Extraordinary General Meeting of The Institute be convened, to be held on Thursday, 2nd August, 1934, at 6 p.m. for the purpose of formally inaugurating the new Guild and of winding up the existing Benevolent Fund and transferring the assets thereof to the Guild. It was also unanimously decided to invite the President to take the Chair on this occasion. The proceedings at this meeting are recorded in the foregoing Report and Minutes (pages 215/217).

The first meeting of the General Committee of the Guild of Benevolence was held on Friday, 10th August, 1934, when the first Executive Committee was appointed as follows: Messrs. George Adams (Chairman), J. Carnaghan, T. A. Crompton, J. Hamilton Gibson, R. Rainie, and Capt. B. Warwick.

INSTITUTE NOTES.

ADDITIONS TO THE LIBRARY.

Purchased.

King's Regulations and Admiralty Instructions (K.R. 4-5/1934). H.M. Stationery Office. 2d. net.

Merchant Shipping: Outline of a scrapping and rebuilding or modernising scheme for British Cargo Vessels discussed between the President of the Board of Trade and Representatives of Shipowners and presented in accordance with the President's statement to the House of Commons on 3rd July, 1934. H.M. Stationery Office. 1d. net.

Merchant Shipping: The Merchant Shipping Load Line Convention (Colonial) No. 2 Order, 1934. H.M. Stationery Office. 1d. net.

Presented by the Publishers.

"Recommended Materials for Automobile Front Axles, Chassis and Fittings". The Mond Nickel Co., Ltd.

"Alloy Steels To-day". The Mond Nickel Co., Ltd.

The following British Standard Specifications:
No. 110-1934. Air-Break Circuit-Breakers for Voltages not exceeding 660 Volts. (Excluding totally-enclosed and flame-proof types). (Revised July, 1934).
No. 560-1934. Engineering Symbols and Abbreviations.
No. 526-1933. Definitions of Gross and Net Calorific Value. (Addendum Slip C.D.(C)3881).

Report of the Advisory Council of The Science Museum for the Year 1933. H.M. Stationery Office. 9d. net.

The Institution of Civil Engineers. Selected Engineering Papers as follows:—
"Impact in Railway Bridges—Retrospect and Present-day Aspect", by Gribble.
"The Enclosure of the Zuyder Zee", by Van Kuffeler.
"The Manufacture of Gears", by Browne.
"Aerial Surveying", by Anderson.
"Tension, Length, and Sag of Stay Ropes", by Watson.
"Survey Work on the Lochaber Water-Power Scheme", by Duncan and Jones.
"Elastic Failure of Thick Cylinders", by Booth.
"Wind Pressures on Buildings", by Bailey.
"Signalling and Block Working on Railways in India", by Smyth.
"Water-Supply Problems in Australia", by East.
"New Methods of Testing by Impact", by Lavery and Southwell.
"Wellington Harbour, N.Z., and its Improvement", by Marchbanks.
"Laying a 30-inch Suction Pipe in the Dead Sea", by Tulloch.
"The Proportioning of Railway Rail-Sections from an Economic Standpoint", by Inglis.
"An Electrical Analogy for Use in the Design of Statically Indeterminate Structures", by Hay.
"On Stresses in Railway-Track, by an Extension of the Theorem of Three Moments, and some Deductions therefrom", by Gough.
"The Construction of Brett's Wharf, Brisbane", by Cullen.
"The Mechanical Gear of Bangkok Memorial Bridge, Siam", by Thompson.
"Elasticity", by Vivian.

Transactions of the Institution of Engineers and Shipbuilders in Scotland, Vol. LXXVII, 1933-34, containing the following papers:—
"Flame Cutting of Steel for Welded Joints", by Clarke.
"Liquid Fuel from Coal for Naval Purposes", by Dunlop.
"The Anglo-Persian Oil Company's Pipe-Lines in Persia", by Hartley.
"Shipyard Methods and Layout", by Barrie.
"Mechanical Methods of Solution of Stresses in Frames", by Lobban.
"Concrete Roads, with Special Reference to Crack Control and Shrinkage Forces", by Walker.
"Decoration of Passenger Vessels", by Tabb.
"Some Influences on a Shipowner's Choice of a New Cargo Ship", by Campbell and Ramsey.
"A Comparative Method of Estimating the Hull Weight of a Ship", by Johnson.
"Some Notes on Rudders and the Steering of Ships", by Abell.
"Automobile Transmission Systems", by Pomeroy.
"Tides and Tidal Phenomena", by Gardner.

The British Electrical and Allied Industries Research Association: Sub-Committee J/E: Joint Committee: Steels for High Temperatures: The following Reports from the National Physical Laboratory:—
1st Report on the Properties of Complex Molybdenum Steels.
7th Report on the Properties of Molybdenum Steels at High Temperatures.
8th Report on the Properties of Carbon Steels at High Temperatures.
Progress Report on the Corrosion of Steels in Superheated Steam.
Progress Report on the Corrosion of Steels in Flue Gas.

"Education for Industry and Commerce in England", by A. Abbott, C.B.E. (formerly H.M. Chief Inspector of Technical Schools). Oxford University Press (Humphrey Milford). 228pp., 5s. net.

This book bears the *imprimatur* of Lord Eustace Percy, a sufficient guarantee of its value to those interested in technical education. Mr. Abbott gives a review of the history of technical education in this country. It may surprise the reader when he is reminded that the Schools Enquiry Commission of 1867 was instructed to enquire as to "the inferior rate of progress recently made in manufacturing and mechanical industry in England compared with that of other European countries". Also that the Reports of the Royal Commission on Technical Education issued in 1882 to 1884 showed "that England was relatively backward both in her provision of technical education and in the esteem in which this branch of education was regarded". It may be remembered that the Education Act of 1870 made education compulsory. It was as late as 1904 that State aid was given through the Board of Education from what was known as "whiskey money", thereby extending the range of education for willing students. Another feature to which attention is called is the more rapid appraisement of these facilities in the North of England as compared with the South. The author also notes the importance of the introduction of the National Certificate in 1921 jointly by the Board of Education and the Institution of Mechanical Engineers.

One significant passage under the heading of "Recruitment" reads,: "If we cling to our traditional methods of recruitment and training, while our competitors abroad adopt every possible means—as many of them are doing—for securing an adequate and appropriate training for every grade of industrial worker, from the highest to the lowest, there can be only one result. Our trade will decrease and our standard of life will diminish".

In the Appendix is given the genesis and development of technical education in the City of London College started in 1851 by a number of London clergymen under the chairmanship of the Rev. Charles Mackenzie, which to-day stands in the forefront of educational institutions in the City of London.

A perusal of this book will well repay the reader and extend his vision of the whole subject. Mr. Abbott writes about something of which he has full expert knowledge coupled with a deep sympathy in the development of the youth of this country.

"First Year Electrical Engineering", by D. J. Bolton, M.Sc. Edward Arnold & Co. 258pp., 118 illus. 5s. net.

This book is admirably suited to the needs of first year students at a day or evening technical school. It contains introductory matter dealing with the principles relating to the electric circuit, cells, magnetism and electrostatics in the order given, together with their application to instruments, illumination, telegraphy and telephony, and motors and dynamos. The book is really self-contained and independent of a training in general science on the part of the student. This no doubt the author has found necessary in his teaching experience. It is in no hypercritical spirit, however, that we point out that the student requiring the exceedingly simple treatment shown in some parts of the book could hardly be expected to understand at this stage the derivation of the formula for calculating resistance as given on page 38. In such a doubtful case it is, perhaps, better just to state the equation and leave the proof to a later stage.

We commend the heavy type used on the first introduction of important words and phrases for the reasons stated by the author in his preface, but the numerous footnotes in small type are more irritating than helpful in a book of this nature and would be better omitted altogether or incorporated in the general text. This would neither break the sequence nor leave anything to be unlearned later. The attempt to adopt standard nomenclature is highly important. It is only by a bold effort that the general use of such standard terms can be brought about, and no one is in a more favourable position to make that effort than a teacher. It is therefore considered that the author might have gone even further than he has done in this respect. For example, after one reference to "capacity", even if this were necessary, he might have used "capacitance" exclusively. It might be assumed that those using this book are coming into contact with these terms for the first time, and if the general use of standard terms is desirable then no choice should be offered to them.

Abundant use is made of analogies. These in the hands of a careful teacher are invaluable, and it is as a text-book used by a teacher who treats his subject experimentally that this good book will fulfil its aim most satisfactorily.

BENEVOLENT FUND.

The Committee gratefully acknowledge the following donations, which were received prior to the inauguration of the Guild of Benevolence: A. E. Elliott (Member), 3s. 6d.; A. Girdwood (Member), £1 1s.; N. N. Macpherson (Member), 8s. 6d.; H. B. Scott (Member), 4s. 10d.

BOARD OF TRADE EXAMINATIONS.

List of Candidates who are reported as having passed examinations for certificates of competency as Sea-Going Engineers under the provisions of the Merchant Shipping Acts.

Name	Grade	Port of Examination
For week ended 5th July, 1934:—		
Bowman, James N. ...	1.C.	Glasgow
Brandie, Charles	1.C.	"
Jephson, Alexander W. ...	1.C.	"
McPherson, John A. ...	1.C.	"
Wilson, James	1.C.M.	"
Easey, Francis	1.C.	London
Osmond, Francis R. ...	1.C.	"
Sharp, Frank	1.C.	"
Verge, Albert W. F. ...	1.C.	"
Whale, George H.	1.C.M.	"
Whittaker, William ...	1.C.	Newcastle
Wilson, Allan	1.C.	"
Bridge, John H.	1.C.	Liverpool
Fisher, Thomas H. ...	1.C.	"
Jackson, Leonard R. ...	1.C.	"
Kelly, John H.	1.C.	"
Kerr, John	1.C.	"
McDonald, Laurence A. ...	1.C.	"
Scott, Sidney L.	1.C.	"
Mallinson, John S. ...	1.C.M.E.	"
Outram, William C. ...	1.C.M.E.	"
Lawson, Kelso S. ...	1.C.M.E.	"
Lindsay, Stuart M. ...	1.C.M.E.	"
Richmond, Frederick H. W.	1.C.S.E.	"
Hunt, Eric G. M.	1.C.M.E.	London
Bowie, Stanley	1.C.M.E.	Newcastle
Burt, Kenneth	1.C.S.E.	London
Millar, Arthur	1.C.M.E.	Glasgow
Brown, William	1.C.M.E.	London
For week ended 12th July, 1934:—		
Nixon, Frank	2.C.	Liverpool
Wilson, Reginald H. ...	2.C.	"
Green, James	2.C.	Newcastle-on-Tyne
May, John	2.C.	"
Moffitt, Leslie N.	2.C.	"
Montgomery, Albert ...	2.C.	"
Pinkney, Cyril	2.C.	"
Wilson, Edgar J. ...	2.C.	"
Peck, Francis H.	2.C.M.	"
Berry, Albert	2.C.	London
Clark, George J.	2.C.	"
Williams, Clifford T. ...	2.C.	"
Embleton, William ...	Ex.1.C.	Newcastle-on-Tyne
Reid, David R.	Ex.1.C.	"
Campbell, Howard V. ...	Ex.1.C.	London
Clarke, Percy	Ex.1.C.	"
Vipond, Alexander H. ...	Ex.1.C.	"
Gillis, Robert E. C. ...	Ex.1.C.	Cardiff
Bennett, Godfrey L. ...	2.C.	"
Broucher, Stanley	2.C.	"
Roberts, Edward H. ...	2.C.	"
Thomas, Glynn	2.C.	"
Wilson, Edward	2.C.	"
Rundle, John E.	2.C.M.	"
Caird, James H. C. ...	2.C.	Glasgow
Geddes, Douglas M. ...	2.C.	"
Lyle, James	2.C.	"
McLean, James	2.C.	"
McMurchie, Duncan ...	2.C.	"
Pearson, Robert S. ...	2.C.	"
Wyllie, William A. ...	2.C.	"
For week ended 19th July, 1934:—		
Ross, Thomas N.	1.C.	Glasgow
Watson, David C.	1.C.	"
Brown, William	1.C.M.	"
McFarlane, Thomas A. ...	1.C.M.E.	"

Name	Grade	Port of Examination
Cowley, John A.	1.C.M.E.	London
Vose, William A.	1.C.M.E.	,,
Brown, Alasdair L. ...	1.C.M.E.	,,
Ward, Walter	1.C.M.E.	Newcastle
Graham, John R.	1.C.M.E.	,,
Rea, Arthur	1.C.M.E.	,,
Goodram, Frederick ...	1.C.M.E.	,,
Austwick, Stanley	1.C.M.E.	,,
Coslett, Leonard J. ...	1.C.M.E.	Cardiff
Pringle, Robert C.	1.C.M.E.	Liverpool
Martin, Donald	1.C.M.E.	,,
Drover, George W. ...	1.C.M.E.	,,
Davies, Oakden G.	1.C.M.E.	,,
Forbes, Thomas H. ...	1.C.S.E.	,,
Ferguson, William J. ...	1.C.	,,
McWaters, Hector	1.C.	,,
Elias, John	1.C.	,,
Brown, William H. ...	1.C.	,,
Williams, Ralph F. ...	1.C.M.	Cardiff
Stewart, Hugh T.	1.C.	,,
Hodgson, John P.	1.C.	,,
Grieve, Thomas	1.C.	,,
Farthing, William J. ...	1.C.	Newcastle
Gray, William	1.C.	,,
Little, Joseph	1.C.	,,
Taylor, John	1.C.	,,
Harrison, John	1.C.M.	,,

Name.	Grade.	Port of Examination.
Gauld, Archibald L. ...	1.C.	Glasgow
Greig, William A.	1.C.	,,
Logue, William	1.C.	,,
Nisbet, Thomas S. D. ...	1.C.	,,
For week ended 26th July, 1934 :—		
Ferguson, Edward ...	2.C.	Dublin
Mailer, Arthur D. ...	2.C.	Glasgow
Mewhorter, John	2.C.	,,
Milne, James D.	2.C.	,,
Murray, James C. ...	2.C.	,,
O'May, Hugh H.	2.C.	,,
Ritchie, Alexander B. ...	2.C.	,,
Pitkeathly, Douglas S. ...	2.C.M.	,,
Hoffmann, Harold	2.C.	Liverpool
Wood, Francis A.	2.C.	,,
Hall, Herbert	2.C.M.	,,
Easton, Leslie	2.C.M.	Newcastle
Hindson, Ronald J. ...	2.C.M.	,,
Holmes, Arthur H. ...	2.C.M.	,,
Beavis, Jack C.	2.C.	London
Buchanan, Bryan	2.C.	,,
Filshie, James F.	2.C.	,,
Mallett, Alfred J.	2.C.	,,
Scotchmoor, John W. ...	2.C.	,,
Timpson, Arthur D. ...	2.C.	,,
Gardner, Bertie A	2.C.S.E.	Liverpool

ABSTRACTS.

The Council are indebted to the respective Journals for permission to reprint the following abstracts and for the loan of the various blocks.

Converting Air-injection Engines to Solid Injection

Notable Results in Large Tank Ships.

By Dr. Ing. Karl Mohr.

"The Motor Ship", July, 1934.

The very satisfactory experience gained with compressorless Diesel engines of large size has caused owners of motor ships propelled by air-injection engines to consider the possibility of adopting solid injection, resulting in reduced fuel consumption, owing to the elimination of the air compressor. With new engines having a moderate consumption of injection air, the power required is in the neighbourhood of 6 per cent. of the engine output, which, after a considerable period of service, may increase. Thus, a saving of at least 6 per cent. can be obtained in the fuel consumption with airless-injection engines.

In place of a reduction in fuel consumption it might naturally be considered that an increase in output could be obtained by employing the same mean effective pressure in the working cylinder, so that the power used to drive the air compressor would actually be added to the shaft output. Fundamentally, such an arrangement is possible, but the increase in output is scarcely to be attained with complete safety without considerable modifications, and the combustion chamber of the air-injection engine has not the right shape for satisfactory results. From the constructional point of view, the existing camshafts are too weak to operate the fuel injection pumps with the sudden rise of pressure up to 300 atmospheres or more.

The power required for driving these pumps is naturally very much higher than that for pumps of air-injection engines. The airless-injection pumps give rise to much higher stresses in the driving mechanism than occur with the valve gear for actuating the inlet, exhaust, starting and fuel valves. If the existing camshaft is used, there is greater wear on the gear wheels, even if not a danger of breakage. The strengthening of the camshaft drive or the provision of a new fuel pump drive is costly, so that it is seldom such a method is employed.

In order to overcome these difficulties, Fr. Krupp Germaniawerft, A.G., have acquired the patent rights and the experience of Prof. Vadim Archaouloff, and have combined with it their own constructional knowledge gained in the manufacture and operation of airless-injection engines. The fundamental idea of the Archaouloff system is to utilize the compression pressure in the engine cylinder to drive the fuel injection pump.* A mechanical drive for the pump is therefore unnecessary. All that is required is a connection to the combustion chamber of the working cylinder, from which a comparatively small pipe leads to the air cylinder. Fig. 1 shows the Krupp development of the Archaouloff system, which is illustrated in Fig. 2 in its complete form.

In Fig. 1 (A) is the air cylinder of the injection pump, and (B) the fuel pump itself. (C) is

*A full description of the system was given in "The Motor Ship" in June, 1933.

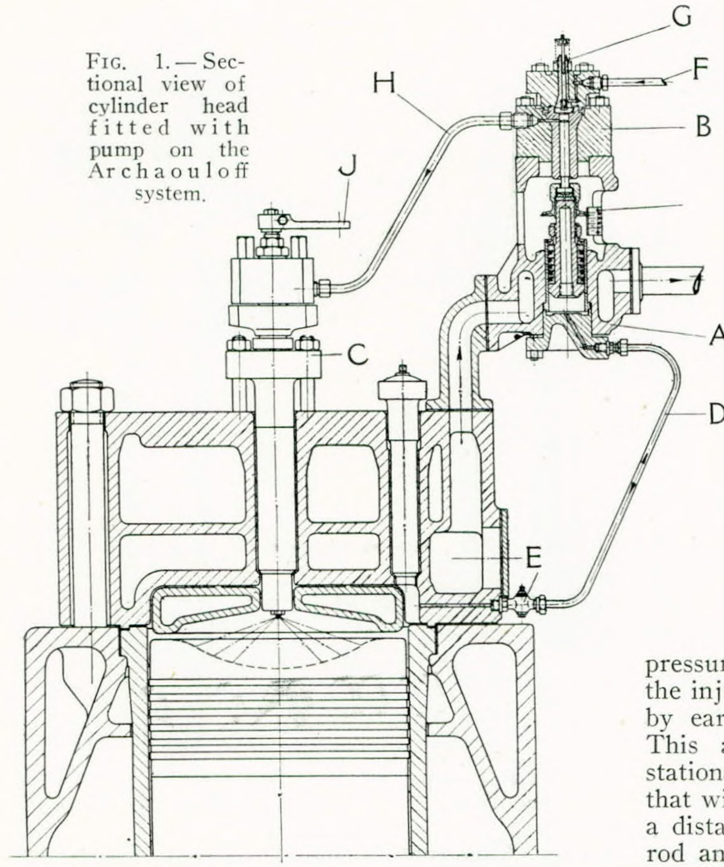


FIG. 1.—Sectional view of cylinder head fitted with pump on the Archaouloff system.

the fuel valve and (D) the pressure piping between the combustion chamber and the fuel pump. The connection can be closed by means of the cock (E), and the bore is cooled by being fitted in the cooled cylinder head casting. The entrance of the fuel to the pump is from the pipe (F) employed with the original pump, and (G) is a non-return valve. The fuel is supplied from the pump to the valve through the pipe (H), and (J) is a lever for altering the tension of the spring. The levers of the individual valves are coupled together, and are operated from the control station when the engine is started from cold.

The fuel enters the injection pump during a period of low cylinder pressure, and in the case of the conversion of existing engines is delivered from the original fuel pump. This has the advantage that the control and governing gear, as well as a considerable portion of the pipe line, may be utilized. In new engines, the fuel is delivered direct to the injection pump, and the control is effected on the pump itself.

It might be objected that it is impossible with an injection pump, the working of which depends upon the compression pressure in the combustion cylinder, to obtain a sufficiently exact and regular injection. It should, however, not be forgotten that with constant revolution speed, the conditions in the cylinder remain practically unaltered. So long as the closing pressure of the fuel valve spring is not altered, the injection, at all strokes of the pump, must occur at a similar position of the crank, and practical experiments have indicated that this actually occurs. If a number of indicator diagrams are taken successively on the same paper, there are only negligible differences in the combustion line, such as are customary with Diesel engines. To obtain the correct combustion and the desired maximum pressure, the beginning of injection must be varied, which can be effected with the usual fuel pumps by turning the cams. With the Archaouloff system there are the following possibilities :—

1. Alteration of the relation of the air piston to the fuel pump diameter in the injection pump. This modification only comes into question essentially when changing over from one grade of fuel to another with very different ignition characteristics.

2. Modification of the compression pressure. If the compression end pressure be raised, the injection pressure of the fuel valves is attained by earlier ignition; if lowered by later ignition. This arrangement is only to be utilized with stationary engines. It has the advantage over (1) that with most engines it can be effected by placing a distance piece between the flanges of the piston rod and big-end or similar means, so that no new part has to be used.

3. Alteration of the tension of the springs of the fuel valves. This modification is also easy to carry out.

The same compression pressure is used as in air-injection engines, namely, 28 to 33 atmospheres,

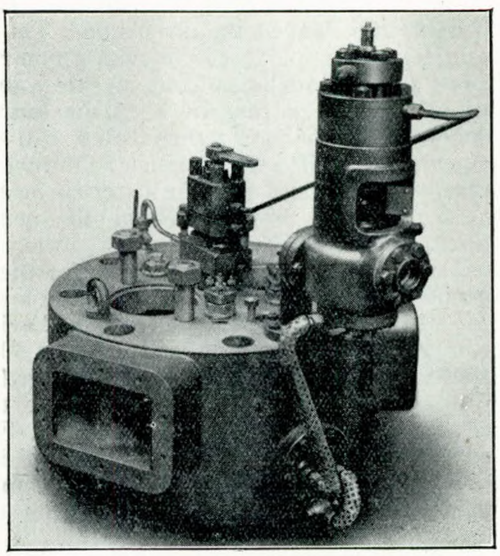


FIG. 2.—The pump fitted to a cylinder head.

with a warm engine. The relation between the surface of the fuel plunger and the air piston of the injection pump depends upon the desired injection pressure, and is usually about 1 to 12.

When starting the engine, the fuel valve spring should be slackened and a lower injection pressure is desirable than when the engine has warmed up. In service it is found that there is a definite automatic regulation of the timing of the point of ignition, also of the ignition pressure, even with a widely varying speed of revolution as in marine engines. If, for instance, the speed falls, the compression pressure also falls, although to a smaller extent, and the injection occurs later, so that knocking is prevented.

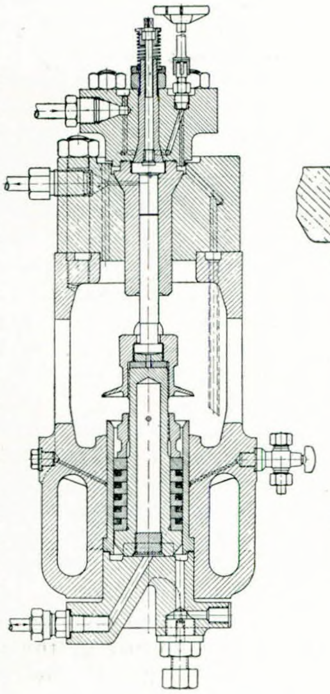


FIG. 3.—Fuel pump used with the Archaouloff system.

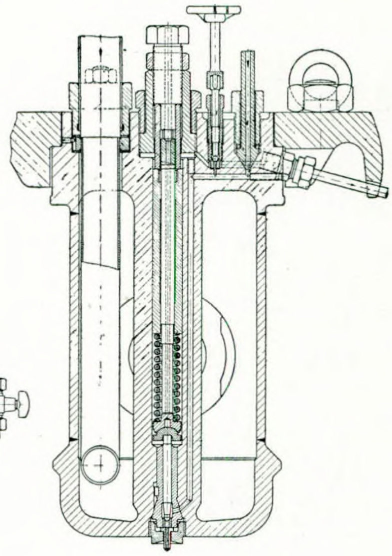


FIG. 4.—One type of fuel valve.

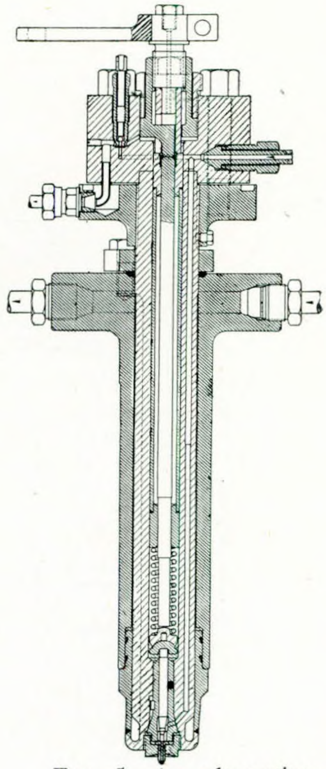
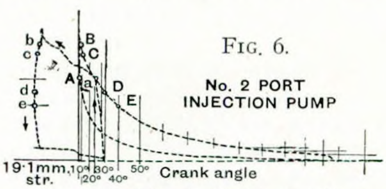


FIG. 5.—An alternative design of valve.

Fig. 3 shows a section of a Krupp injection pump, for which is claimed ready accessibility and reliability in operation. The air cylinder has a loose liner of special cast iron. The fuel plunger is adjustably attached to the air piston. The head of the injection pump, which contains a non-return valve for the fuel delivery and an air valve, is removable, so that in case of need the bush and the plunger, also the non-return valve, can easily be changed. Two different designs of the fuel valve are seen in Figs. 4 and 5. The external measurements of the valve are based upon the necessity of utilizing it in existing cylinder covers. The valve shown in Fig. 4 is, for example, for the two-stroke engine of the type used in the motor ship "F. H. Bedford, Junr.",* the engine having a diameter of 680mm. with a stroke of 1,300mm. The fuel valve previously used was arranged with cast iron. The new fuel valve is so made that a special seating is unnecessary. The valve, Fig. 5, is used when the new valve has to be fitted in the comparatively limited space for the existing air injection valves, and is employed on the motor tanker "Calgarolite"† and the passenger and cargo ship "Ciudad de Sevilla" (ex "Infanta Beatriz").‡ To prevent carbon depositing on the nozzle, the valve is cooled by sea water, which is an arrangement that Krupps employ with all single-acting two-stroke and four-stroke engines. All the cooling spaces are galvanized to prevent corrosion, and to render cleaning an easy process. The valve shown in Fig. 4 has large hand holes, whilst that illustrated in Fig. 5 is in sections; when dismantled its cooling spaces are easily cleaned. Both valves are provided with light needle seats interchange-

FIG. 6.



M.S. "Wilh. A. Riedemann".

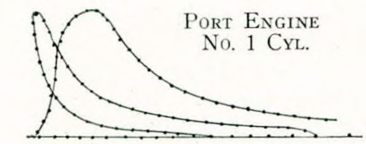
able with those of the compressorless Krupp engine. The needle is of specially light construction, so that exact timing of the opening and closing of the valve in accordance with the pressure of the injection pump is assured.

The combustion in the converted engine is very

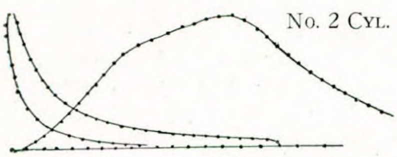
*A 16,000-ton Standard oil tanker, "The Motor Ship", December, 1930.

†The new Krupp two-stroke engine, "The Motor Ship", June, 1929.

‡"Werft Reederi Hafen", 1926.

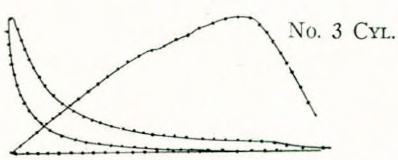


M.E.P. 4·85 kg./cm², 447 i.h.p., 88 r.p.m.



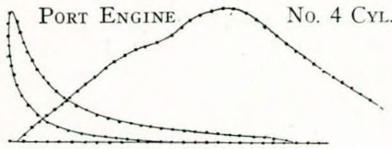
M.E.P. 5·09 kg./cm², 470 i.h.p., 88 r.p.m.

M.S. "Calgarolite".
Cyl. dia. 680 mm.

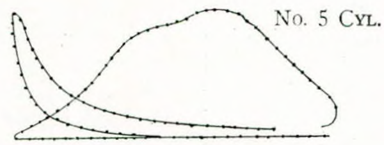


M.E.P. 4·97 kg./cm², 459 i.h.p., 88 r.p.m.

Fig. 7.—Set No. 1.

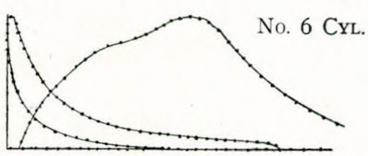


M.E.P. 4·85 kg./cm², 447 i.h.p., 88 r.p.m.



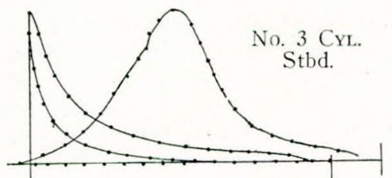
M.E.P. 4·85 kg./cm², 447 i.h.p., 88 r.p.m.

M.S. "Calgarolite".
Cyl. dia. 680 mm.

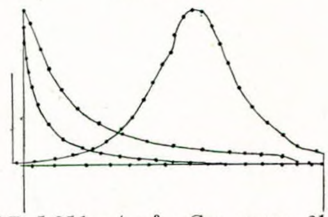


M.E.P. 4·97 kg./cm², 459 i.h.p., 88 r.p.m.

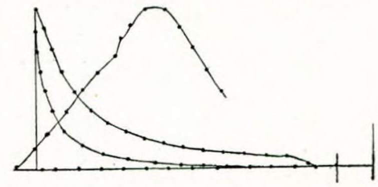
Fig. 7.—Set No. 2.



M.I.P. 5·2 kg./cm².; Cpn. press, 31 kg./cm².; max. press., 42 kg./cm².; temp., 237 deg. C.



M.I.P. 5·95 kg./cm².; Cpn. press., 31 kg./cm².; max. press., 42 kg./cm².



M.I.P. 6·15 kg./cm².; Cpn. press., 31 kg./cm².; max. press., 43·5 kg./cm².

Fig. 9.—M.S. "Persephone".

good. Despite the unaltered combustion chamber, which is far too flat for airless injection, there is an unexpectedly satisfactory utilization of the combustion air. It would appear that the regularly timed course of the injection is of importance in the Archaouloff system. As the injection pump is under the influence of the pressure within the cylinder, the injection after the first ignition continues under the influence of the increasing pressure in the injection pump up to the point at which the fuel plunger suddenly closes. The fuel is, therefore, pulverized up to the end of injection. The operation of the injection device in the injection pump is to be seen in the indicator diagram of Fig. 6, which shows two diagrams which were taken one immediately after the other. For the diagram on the right, the indicator drum was driven by the indicator mechanism of the working cylinder and for the left diagram by the piston rod of the injection pump itself. The corresponding points of the two diagrams are indicated by similar letters, those for the working piston diagram being with capitals and for the fuel pump diagram with small letters. It is to be noted that the injection process is concluded shortly after the dead point, and, at any rate, occurs as quickly as with air injection when cam-operated pumps are used.

It may also be noted that the commencement of injection at (A.a) occurs suddenly, and that the pressure rise in the pump during injection corresponding to the pressure rise in the working cylinder occurs in wave formation. In the engines which have hitherto been converted by Krupps, the normal speed is between 80 and 110 r.p.m. With a pipe length of about 1 metre and a sound speed in the contents of the combustion space of about 500 metres per second, the sound wave travels from the working cylinder to the injection pump in 0·002 second, which at a speed of 100 r.p.m. corresponds to a crank angle of 1·2 deg. The injection period is, however, about 15 deg.

In this connection, it is to be noted that in

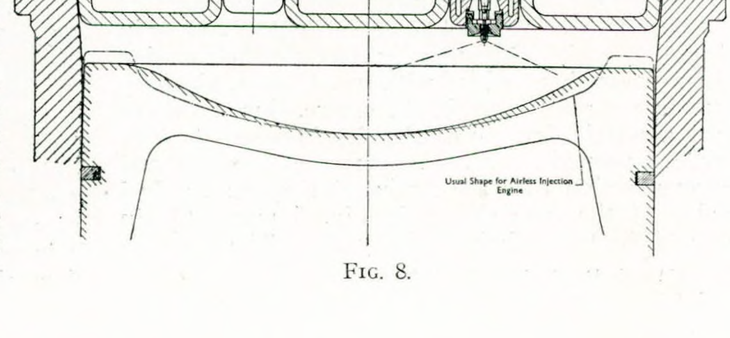


Fig. 8.

contrast to an injection mechanism having cam-operated pumps, with the Archaouloff system, the small quantity of air which is contained in the fuel in the injection pump does not affect the correct timing of the injection, nor hinder satisfactory pulverization. As the commencement of injection depends only on the attainment of a definite compression pressure, any air in the injection pump is pre-compressed by the steadily rising cylinder pressure and does not prevent the injection at the right time after the attainment of the desired pressure. With a cam-driven pump, the time for the pre-compression is determined by the shape of the cam, and if, owing to air in the fuel, a longer time for pre-compression is necessary, the injection is correspondingly retarded.

The satisfactory operation of the combustion process is seen in the indicator diagrams which are taken from a converted engine. Fig. 7 shows a set of cards from the tank ship "Calgarolite". As with the conversion of the engine of this ship fuel economy was the first aim, a speed of 88 r.p.m. was chosen when running in ballast and 87 r.p.m. when loaded. The mean indicated pressure, therefore, was lower than when air injection was employed. On two voyages with the ship loaded, the following comparisons before and after conversion were obtained :—

Method of Injection.	Air.	Archaouloff.
R.P.M.	86·8	87·5
M.I.P.	5·94 Atmospheres	5·12 Atmospheres
Fuel consumption per day.	174 barrels = 27,700 litres	154 barrels = 24,500 litres
Speed.	12·02 knots	11·92 knots

Thus the economy of fuel amounted to 11·5 per cent., which is the figure usually attained. From this experience there is no doubt that the conversion of existing air injection engines with a fuel valve disposed in the centre of the cylinder cover, and operating on the Archaouloff system, will give completely satisfactory combustion. It was, however, doubtful whether such a conversion without a corresponding change of the cylinder cover would be possible in engines which have one or more eccentrically placed fuel valves in the cover. This question was decided recently in an experiment on a single-acting two-stroke Krupp engine with valve scavenging, having a cylinder diameter of 650mm. and a piston stroke of 1,300mm. It is installed in the motor tank ship "Persephone".* The cylinder covers of this engine were originally provided with two 130mm. diameter fuel valves not located in the centre, since no space was available for a central valve between the two large scavenging valves. In the experimental reconstruction with the Archaouloff system, a fuel valve of the type shown in Fig. 5 was fitted in one of the two existing valve cages. The arrangement was unsymmetrical and the combustion space took the form shown in Fig. 8.

*Werft Reederi Hafen", 1926.

Experiments were carried out to show to what extent the cylinder could be loaded. A few characteristic indicator diagrams are shown in Fig. 9. The upper diagram corresponds roughly to the performance when the same revolution speed is maintained. The centre diagram refers to the engine reconstructed to give the same indicated power as with air injection, whilst the lower diagram indicates the highest power attained during the trials. Up to 6 atmospheres M.I.P. the exhaust was smokeless, and with the M.I.P. at 6·15 atmospheres there was only a very light grey colour to the exhaust. Thus, even with a combustion chamber which is not essentially suitable for airless injection and when high M.I.P. is maintained, the Archaouloff system proved successful.

Manœuvring of the converted engine is equally light and quick as with compressorless engines, having fuel pumps actuated from cams. The engine

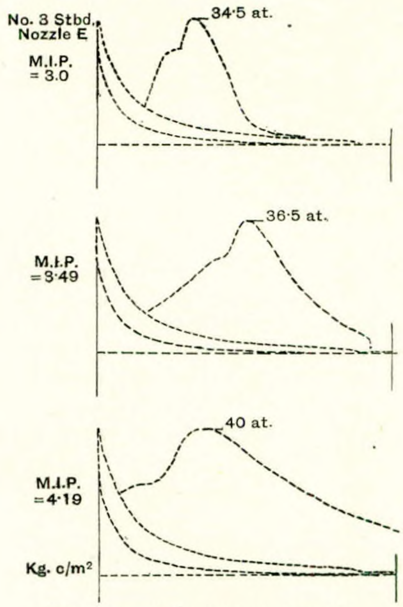


FIG. 10.—M.S. "Persephone".

also runs with very low revolutions and light loads, quite regularly and without shock. The automatic control is quite clearly indicated in Fig. 10. Whilst at 88 r.p.m. in Fig. 9 the compression pressure is 30 atmospheres, in Fig. 10 at 46 r.p.m. it is 26 atmospheres. The commencement of injection with reduced revolutions occurs nearer to the dead point, and therefore there is little tendency to pre-ignition.

The three diagrams in Fig. 10 refer to varying fuel settings, but with constant speed of revolution, with the object of examining the process during starting. At the commencement of the starting period too great a quantity of fuel was injected for the corresponding speed of revolution. It is seen that an increase in the quantity of fuel gives rise to an increase in ignition pressure, but that even with the very considerably increased fuel quantity, in the third diagram, there is no danger of rise of pressure. The tension of the fuel valve springs was not altered, corresponding to full load ignition pressure.

The indicator diagrams of the starting period for an engine which had been stopped several days to be fitted with the Archaouloff mechanism showed that at the third revolution ignition occurs. This was the first engine equipped by Krupps with the Archaouloff system, which, without previous testing, was installed on board, and after a short trial left for its normal voyage.

The satisfactory operative characteristics of the Archaouloff system have been confirmed in all details by the engine-room staff on ships in which it is fitted. It is agreed that the engines thus converted require less attention than the air-injection units.

As the parts of the Archaouloff plant are simple and can readily be fitted, the expenditure on conversion is relatively small. For instance, the cost of the modification in the tank ship "Calgarolite", with two engines of 2,500 b.h.p. each, was about 6·50 marks per b.h.p. This may be compared with the economies effected, which represent a reduction in fuel consumption of 14gr. per b.h.p. hour. If there are 250 running days per year and the fuel price is 50 marks per ton, the economy works out at 4·20 marks per b.h.p. per annum. Thus, the whole plant is paid for in 18 months through the fuel economy.

The figures are naturally liable to variation according to the price of oil and the period of running per annum; the cost of the alterations differs in varying cases, dependent, for instance, on whether the fuel valves can be changed without any alterations to the cylinder covers, or whether substantial modification to pipes is necessary. The saving of 14gr. per b.h.p. represents about 8 per cent. of the consumption, and is an extremely conservative figure since actual results have shown a reduction of over 11 per cent. For this reason it is readily to be understood why Krupps, in the short time of one year, have already completed or have on order conversions on the Archaouloff system for 20 ships' engines having a total output of 40,000 b.h.p.

Liverpool and the Atlantic Ferry.

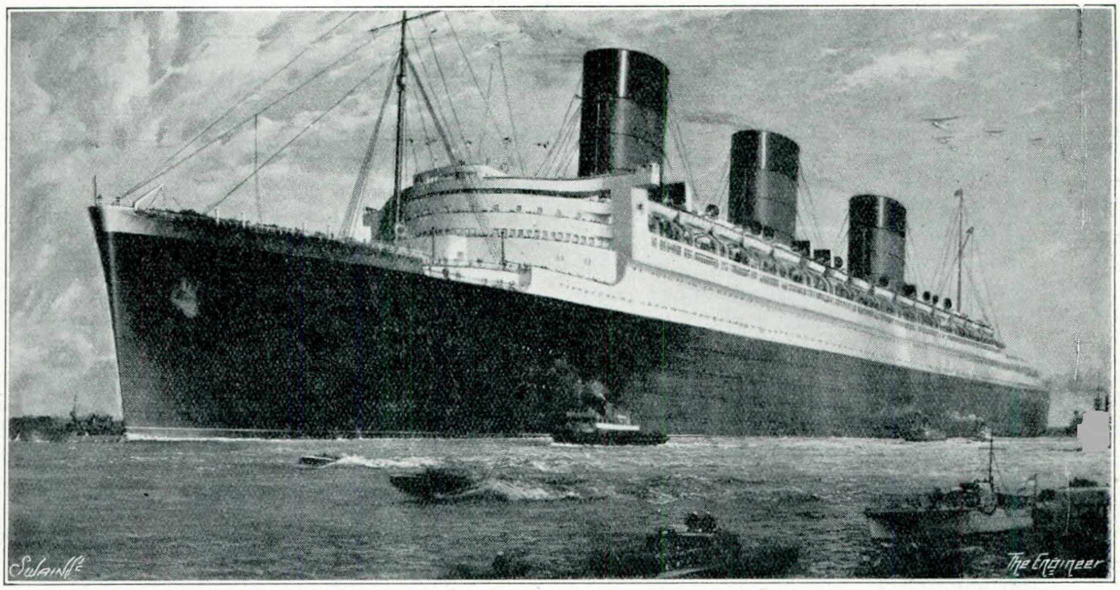
"The Engineer, 20th July, 1934.

The following interesting tables of particulars and illustration of the new Cunarder are taken from a paper read before The Institution of Mechanical Engineers, Liverpool Summer Meeting, June 26th, entitled "Liverpool and the Atlantic Ferry", by J. Austin, Superintendent Engineer, Cunard Steam Ship Company.

PARTICULARS OF PRESENT-DAY BIG SHIPS.

Ship.	Date.	Owners.	Builders and where built.	Gross tonnage.	Length, feet.	Moulded Breadth, feet.	Depth, feet.	Main boilers.	Type of Machinery.	No. of Propellers.
Mauretania	1907	Cunard	Swan, Hunter & Wigham Richardson, Newcastle-upon-T'ne	30,696	762·2	88·0	57·1	Scotch	Direct turbine	4
Olympic	1911	White Star	Harland & Wolff, Belfast	46,439	852·5	92·5	59·5	Scotch	Reciprocating and turbine	3
Aquitania	1914	Cunard	J. Brown & Co., Clydebank	45,647	868·7	97	49·7	Scotch	Direct turbine	4
Berengaria	1912	,,	Vulcan-Werke, Hamburg	52,101	883·6	98·3	57·1	Water-tube	Direct turbine	4
Majestic	1921	White Star	Blohm & Voss, Hamburg	56,621	915·5	100·1	58·2	Water-tube	Direct turbine	4
Leviathan	1914	United States Lines	Blohm & Voss, Hamburg	48,943	907·6	100·3	58·2	Water-tube	Direct turbine	4
Bremen	1929	Norddeutscher Lloyd	A. G. Weser, Bremen	51,656	898·7	101·9	48·2	Water-tube	S.r. geared turbine	4
Europa	1928	,,	Blohm & Voss, Hamburg	49,746	890·2	102·1	48·0	Water-tube	S.r. geared turbine	4
Empress of Britain	1931	Canadian Pacific	J. Brown & Co., Clydebank	42,348	733·3	97·8	56	Water-tube	S.r. geared turbine	4
Conte di Savoia	1932	"Italia" (Flotte Riuniti Cosulich-Lloyd Sabaudo - Navigazione Generale)	Cantieri Riuinti dell Adriatico, Trieste	48,502	814·6	96·1	32·4	Water-tube	S.r. geared turbine	4
Rex	1932	,,	Soc. Anon. Ansaldo Sestri Prente	51,062	879·9	97	30·7	Water-tube	S.r. geared turbine	4
Normandie	Building	Compagnie Générale Transatlantique	Chantiers et Ateliers de St. Nazaire (Penhoet), St. Nazaire	68,000	962	117·7	91·8	Water-tube	Turbo - electric drive	4
No. 534	Building	Cunard White Star	J. Brown & Co., Clydebank	73,000				Water-tube	S.r. geared turbine	4

S.r., single-reduction.



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Artist's Impression of Q.S.S. No. 534 (from an Oil Painting).

NORTH ATLANTIC RECORD PASSAGES, 1909-33.

Date.	Nationality.	Name of Ship.	Owners.	From	To	Sea Miles Knots.	Average Speed, Knots per Hour.	Time. d.	h.	m.
1909	British	Mauretania	Cunard	Daunts Rock	Sandy Hook	2,784	26·06	4	10	51
		,,	,,	Sandy Hook	Daunts Rock	2,809	25·61	4	13	41
1909	,,	Lusitania	,,	Daunts Rock	Sandy Hook	2,784	25·85	4	11	42
		,,	,,	Sandy Hook	Daunts Rock	2,808	25·10	4	15	52
1929	,,	Mauretania*	,,	Cherbourg	Ambrose C.L.V.	3,162	26·9	4	21	44
		,, *	,,	Ambrose C.L.V.	Plymouth	3,098	27·22	4	17	50
1930	German	Europa	Norddeutscher Lloyd	Cherbourg	Ambrose C.L.V.	3,157	27·91	4	17	6
1933	Italian	Rex	"Italia" (Flotte Riuniti Cosulich-Lloyd Sabaudo - Navigazione Generale)	Gibraltar	New York	3,181	28·92	4	13	58
1933	German	Bremen	Norddeutscher Lloyd	Ambrose C.L.V.	Cherbourg	3,200	28·51	4	16	15

* The s.h.p. developed on the westward passage was 78,800 and on the eastward passage 80,000.

Tonnage of s.s. "Normandie".

"The Engineer", 3rd August, 1934.

Sir,—We notice that the registered tonnage of our s.s. "Normandie" is given as 68,000 tons. We would like to point out that 68,000 tons was the rough estimate submitted by the shipyard at the time of the laying of the keel, at which moment it had not even entered into discussion exactly what would be the nature of the enclosed spaces.

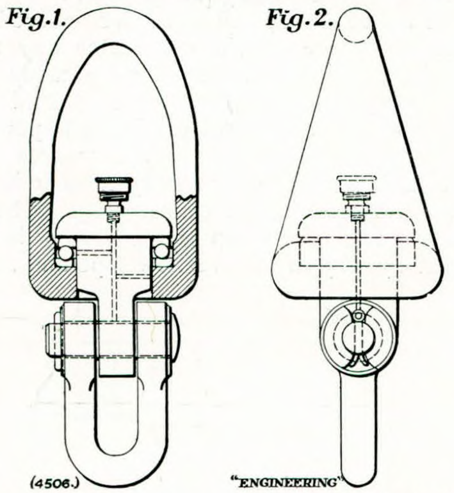
It is over eighteen months ago since we announced to all and sundry that the approximate gross register would be about 75,000 to 76,000 tons. This ship has now taken final shape, and as far as can be calculated, the gross registered tonnage will be 79,280 tons.

For the
COMPAGNIE GENERALE TRANSATLANTIQUE, LTD.,
G. C. RHODES,
London, S.W.1, July 31st. Director.

The Murphy Screwless Swivel.

"Engineering", 1st June, 1934.

The ordinary swivel, so widely used for crane hooks, ship's derricks, boat falls and similar purposes, consists, as is well known, of a stirrup through the boss of which the eye bolt carrying the shackle is passed. The eye-bolt shank is screwed and fitted with a nut and washer inside the stirrup. It is this screwed shank that carries the whole load, and, apart from its intrinsic



liability to fatigue failure, it is impossible to inspect it without removing the nut which, as often as not, may have seized. A new type of swivel in which no screwed parts are used is shown in the above illustrations, Figs. 1 and 2. This is known as the "Murphy Swivel" and is made by Messrs. Harland and Wolff, Limited, North Woolwich, London, E.16. The centre pin, as will be clear from Fig. 1, has a solid head which takes the load through a thrust bearing, and is formed with an eye at the other end to take the shackle. The oil holes and grease lubricator shown in this view are optional. The stirrup also differs markedly from the conventional design, for, as shown in Fig. 2, it has a tapered contour. This not only makes it stiffer but less likely to catch on obstructions. The projecting boss of the ordinary design has not this advantage, but cannot be made otherwise as the nut would then be inaccessible. The shackle of the Murphy swivel, again, has been designed to present no projecting part, the split pin being sunk in the eye. Complete examination of the swivel can be made by simply knocking out the shackle pin, and no periodical heat treatment is required for the centre pin, as is the case with a screwed pin. The shackle eye and the underside of the stirrup take up reversal of load, when the swivel strikes the ground for instance, and neither the centre pin nor the shackle is affected.

Shipping Economics.

"The Engineer", 3rd August, 1934.

The annual report of the Chamber of Shipping of the United Kingdom, which has just been issued, refers to the past year as one of increasing gravity for shipping, which, it states, has barely been touched by the slight improvement in international trade and the distinct signs of recovery in home trade during the past few months. Tramp freights fell a further 3 per cent. during the year, and were on an average 22½ per cent. below pre-war rates. As compared with pre-war the loss of coal exports meant 700 fewer tramp ships with outward cargo each month, while the world increase of motor and oil-burning tonnage to 45·4 per cent. of the total caused a further loss on bunker exports. The cutting of rates has been continued by foreign owners. Trade restrictions with high manufacturing costs at home, and low costs of production, depreciated currencies, and lack of purchasing power abroad, have deprived liners of much of their outward cargo. Homeward cargoes have been better, but the position of many passenger lines, already acute, has become still graver. Running costs were 40 to 50 per cent. above pre-war, compared with a cost of living of 40 per cent. above 1913. As to the financial position of the shipping industry, a large part of it is, it is stated, being starved. Great Britain's invisible shipping exports were £59 millions in 1933, compared with £62 millions in 1932, £130 millions in 1929, and £94 millions in 1913. A reduction of just over one million gross tons took place last year in the volume of tonnage laid up, but that is more than accounted for, the report says, by the scrapping and sale abroad of 1¼ million gross tons of shipping. During the past six months, however, there has been some increase in the number and tonnage of ships in commission.

Navigation in Fog.

"The Engineer", 3rd August, 1934.

A large company of British and Italian shipowners and representatives of shipping interests took part in the demonstration of Marchese Marconi's latest invention for aiding navigation at Sestri-Levante, near Genoa, on Monday, July 30th. The new device operates on the ultra-short wave principle, and provides means whereby a master can navigate his ship on a straight line into the most difficult harbour entrance, even when land is not visible. A further application of the new device gives the correct bearing of the ship relative to a beacon station while the ship is within its range. For the purpose of the demonstration a wireless transmitter working on a wave length of 60cm. was erected 300ft. above sea level on a hill behind Sestri-Levante, and the receiving apparatus was installed in Marchese Marconi's yacht "Elettra". The yacht put out to sea and steamed in between two buoys anchored in the bay, 90 yards apart, which represented the harbour entrance. The chart room was darkened and the ship was navigated by the audible signals from the rotating beacon and the needle on the receiving instrument, which operates over a dial, one half of which is green and the other red. All the navigator has to do is to keep his ship on a course which will maintain the pointer of the dial on the centre line between the red and green divisions. A range-finding system is also incorporated in the new device, which, by a combination of wireless and acoustic signals, enables the navigator to determine his distance from the harbour within a 2-mile limit.

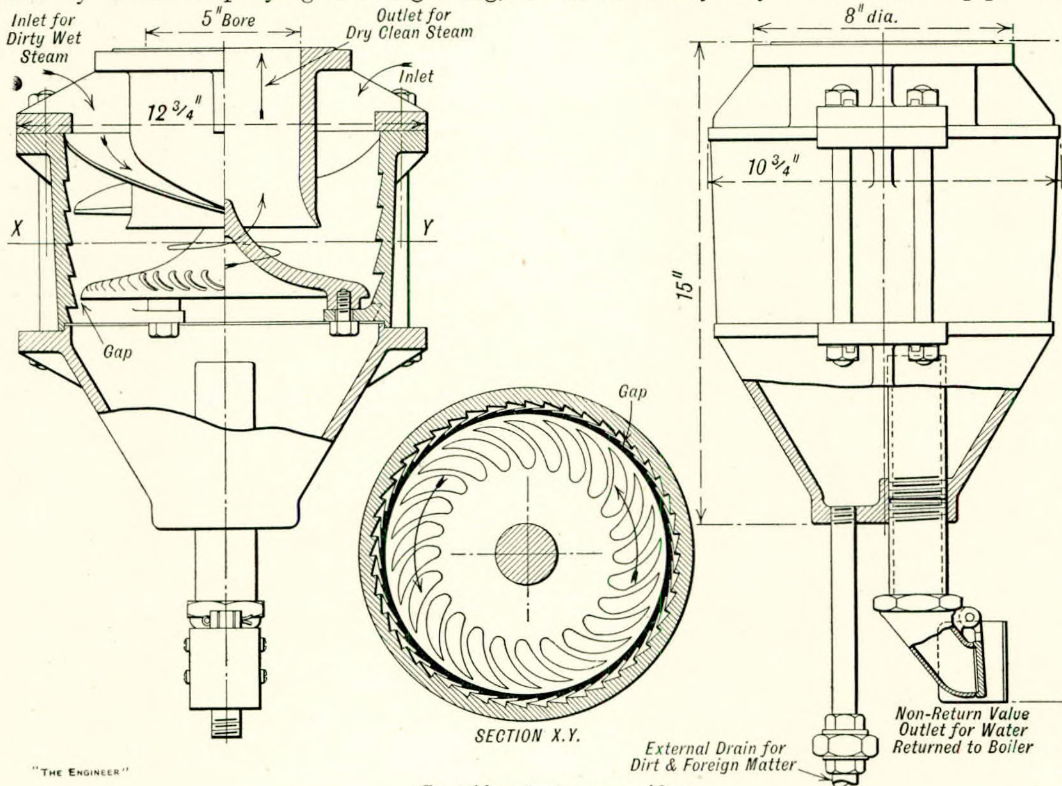
A Steam Purifier.

"The Engineer", 15th June, 1934.

Considerable damage may be done to superheaters by water and dirt carried over from the boiler by the steam. Troubles of a like kind in the prime mover may also frequently be traced to the presence of impurities in the steam. The Hopkinson-Moynan centrifugal steam purifier, illustrated by the accompanying line engraving, is designed to obviate these troubles. The separation of moisture and dirt from steam is effected by centrifugal action. On entering the purifier a gyratory motion is imparted to the steam by the vanes in the body of the purifier, with the result that water and all foreign matter are thrown against the surrounding walls on which are arranged inclined radial serrations. The water and sediment are caught by these serrations, and forced by the gyratory motion of the steam, assisted by gravity, down into the purifier sump. The inclination of the serrations, together with this motion, assures a positive self-cleaning action, and, therefore, the purifier cannot become choked with sediment. On leaving the vanes, the steam continues its gyratory motion, but is deflected upwards into the discharge orifice by a specially designed conical deflector plate. This change in general direction does not, however, entail a sudden alteration in direction of flow, since the gyratory motion of the steam becomes a natural vortex greatly facilitating the change.

The deflector has on its surface curved radial grooves which are provided to catch any further traces of water or dirt which might possibly remain after the purifying treatment encountered by the steam in its passage through the first portion of the purifier. The shape of these grooves is such that a similar self-cleaning and ejecting action takes place as in the serrations of the body. The water is returned from the sump of the purifier back into the boiler by way of an overflow pipe and a bronze foot valve, which, in the event of the water level rising abnormally and covering the valve, prevents water from the boiler being drawn into the purifier. This valve is designed for easy operation, and will return the water back into the boiler, under all conditions, without choking. It is also protected by a shield from surging effects of the water in the boiler. For the periodic removal of the dirt and sludge which accumulate in the sump, a drain pipe is carried from the lowest portion of the purifier to the exterior of the boiler drum, where, by opening a suitable valve, the boiler pressure blows the accumulation out of the drain.

In the design great care has been taken to ensure that pressure-drop is reduced to a minimum. As there are no baffles, there is an unobstructed



Centrifugal steam purifier.

passage through the purifier. It will be realised that the application of centrifugal action does not entail the use of moving parts, and there are, therefore, no troubles due to wear and tear. All parts are robust, and there is no possibility of anything becoming loosened and being carried into the steam range to cause damage, and ample steam space in the purifier eliminates the risk of choking. The purifier can be quickly dismantled and re-erected when inspection becomes necessary. The unit cannot, of course, be made any larger than will pass through the manhole, but to meet boiler demands, two or more units are mounted on a manifold. This type of purifier for installation inside the boiler has the advantage that moisture collected by it is retained actually inside the boiler, where it is returned to the boiler water without loss of heat or pressure. Also, it has the fuller advantage that it is in equilibrium and not subjected to pressure.

The Work of the Ship-Model Tanks.

"Engineering", 3rd August, 1934.

Sir Arthur Eddington has observed, in one of his addresses on relativity, that although a pig stratified into rashers might provide a biologist with studies of absorbing interest, he would obtain a better idea of how the animal functioned by contemplating the complete pig.

That the recent Summer Meeting in London of the Institution of Naval Architects should bring this analogy to mind is due solely to its peculiar fitness. In no sense is it derogatory; for, extending the parallel a stage further, whilst a certain domestic utility may attach to the complete pig, the maximum return of nourishment can only be enjoyed after it has been dissected, and the rashers separately submitted to the appropriate heat-treatment.

William Froude, eulogised by Sir Westcott Abell in the first paper delivered, may be said to have applied both methods of study to the problems of ship resistance. Having first philosophically surveyed the subject, he set to work in the pioneer tank at Chelston to examine the separated components, and later, in open water, carried out the complementary towing trials with H.M.S. "Greyhound". The opportunity to emulate them has been the "baton in the knapsack" to every tank superintendent for the last half-century.

To-day, as Lord Stonehaven described in his presidental address, more than a score of experiment tanks are in active operation, to an increasing extent on more or less routine tests of a commercial character, but still pursuing at every opportunity the more rarified investigations designed to confirm, qualify or extend the pure theory to the point where the last vestiges of empiricism shall become obsolete and unnecessary. Every current ship-type of importance, from the barge to the battleship, has been taken in review, but, so far as may be judged from the comments of the investigators themselves upon each other's work, finality is no more imminent in this than in any other department of science. The complete "Organon of the Rational Art of Ship Design" is still only in the form of notes; possibly its eventual editor is, as yet, unborn; but already the work accomplished is so extensive, its origins so widespread, and its expression so diverse, that the need is felt for some greater uniformity of method and nomenclature.

Good work has been done to this end by the Hague Conference of Tank Superintendents, at which the representatives of eight nations attended. The meetings of the Institution of Naval Architects drew delegates from 12 tanks, in ten countries, in addition to the responsible officers of four British establishments. The importance of such an event is manifest. Opinion may not be unanimous on the value of the public discussions, which at times hardly rose to the occasion, but this feature, after all, is a very imperfect criterion. The real value may be expected to lie in the personal contacts effected, and the unofficial and unpublished exchanges of views resulting from them.

The programme of papers embraced practically every department of research in ship resistance and doubtless was planned with that intent. Engineering was rather conspicuously absent, which possibly explains the thin attendance on occasions; the engineers being absent also. For various reasons this is to be regretted. In a society which meets only at comparatively long intervals, no opportunity should be missed of promoting the closer association of its constituent interests, and a programme appealing mainly to a very limited section, in a convention of the whole institution, lies open to a certain degree of criticism on that account, however excellent it may be in other respects.

The modern tendency towards ever-greater specialisation is not to be resisted, even though it may involve changes in demarcation, as for example, the gradual transference of propeller design to the domain of the naval architect, leaving to the engineer only the mechanical problems of construction and fitting. But the need for mutual understanding persists no less strongly than before, and if a paper or two on cognate engineering subjects could have been included without undue interference with the general plan of the meetings the principal *motif* would not have been adversely affected, and the atmosphere of common interest would have been better emphasised.

Lloyd's Register and Fusion Welding

"The Engineer", 3rd August, 1934.

Whenever the welding of pressure vessels is discussed the attitude of the insurance and registration societies with regard to it is mentioned—generally with contumely! It is asserted that by their refusal to recognise it as a trustworthy method of joining plates they are arresting progress. Charges of this kind must not be taken too seriously; for they are no more than a phenomenon which occurs in the advance of every new invention. As long as resistance to innovations is not carried on too long or too far it serves a useful purpose by preventing hasty action and avoiding undesirable results which may do more to check real progress than intelligent restraint. In the case of welding, most engineers, despite what they sometimes say, are really on the side of caution, for they know, none better, that welding is a difficult process, calling for great care and close supervision. Probably there is not one of them that has not slept better o' nights because the attitude of insurance companies has obliged him to use riveted or solid pressure vessels.

But in the past few years improvements have been effected in methods of welding, and the time is coming when the resistance to it may be safely slackened. A good deal of experience has been gained, particularly in America, with fusion welded vessels subjected to very high pressures, and—unless failures are being hushed up—accidents are extremely rare. Moreover, methods of examining welds without destruction are coming into workshop use, and before long it will be quite possible to say with certainty, by visual examination, whether a weld is good or bad and to indicate without hesitation any defects that may exist. As far as pressure vessels are concerned, the tendency at the moment seems to be towards the adoption of fusion rather than lap welding, despite the fact that several ingenious and successful types of lap joints have been devised. The tendency is quite comprehensible, for, even neglecting the nature of the weld, the truly symmetrical form of the vessel is manifestly advantageous from several points of view. In the disparaging allusions to the attitude of registration and insurance societies which we have mentioned above, it is not infrequently asserted that Great Britain is more backward than other countries. We learn, therefore, with great pleasure that there are now available at Lloyd's Register of Shipping tentative requirements for fusion welded pressure vessels. We believe we are right in saying that these are the first regulations in existence issued by a classification society, and we should like to congratulate the Committee and the engineering staff of Lloyd's Register on their courage and enterprise in issuing them. The requirements are entitled as "for pressure vessels intended for land purposes", but it is hardly open to question that before long they will—if found to be satisfactory—be extended to marine services. The term "fusion weld" is applied to all welded joints made by the oxy-acetylene or the oxy-hydrogen process or by the metal arc with covered electrodes, or other arc processes in which the arc stream and the deposited metal are shielded from atmospheric contamination. The pressure vessels are broadly divided into two classes; the first, fired pressure vessels and vessels subject to internal steam pressure above 50lb. per square inch, the second, all pressure vessels not included in the first class. It will be seen that the first class covers the welding of steam boilers, whilst the second may apply, for example, to air containers. With regard to the former, this significant clause is included in the requirements: "The welding of Class 1 Pressure Vessels is to be done only by firms who have demonstrated to the satisfaction of the Society's surveyors that they are capable of making efficient welds consistently. For this purpose a surveyor will make a preliminary visit to the works in order to inspect the welding plant, equipment and organisation, also to arrange for the carrying out of a series of tests. Subsequently, a surveyor will report annually on the conditions which obtain at the works, and if considered necessary, will carry out further tests". When it is recalled how frequently the effect of the human element in welding has been insisted upon, the significance of this provision will be appreciated. That the "Requirements" include a full specification for tests and test pieces need scarcely be said, but it ought to be noted that X-ray photographs of the entire length of welded seams, either longitudinal or circumferential, are to be taken. The X-ray methods employed must be sufficiently accurate to reveal a defect having a quantitative thickness greater than 2 per cent. of the depth of the weld. Although manufacturers have used X-rays for their own satisfaction, this is to the best of our knowledge the first boiler inspection specification in which their employment is laid down as a requirement, though we understand that the Admiralty proposes to make X-ray examination of welded seams a routine test. Whilst it is probable that X-rays will be preferably employed, it must not be forgotten, as Dr. Pullin has shown, that in certain circumstances the emanations of radium have advantages, particularly where thick plates or seams in inaccessible positions are concerned, and although not specifically mentioned, we have no doubt that photographs taken by that method would be accepted by the Society.

Probably by the time these words are published most of the boilermakers in the country will have studied the Requirements. It is equally probable that some of the clauses will be criticised, but however that may be, we are confident that our readers will join with us in commending Lloyd's Register on its action, and in welcoming the appearance of regulations which will help to place the welding of pressure vessels on a better foundation. It remains now to be seen what attitude the boiler insurance companies will take in respect of welded pressure vessels constructed to Lloyd's Register requirements.

Boiler-explosion Inquiry.

"Engineering", 3rd August, 1934.

In accordance with the Boiler Explosions Acts, 1882 and 1890, inquiries have been conducted by the Board of Trade officials into a number of explosions. Reports of the investigations have been published recently, and of one of these we give a brief summary below.

Failure of a Cast-Iron Tee-Piece in S.S. "City of Cairo".—On February 22nd to 26th, 1934, a formal investigation was held at Liverpool by two Commissioners appointed to inquire into the disastrous accident on board the Ellerman steamship "City of Cairo", on November 5th, 1933. The result of the investigation is contained in Report No. 3245. At the time of the accident the vessel was a day out from Marseilles on a voyage to India. The accident was due to the failure of a cast-iron tee-piece in the auxiliary steam pipe from the auxiliary boiler, and the finding of the Commissioners was that the fracture of this fitting was due to water hammer. The accident, unfortunately, resulted in the death of a junior engineer and of four firemen, and injuries through scalding to five others.

The report is accompanied by a series of sketches showing the position of the three main boilers and the auxiliary boiler, the position of the superheaters and the lay-out of the main and auxiliary steam pipes, the various valves, connections and fittings, and also the drains. A sketch is also given of the tee-piece which failed. All boilers were single-ended return-tube boilers working at 225lb. per sq. in., the three main boilers being placed side by side across the ship just forward of the engine room, with the auxiliary boiler in the centre of the ship in the forward part of the stokehold. With this arrangement, the steam pipes from the auxiliary boiler were necessarily of considerable length, the auxiliary steam pipe being apparently some 30ft. long. This particular pipe, of solid-drawn steel and 4½in. bore, had expansion bends in it and was connected at its after end to a junction box, and at its forward end to the tee-piece. It was practically horizontal. With the main boilers in use and the auxiliary boiler shut down, water was almost bound to collect in it. Under these circumstances, it is easy to see that there was always a possibility of water hammer action being set up, and the inquiry brought to light the fact that two accidents had previously occurred. One of these occurred as long ago as September, 1926, and the other in March, 1932. Neither of these failures, however, had been reported to the Board of Trade.

On the morning of the accident, the ship was steaming with her three main boilers, but as she was meeting strong head winds the chief engineer decided to raise steam in the auxiliary boiler. Before lighting up, he gave orders to test the joints on the superheater of the boiler. Under the supervision of the second engineer, steam was therefore admitted from the auxiliary steam pipe to the superheater, when, as the report says, at 11.34 after "the flow of water and steam from the auxiliary pipe range into the superheater had been going on for some minutes, a loud explosion was heard, and a great volume of steam rushed into the boiler room, and most of the people in that part of the ship were either killed or badly scalded". The second engineer, Mr. McKinney, and the sixth engineer escaped, but the latter lost his life a few moments later in a gallant attempt to rescue the firemen. After the steam had cleared away, examination showed that the tee-piece referred to had fractured completely close to one of the flanges.

The report is a very interesting one, and it shows how, with all the excellent rules laid down by the Board of Trade and Lloyd's Register, and the supervision of competent engineers, a potential source of danger may exist for a long time without being detected. It is a recommendation of the Board of Trade that isolating valves should be fitted in main and auxiliary steam pipes, and in the report the Commissioners say that, in the light of this case, it is a recommendation which should be invariably accepted and carried out by all ship owners. Had such an isolating valve been fitted in the "City of Cairo", it is probable the accident would never have occurred.

Geared Turbines to Geared Diesels.

An Interesting conversion has just been completed by the Wilton-Fijenoord Yard, Rotterdam, the Rotterdam Lloyd turbine-driven Steamship "Modjokerto" being provided with double-acting M.A.N.-type Diesels and Vulcan gearing. The power has been doubled and the speed raised from about 11½ knots to 15½ knots. A Maier-form bow has been adopted.

"The Marine Engineer", August, 1934.

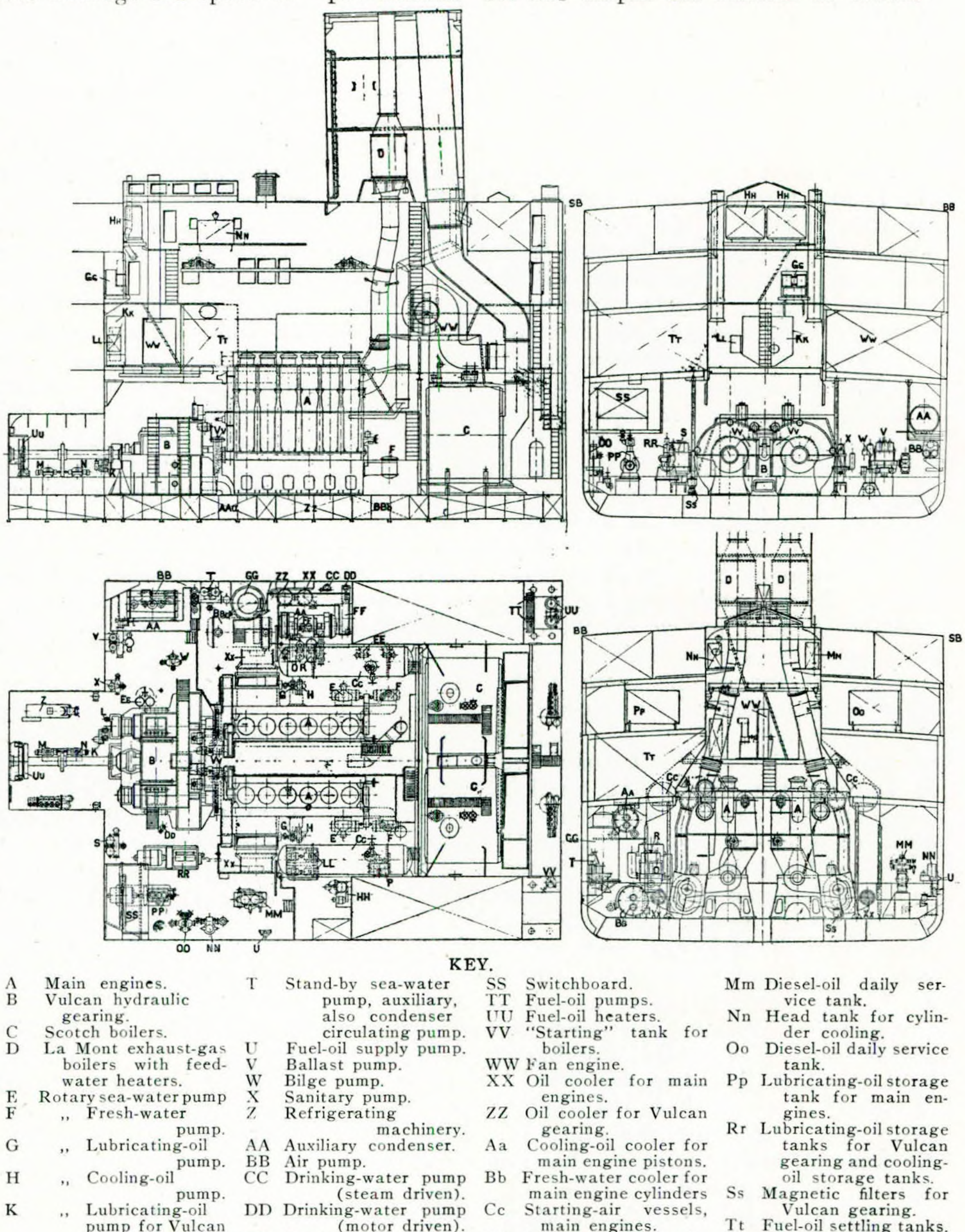
In the beginning of 1933 the Rotterdam Lloyd decided to have their cargo steamship "Modjokerto" converted in order to increase her speed. This conversion was entrusted to the Wilton-Fijenoord yard at Rotterdam-Schiedam. The "Modjokerto" had a gross tonnage of 8,396 tons and a deadweight capacity of about 11,500 tons. She was built in 1922 at the Wear shipyard of William Gray & Co., Ltd., Sunderland. Her original dimensions were: length 430ft., breadth 57ft., moulded depth 41ft., draught 29ft. 11in. The propelling machinery consisted of a geared turbine installation of about 3,500 s.h.p., with cylindrical oil-fired boilers; the machinery was supplied by the Central Marine Engine Works. With this installation the vessel had an average sea speed of 11-11½ knots, and was run in the Pacific service (Batavia-San Francisco) of her owners.

The above-mentioned speed, however, is not sufficient for this service to-day, and the vessel's owners were of the opinion that in order to face competition from owners running more modern vessels, an average speed of about 15½ knots was required. Thanks to systematic model tests carried out in the experiment tank, it was found that by lengthening the bow portion of the vessel by some 30ft. it would be possible, with modifications to the form, to attain the desired speed. The vessel has not only been lengthened, but at the same time the Maierform for the bow sections has been adopted. The model trials showed that in the lengthened vessel the desired average sea speed of 15½ knots could be attained with an engine output of about 7,000 s.h.p.

This very interesting conversion is another example which shows that it is quite practicable to modernize vessels that can no longer be run on an economic basis, through the modification of the hull and propelling machinery. Dutch owners have not been slow to appreciate these possibilities, and up to the present a total of about 20 vessels, aggregating some 170,000 gross tons, have been modified and fitted with new machinery in Holland.

The original turbine machinery of about 3,500 s.h.p. has been replaced by two high-speed Diesel engines, capable of developing, through Vulcan reduction gearing, a total output of 7,000 s.h.p. The steam-driven deck and engine-room auxiliaries have been retained, for which the necessary steam is supplied by one of the two original Scotch boilers; the other boiler serves as stand-by. For normal sea service, the steam for driving the steering engine and steam dynamo, refrigerating engine, feed pump and air pump, is supplied by two La Mont exhaust-gas boilers. The circulating pumps, as well as a sanitary and bilge pump, are driven off the main engines.

The two main engines are Fijenoord-M.A.N. double-acting two-stroke cycle airless-injection units. Each has six cylinders of 530mm. diameter and 760mm. stroke, and at 215 r.p.m. develops 3,685 b.h.p.; the piston speed is 1,080ft. per minute. At this output the number of revolu-

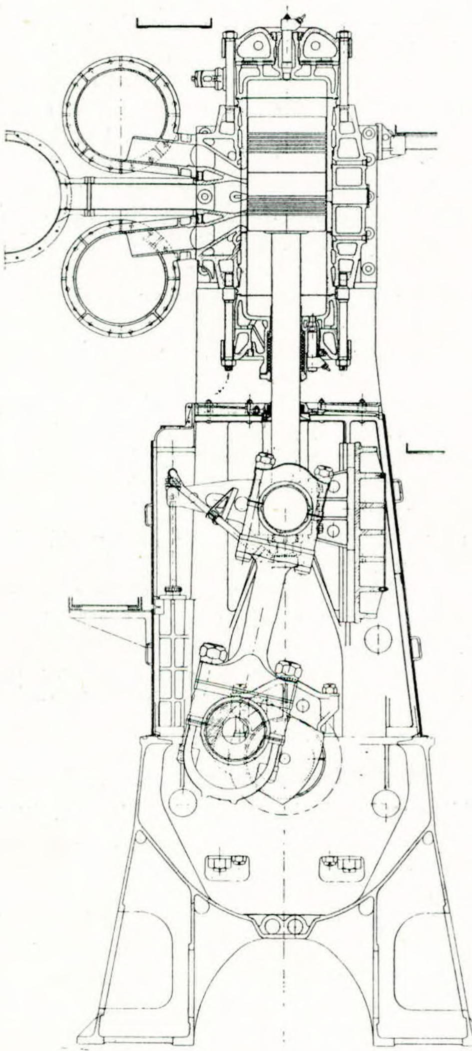


KEY.

- A Main engines.
- B Vulcan hydraulic gearing.
- C Scotch boilers.
- D La Mont exhaust-gas boilers with feed-water heaters.
- E Rotary sea-water pump
- F ,, Fresh-water pump.
- G ,, Lubricating-oil pump.
- H ,, Cooling-oil pump.
- K ,, Lubricating-oil pump for Vulcan gearing.
- L ,, Diesel oil supply pump.
- M ,, Bilge pump.
- N ,, sanitary pump.
- O Stand-by fresh-water pump.
- P ,, lubricating-oil pump.
- R ,, cooling-oil pump.
- S ,, lubricating-oil pump for Vulcan gearing.
- T Stand-by sea-water pump, auxiliary, also condenser circulating pump.
- U Fuel-oil supply pump.
- V Ballast pump.
- W Bilge pump.
- X Sanitary pump.
- Z Refrigerating machinery.
- AA Auxiliary condenser.
- BB Air pump.
- CC Drinking-water pump (steam driven).
- DD Drinking-water pump (motor driven).
- EE Feed pumps.
- FF Oil separator.
- GG Turbulo bilge and ballast water separator.
- HH Lubricating-oil purifier
- KK Lubricating-oil heater for purifier.
- LL Electrically-driven circulating pumps for the La Mont boilers.
- MM Auxiliary compressor.
- NN Fuel-oil transfer pump
- OO Coconut oil pump.
- PP Steam dynamo.
- RR Diesel-driven dynamo.
- SS Switchboard.
- TT Fuel-oil pumps.
- UU Fuel-oil heaters.
- VV "Starting" tank for boilers.
- WW Fan engine.
- XX Oil cooler for main engines.
- ZZ Oil cooler for Vulcan gearing.
- Aa Cooling-oil cooler for main engine pistons.
- Bb Fresh-water cooler for main engine cylinders
- Cc Starting-air vessels, main engines.
- Dd Starting-air vessels, Diesel dynamo.
- Ee Oil strainer for Vulcan gearing.
- Ff Oil strainer for main engines.
- Gg Turbulo Diesel-oil filter.
- Hh Lubricating-oil supply tank for Vulcan gearing.
- Kk Lubricating-oil settling tank.
- Ll Cylinder lubricating-oil measuring tank.
- Mm Diesel-oil daily service tank.
- Nn Head tank for cylinder cooling.
- Oo Diesel-oil daily service tank.
- Pp Lubricating-oil storage tank for main engines.
- Rr Lubricating-oil storage tanks for Vulcan gearing and cooling-oil storage tanks.
- Ss Magnetic filters for Vulcan gearing.
- Tt Fuel-oil settling tanks.
- Uu Shafting brake and hand-turning gear.
- Vv Electric turning gear.
- Ww Store.
- Xx Silencer.
- Zz Lubricating-oil drain tank (main engines).
- AAa Lubricating-oil drain tank (Vulcan gearing).
- BBb Cooling-oil drain tank (main engines).
- SB Starboard.
- BB Port.

Engine-room arrangement of the "Modjokerto", as a geared motorship.

tions of the propeller is 98 r.p.m., giving a reduction ratio of nearly 2·3 to 1. Scavenging air is supplied by a rotary scavenging blower, which is placed athwartships against the bedplate and is driven by a duplex Renold roller chain direct from the crankshaft. In the suction and delivery ports of the pump director valves are provided to ensure that the air current has always the same direction, irrespective of the sense of rotation of the engine. This Roots-type blower is similar in design to that employed on the engines of the "Königin Luise", described in the July issue. The usual M.A.N. loop scavenging system is used. In the middle



Section through M.A.N.-type main engine.

front of the cylinder beam, the fuel pumps are located, these being superimposed in two groups, one for the top and one for bottom side of the cylinders, so that both pumps of each cylinder are operated by the same cam. The injection-pump camshaft is driven by means of a duplex Renold chain from the after end of the crankshaft. This chain runs over two guide or jockey sprockets, one of which is fixed in position and drives the governor, while the other is movable for adjusting the chain tension.

The cylinders and covers of the main engines are cooled by fresh water, which is pumped in a closed circuit; the pistons are oil-cooled. For cooling the circulating water, the piston cooling oil, and the lubricating oil for the main engines and Vulcan gears, multitubular coolers are provided, the sea water which circulates through these also passing through the auxiliary condenser.

At the forward end of the crankshaft there is an auxiliary chain-driven shaft to which the fresh and sea-water cooling pumps, of Houttuin make, are coupled. The Stothert & Pitt lubricating oil and cooling-oil pumps are driven by an extension shaft which is attached to the scavenging air blower. As stand-by for the pumps driven off the main engines, steam-driven duplex pumps are provided, which are also used during manœuvring.

The lubricating oil for the Vulcan gearing and couplings is pumped by means of a gearwheel pump, driven from the port side pinion shaft, into a pressure tank placed in the engine-room casing, whence it flows to the couplings, the bearings, and the gearwheel sprayers. Aft of the Vulcan gear a Houttuin sanitary pump and a bilge pump are driven from the main shaft by means of a roller chain.

Performance of the White Combination Machinery

"The Marine Engineer", August, 1934.

The first set of White combination machinery to be completed by White's Marine Engineering Co., Ltd., Hebburn-on-Tyne, was installed a few months ago in the "Adderstone" (ex "Boswell"), a single-screw cargo steamship of 7,780 tons deadweight capacity and 400ft. length between perpendiculars. The White system of combination machinery consists, it will be recalled, of a small, light-weight, quick-running reciprocator which drives the same line of shafting as does the exhaust turbine, through single reduction gearing; Bibby couplings are provided in the system and the reciprocator used in the "Adderstone" is provided with forced lubrication.

The Scotch-type boilers of the vessel are fitted with White oil-burning equipment, Howden's forced draught, and the latest form of Sugden combustion-chamber superheater is employed, the boiler pressure is 200lb. per sq. in., and the final steam temperature in service has so far been 600° F. For further details of the installation readers are referred to the April issue, which included engine-room illustrations and an engine-room layout drawing.

The reliability of the new machinery of the "Adderstone" has now been thoroughly tested and proven to the satisfaction of its sponsors. The vessel left the Tyne on its "maiden" voyage after only a very short trial, and proceeded light ship to Cardiff to load. On this passage she met very heavy weather in the English Channel. After loading at Cardiff, she sailed for the River Plate, encountering very heavy weather in the Bay and bad weather generally up to the Cape Verde Islands. She arrived at Buenos Aires after a non-stop run of 26½ days. In the River Plate she discharged and loaded at a number of different berths, including up river, and was continuously under steam. She returned to Antwerp fully loaded, making the passage in 27 days, encountering several days of head winds and heavy seas. Immediately she was discharged the "Adderstone" proceeded light ship from Antwerp to the Tyne (Tyne Dock); this run was made on one boiler. She was only 48 hours in the Tyne, and left fully loaded for Genoa, steaming on one boiler only, enjoying fine weather to Gibraltar, which she passed 6 days 8 hours out from the Tyne. Between Gibraltar and Genoa she had one day heavy seas and (gale force) wind, and arrived at Genoa non-stop 10 days 9 hours out from the Tyne, having averaged 9·73 knots on 12½ tons of oil per day, equivalent to a North Country coal consumption of 19 tons per day. The vessel discharged in Genoa in two days and proceeded in ballast to Montevideo, still steaming on one boiler.

Throughout both voyages the White machinery functioned perfectly and gave no trouble, the rapid manœuvring qualities being specially commented upon by both deck and engine-room staff. In this connection it may not be out of place to quote an extract from a letter which the captain of the "Adderstone" sent to his owners: "The engines and boilers have given every satisfaction during the run", the letter states, "and I must again repeat my remarks of the past that from bridge control I obtain immediate and very effective response to engine telegraph orders, the vessel being a pleasure to handle".

The following figures relate to the "one-boiler-only" passage of the vessel to Genoa.

H.P. receiver pressure ...	196lb. per sq. in.
L.P. receiver pressure ...	47lb. per sq. in.
L.P. exhaust pressure ...	1·5lb. per sq. in.
Vacuum	28·5in.
Sea temperature	74° F.
Feed temperature... ...	230° F.
Fan pressure	1¼in.
Funnel gases temperature	365° F.

Oil Fuel Unit.

Pressure at burner	...70/75lb. per sq. in.
Temperature of oil	... 190° F.
Size of tips ...	... 76 thou.

Consumption of fuel oil...	12·5 tons per day, all purposes.
Equivalent coal	19 tons per day (North Country).
Specific consumption, all purposes	0·7lb. per i.h.p. per hour.
Specific consumption, main engines	0·57lb. per i.h.p. per hour.
Average power	1,640 i.h.p.
Average speed	9·73 knots.

The fuel oil used had a specific gravity of 0·991, and a calorific value of 18,300 B.th.u.'s per lb. All concerned are to be congratulated upon the results achieved.

The Institution of Welding Engineers.

Indicative of the growth of the Institution of Welding Engineers is the appointment of a full-time Secretary and the acquisition of new offices at 7/8, Holborn Hall, Grays Inn Road, London. This step was necessitated by (*a*) the rapid growth in membership during the last few years, and (*b*) the work entailed in consequence of the fact that the Institution is widely recognised as the body pre-eminently fitted, both by its achievements and its declared objects, to represent every welding interest in Great Britain.

Seldom a day passes when the office does not receive enquiries concerning membership and requests to co-operate or give information on one or other aspect of welding. The Council is alive to every movement which will further the interests of welding and welding engineers and the programme of lectures for the 1934-35 Session, which will be given at The Institute of Marine Engineers, is well in hand.

Membership of the Institution is now recognised as a necessary qualification of all who claim to be welding engineers or to speak for the welding industry; indeed, the Institution now occupies a position of vital importance to the industry.

Importation of Marine Engine and Boiler Parts.

"Shipbuilding and Shipping Record", 26th July, 1934.

The Finance Act of 1934 is now in operation. In its passage through Parliament, no alteration has been made in the important provisions affecting imported materials for marine engines and boilers, which we referred to in a recent issue and which are designed to remove the disability under which certain shipyards and marine engine shops have been suffering through the non-registration of certain premises under Section 11 of the Import Duties Act for the purposes of duty-free importation of shipbuilding goods.

Section 9 of the Finance Act provides that where certain specified goods are imported for use in the construction or repair of the boilers or propelling machinery of ships or of the accessories of such boilers and machinery, they shall not be subjected to any import duty under Part I of the

Import Duties Act. Duty-free admission under the section applies to the following list of goods, but the section contains procedure for the list being varied by Treasury Orders made on the recommendation of the Import Duties Advisory Committee :—

1. Iron or steel shafts and shafting (including turbine rotor shafts) and cranks and webs therefor.
2. Iron or steel connecting rods, piston rods and crossheads.
3. Iron or steel plates not less than one-eighth of an inch nor more than two inches in thickness.
4. Iron or steel shrouds for turbine gear wheels.
5. Iron or steel cylinder cover castings and piston castings.
6. Propeller castings, being complete propellers or blades or bosses.

Simultaneously with the passing of the Finance Act, the conditions laid down by the Commissioners of Customs and Excise for the administration of the new provisions have been embodied in Customs Notice No. 324, copies of which may be obtained free of charge from local Customs officers. At first sight the conditions appear rather formidable, but in actual practice the firms who will benefit should have no difficulty in operating the procedure.

The new arrangements do not supersede or limit in any way the provisions of Section 11 of the Import Duties Act for the direct importation of shipbuilding goods free of duty into registered shipbuilding yards. They should, however, benefit certain shipbuilding and marine engineering establishments, which in the past have had to pay import duties on goods covered by the present provisions, merely because of the non-registration of the premises to which the goods were imported for work to be done on them.

The Voyage of the "Arcgow".

"Shipbuilding and Shipping Record", 19th July, 1934.

The following letter from the commander of the "Arcgow" has been received by Sir Joseph Isherwood & Co., Ltd. :

s.s. "Arcgow",
at Buenos Aires.
June 16.

Dear Sir,

We got into berth and commenced discharge at 1 p.m. to-day and expect to complete on the 23rd.

I trust you will think with me that the performance just completed is a truly marvellous one, the results being as follows :—

Total time on passage ...	29 days 16hr. 22min.
Total distance	6,047 miles.
Average speed	8·5 knots
Coal consumed	275 tons all purposes
Consumption per 24 hours...	9·26 tons
Deadweight of cargo and bunkers only	7,075 tons

During several days of strong head winds and gales, the ship did remarkably well and pushed through high head seas without the slightest difficulty, and with good speed.

The whole passage was made on one boiler and the one man on the fires had a very easy job. I watched him clean his fire on several occasions and a full head of steam was maintained throughout.

We kept in touch with the "Arcwear" and there was remarkably little difference in the performance of each ship.

We probably picked up about 100-120 miles on her on the whole run from Ushant to Rocalada.

You will note that this consumption is slightly less than that given you in my daily message. It is difficult to get an accurate weight by spring balance at sea. We put 263 tons of coal into the cross bunker at Cardiff, and it was very easy to get the exact amount consumed with a remaining balance of 8 tons. This amount brought us up river to Buenos Aires and we are still using it. I am sure you will consider this a marvellous performance. It seems unbelievable even to those of us who have actually seen it.

The machinery worked without a hitch, and we were able to make a non-stop run.

Yours obediently,
(Sgnd.) E. R. Howe,
Master.

High Pressure Superheated Steam in Marine Turbines.

By A Marine Engineer.

"The Journal of Commerce and Shipping Telegraph", 9th August, 1934.

For general application the statement is true that there are limits, according to circumstances, beyond which it is unprofitable to advance in the direction of higher steam pressures and temperatures, but it is now also permissible to believe that for special cases there may be no limits beyond those naturally occurring—the critical pressure of steam generation and the durability of metals employed with superheated steam.

Larger types of steamships may be regarded as special because the weight of plant and the space occupied in relation to power developed are important considerations. The question arises as to whether modern marine practice in this country is not erring on the side of caution instead of leading with developments in connection with the utilisation of higher steam pressures and temperatures. Since the pioneer high-pressure turbine steamer "King George V." in 1926 used the highest working pressure of any vessel afloat (545lb.) not much advance has been made, and abroad such express steamers as the "Rex", Conte di Savoia", and the "Bremen" are equipped with comparatively moderate steam pressures and temperatures.

From Dr. G. Bauer's paper, read before the Hamburg Experiment Tank Society, it is very interesting to note that if he re-designed the plant of the "Bremen", after only six years, he would use drum-type boilers with a working pressure of 60 atmos. (882lb. per sq. in.) and steam superheated to 450° C. (842° F.) and thereby increase the horse-power 50 per cent., while reducing weight by 500 tons, space occupied by 17·4 per cent., and fuel consumption by 17 per cent. Such a statement from a recognised authority, which is well supported by technical data, cannot be turned aside; it will give many something to think about.

It is not many years since the late Sir Charles Parsons stated that when pressures of 1,000lb. became practicable at sea, the efficiency of the turbine would equal that of the Diesel engine; the "Uckermark" had been running since 1930, using steam pressures approaching 3,200lb. per sq. in. in the first instance, but latterly at 1,000lb., in steam generators of the Benson type, the lower pressure being a little above the working pressure of the turbine, and to which the higher pressure was formerly throttled down to. It is claimed for this steamer that its economy with oil burning is equal to that of the Diesel engine when the price of furnace oil is 25 per cent. cheaper than Diesel oil.

What is the advantage in raising steam pressures? It is simply that full advantage may be taken of the possibilities of superheating. By raising steam temperature alone, so far as may be practicable, an improvement in thermal efficiency of about 4 per cent. will attend every increase of 100° F., but if the pressure is raised correspondingly the increase in efficiency will be around 8 per cent. Assuming that not more than 850° F. can be arranged for the steam temperature, without using expensive alloy metals, what will be the corresponding pressure at which the turbine will operate? This, of course, does not concern the pressure at which it may be most economical to generate.

The matter is governed by the condition of the exhaust steam as regards its "wetness", or moisture content. An average of 10 per cent. is usually considered to give the best efficiency consistent with safe working. Power is obtained from the region of the dryness fraction as well as from the superheat range, and if the exhaust is too dry this is a sign that heat is passing to the condenser.

In marine practice, resuperheating of the steam at any stage of its passage through a turbine is inadmissible, or difficult to arrange, and, therefore, the steam temperature at its working pressure must be such that, when all changes have occurred, the final exhaust is in the desired state. There is, therefore, a definite relation, according to turbine design and arrangement, between pressure and temperature of the steam at the turbine stop valve.

In the paper referred to, Dr. Bauer gives proofs that turbine operation is highly efficient at working pressures between 60 and 90 atmos. He considers that a normal turbine set, with four steam tapping stages for feed-water preheating (but no resuperheating) gives an exhaust 10 per cent. wet from steam at 60 atmos. and 450° C. In round figures, this may be called 900lb. pressure and 850° F., without affecting the wetness value. In land turbines, and without resuperheating, it would be possible to associate a pressure of 650lb. with a steam temperature of 850° F., but the marine turbine is unavoidably less efficient, which has the effect of passing drier steam through, and this must be counteracted by increasing the pressure.

Obviously, everything depends upon the turbine efficiency, but on the basis of the wetness figure given above a pressure of 1,000lb. would give an exhaust wetness of nearly 11 per cent., and 800lb. pressure would give an exhaust a little over 9 per cent. wet. The conclusion is that to profitably utilise the maximum safe superheat that can be carried without the use of special alloy metals, the working pressure at a temperature of 850° F. should be between 800 and 1,000lb. per sq. in., according to turbine efficiency. On the other hand, with 800° F. as the temperature limit a minimum pressure of 600lb. under equal conditions could be used, but with a loss of 4 per cent. in thermal efficiency.

This raises the problem of steam generation at the higher pressures. There are two alternatives. One is to use stronger water-tube boilers at increased cost, or the more modern drum-boilers now being developed, types which have a reasonable water reserve; the other is to adopt the small-tube types, to which extra pressure makes no difference except to increase the rate of heat transfer. Formerly, the latter type was a doubtful proposition for marine service on account of salts—with impure water—being deposited in tubes in the zone of intense combustion, but this trouble has been overcome by arranging the tubes so that deposits, if any, occur in the lower temperature ranges of the flue gases.

Then, while it was formerly considered essential for proper functioning that a pressure near the critical one of 3,200lb. should be carried, these steam generators can be economically used at present down to 1,000lb. per sq. in., and an automatic control can be arranged to vary the steam pressure to suit the load, while the temperature remains more or less constant. It should be mentioned that any deposits in tubes are easily blown through sectionally without interfering with steam generation. It is interesting to note that the two new Hapag-Lloyd, 17,000-ton, turbo-electric liners are being fitted with these boilers.

Doubtless, the evolution of steam generators of this and similar types will do much towards deciding the adoption of higher working pressures in order that superheat may be added to the best advantage. The turbine is ready for operating at the pressure and temperature, and there is no difficulty in arranging superheaters and connections for even higher temperatures than the proposed limit; the boiler or steam generator seems to present more difficulty.

It may be conceded that normal types of water-tube boilers can be arranged to suit pressures up to the limit arranged for turbine operation as referred to, but in favour of steam generators for evaporating at still higher pressures there is the fact that the economy in fuel consumption, due to raising pressure alone, only becomes gradually apparent as a pressure of around 750lb. is exceeded—a statement which would not have been made so readily only a few years since.

It must be recognised that a new era of steam is being entered. Several types of high-pressure steam generators might be mentioned which are now being developed; perhaps the Loffler boiler, which circulates steam at high pressure instead of water, is unique, and it certainly gets over the difficulty attending the use of impure feed water. The most scientific steam generator is, undoubtedly, the Velox, but it rather concerns the use of intermediate pressures.

In any discussion on these problems the opinion is often expressed that while the later developments in the use of superheated steam at high pressures may possibly be utilised to advantage in steamers of the super-liner class, they can hardly be adapted for general service, but when all has been said if it can be established that a simple type of high-pressure generator can satisfactorily operate under marine conditions, and the evidence so far is favourable, there appears to be no reason why the arrangement should not be adopted in many steamers to render the use of high-temperature steam an economical proposition. And as between 700° F., which is generally used, and the proposed temperature of 850° F., the expected 12 per cent. improvement in thermal efficiency or 10·7 reduction in fuel consumption is evidently worth while if high boiler costs can be avoided.

The First Parsons Steam Turbine.

"The Engineer", 20th July, 1934.

In any large collection of exhibits such as are contained in our national museums, individual objects of outstanding importance are sometimes apt to be overlooked when placed in correct chronological position amongst numerous similar exhibits. This difficulty can be solved by the inclusion in the architectural scheme of a special "Hall of Honour", where exhibits of supreme historical importance only are permanently housed, but, naturally, this leaves a serious gap in each collection showing development unless duplication is resorted to. Another method used is to display an "Object of the Week", but besides the question as to whether the period is really long enough it seems clear that the fifty-two objects shown during the course of a year must vary greatly in their degree of historical importance. In a scientific museum a successful method is to give an exhibit special prominence, say, for three months, at a time when attention is focussed upon it, such as the centenary of the birth or death of the inventor, or the jubilee or centenary of the apparatus itself. We are glad to see, therefore, that a special exhibition has been arranged at the Science Museum to mark the jubilee of the first Parsons steam turbine and high-speed generator, which were constructed and patented in 1884. These famous machines, which inaugurated a new era in the generation of power by steam, are now being shown for several weeks in a prominent position near the main entrance of the Science Museum, South Kensington, where they have been carefully preserved during the past 44 years.

Newcastle Museum of Science and Industry.

"Engineering", 27th July, 1934.

Due to a movement started early in 1930 by the late Hon. Sir Charles Parsons, Dr. Wilfred Hall and others, who, in conjunction with the North-East Coast Institution of Engineers and Shipbuilders, approached the Corporation, it was finally decided to install a permanent exhibition in the Palace of Arts which was part of the old exhibition buildings on the Town Moor. This Museum was opened on the 20th inst. by Mr. R. J. Walker, President of the North-East Coast Institution of Engineers and Shipbuilders. The exhibits relate essentially to the industries of the district, especially engineering, shipbuilding and other allied industries, and already a large collection of historic and other matter has been made. Thus there is a model of the Comet, one of the first locomotives made about 1834 by Messrs. R. & W. Hawthorn, Leslie & Company, and alongside is a model, to the same scale, of one of this firm's modern locomotives. There is also a most complete set of models of ships from early times to the present day, including one of the "Great Britain", the first steamship to cross the Atlantic. There is also a model of the "Turbinia", and alongside is the original model, about 2ft. long, by which Sir Charles Parsons determined the best form of hull and the power required to drive it. A number of early Parsons turbines are also shown. Another exhibit is the first breech-loading gun, made by the late Lord Armstrong, as well as his first hydraulic engine. What is probably one of the most complete collections of early incandescent electric lamps in existence has been made by Mr. J. H. Holmes, and among the many notable lamps is one of the first, made by the late Sir Joseph Swan. Early switches, instruments and dynamos are also exhibited. Not only are early engineering products shown but many recent ones, such as a Reyrolle ironclad switchgear, a model of a modern telephone exchange, a model of a grid sub-station, and many others. A large model of the River Tyne from the mouth to above Newcastle is also on view. There is little doubt that this exhibition will prove of immense advantage to the district not only by illustrating the part it has taken, and is taking, in engineering development, but also by serving as an indication of what may be expected of it in the future. Mr. E. W. Swan has been Hon. Curator since the inauguration of the scheme.

The Engineer and Modern Civilisation.*

By Sir Frank E. Smith, K.C.B., C.B.E., D.Sc., F.R.S.
"Engineering", 20th July, 1934.

Before science had gained any appreciable status the engineer had constructed magnificent roads, built fine waterways, erected massive cathedrals, extracted metals from their ores, invented valuable tools, such as the lathe, and built carriages and ships. One can but conclude, therefore, that either consciously or sub-consciously, he followed the principles which nature pursues in creating her own structures. If we examine one of nature's structures such as that of a corn stalk, or the shell of a snail, we observe that they contain the minimum of material to withstand the stresses to be borne, and the most expert mechanical engineer of to-day, if he possessed complete knowledge of the mechanism of stress and was aware of all the properties of all materials, would probably be able to design nothing so good and certainly nothing better for the purpose than the shell of a snail. No doubt our engineer forefathers possessed also that wonderful intuition, which so many engineers possess to-day, and no doubt they profited by their failures as well as by their successes.

The engineer of to-day is, however, distinguished from his predecessor by the knowledge that the properties of any material depend on the properties of the ultimate units of which it is built. Moreover, he seeks to find out why there is this dependency, knowing that with such information he will be able to produce even better structural materials than those now in use. The engineer of to-day is therefore better defined, not as one who moulds things with his hands, but as one who also studies nature and moulds things in accordance with the facts learned.

As for modern civilisation, it is impossible to sum it up briefly. It is a very complex structure made up not only of the contributions of the engineer, but also of much less easily defined contributions of an idealistic character. It is the blend of these two cultures which forms the civilisation of to-day, but the materialistic culture is much more advanced than ever before, and it is this which distinguishes our modern civilisation so markedly from that of a hundred years ago and even from that when this Institution was formed fifty years ago.

* Seventh Quadrennial Gustave Canet Memorial Lecture, delivered before the Junior Institution of Engineers on Thursday, 28th June. Abridged.

The composite work which makes up our civilisation looks quite different when surveyed through the spectacles of an electrical, a civil or a mechancial engineer; and it is as well to examine the picture more carefully to see if there are any outstanding features not readily seen by the untrained eye. The electrical engineer would emphasise that in the last fifty years the output of electrical machinery in Great Britain alone has increased from zero to £21,000,000 in 1930. He would point out how the work of Maxwell, Marconi, Lodge and others has led to outstanding developments in the field of communication and would remind us that the gasfilled lamp represents the results of more research on the structure of matter than any other single article in common use. Finally, he would point to the 4,000 route miles of the grid over which 13,500,000,000kW. are transmitted every year. The civil engineer would describe a very different kind of picture. He would remind us of the great harbours, the roads, the railways and the bridges he has constructed. He would point with pride to such examples of his work as the dam and canal systems in the Sudan and India and to the reduction of epidemics and diseases resulting from improvements in water supply and sanitation. The mechanical engineer would look at the materialistic picture with the eye of a general contributor, since he produces the machinery used by others. Although the wheel and axle, the lever and pulley and the screw were known in prehistoric times it is not their invention that has affected our modern civilisation. It was not until Maudslay devised the slide-rest that the latter became an instrument of precision and it was the exact scientific screw system developed by Whitworth and the true straight edge and the true plane surface, which have led to the development of modern machines and modern tools. Without these if the internal-combustion engine had been invented it could not have been made, even if steel and all the necessary alloys had been available.

The question whether there are any outstanding features in this era which distinguish it from former eras can, therefore, be answered by saying that the great characteristics of the age in which we live are the applications of non-manual power to machinery and the abundance of food. In examining the picture of the prime mover, I shall look at it through the spectacles of the scientist and endeavour to find out why the industrial revolution came when it did and not thousands of years before. The reason is that knowledge of the physics of gases and liquids and of pressure was almost non-existent in those days and without such knowledge progress was impossible. It was Pascal, the mathematical physicist, who showed that a pressure exerted upon a fluid is transmitted in all directions, and it was Torricelli who discovered that the atmosphere exerted a pressure. This was one of the great discoveries of the seventeenth century.

Boyle also made a distinct contribution to the knowledge required for steam engine practice when he proved the relationship between the pressure and volume of a constant mass of gas. The knowledge obtained by Torricelli and Boyle was used by Papin, who observed that a small quantity of water made a large volume of steam, and that this steam appeared to have all the elastic properties of air. I can but surmise that Papin concluded that if he condensed the steam a vacuum would be produced and that water might thus be caused to rise to a higher level by the pressure of the air. In this way atmospheric engines such as those of Worcester, Savery, Newcomen, and the early models of Watt arose. It was only when steam was used at high pressure and allowed to do work by virtue of its elastic properties, as in Trevithick's engine, that there was departure from the simple atmospheric principle.

With such scant knowledge of the internal mechanism of gases the nineteenth century began. The scientist looking at the picture of that period sees over 10,000 steam engines in use in England developing in all about 200,000 h.p. And all these engines were based on a knowledge of atmospheric pressure and the elasticity of gases, though Carnot had already written his wonderful paper on the motive power of heat. There was, in fact, practically no knowledge of the nature of heat, though as far back as 1756 Black had discovered latent heat. He had pondered over the slowness with which ice melts and water disappears in boiling and concluded, since the "caloric" put into the boiling water did not raise its temperature, that the heat was latent. Watt, who was in close contact with Black, measured the change of volume when water vaporised. He no doubt saw that the atmospheric engine worked best when the cylinder was hot and the condenser as cold as possible, and hence concluded that the best efficiency was obtained when the heat was introduced at a high level and rejected at the lowest possible level. Nearly fifty years after Black's discovery of latent heat Rumford made a great discovery that the minute particles of matter were in vibration and that this vibratory motion was heat. Heat was not a material substance; it was a mode of motion. There was thus an explanation of why water under reduced pressure lost heat, and fell in temperature as more and more vapour was formed and removed. On evaporation a particle of the vapour possessed more energy due to its motion than a particle of the liquid at the same temperature and of the same mass. Hence the water cooled. To-day, many of our large refrigerating machines operate on this simple principle.

But the greatest engineering discovery of the nineteenth century was made by Joule and others. This was that heat and work are mutually convertible at a fixed rate of exchange; the law which is known to engineers as the first law of thermodynamics. The new idea was that the vibratory motion of the minute particles of matter, which we call heat, were integrated through an appropriate medium into a larger single motion, and thus a means of doing work was provided. The old idea that heat was indestructible was completely overthrown, and it was realised that when work was done by a steam-engine heat passed out of existence. If, on the other hand, work was done to produce heat a definite quantity of heat came into existence for each unit of work expended. It is difficult to realise that this principle of conversion of heat into work was unrecognised in the early days of Kelvin, whom many here, including myself, knew quite well. Engineering could never have developed in the way it has, had this fact never been discovered.

It is in this way that the scientist sees the birth of the prime mover. To-day, the knowledge of the internal mechanism of gases is fairly complete, the nature of heat is known, and Carnot's cycle of operation is fully appreciated. All that is necessary to convert heat into work or work into heat is a suitable medium. Steam was the first medium chosen, flame or the heated products of combustion has also been employed, mercury has been experimented with, and ammonia and sulphur dioxide are used for special purposes. In all cases the medium is in motion and it is the total heat, or total internal energy of the medium, which changes during the working cycle. In the same way as the first steam engine was an atmospheric one, so the first "gas" engines were atmospheric. There was, however, no internal-combustion engine in the modern sense until some years after Joule had made his famous experiments. It was then apparent that the energy of chemical decomposition and combustion which takes place when an explosion occurs could be converted into work and that a definite relationship existed between the chemical energy and the work it was possible to produce.

The story I have told will appear far too simple to explain why the industrial revolution started when it did and not a thousand years before. It may be that the engineer, with that wonderful intuition of which we are all aware, would have developed the steam engine without any knowledge of the properties of gases and with no knowledge of what heat is and what happens when chemical combination takes place. But the progress would have been very slow and I fear the efficiency of the engines would have been low. There is little doubt that the early engineers sought scientific knowledge on gases and utilized it in their designs, and there is even less doubt that in modern designs the thermodynamical expert and the designer are either the one and same person or are in intimate contact. In that great engineer, Sir Charles Parsons, we had the combination of the two. The defects of the steam reciprocating engine were clear to him and he applied all his inventive genius to bring his turbine nearer and nearer to one working on Carnot's cycle, than which none can be more efficient. Parsons triumphed because he was not only a great engineer but a great physicist. He knew thermodynamics better than most physicists of his generation, and the result of beautiful design in closest accord with thermodynamical principles can be seen in the great steam turbines in our electrical generating stations.

Let us consider the effect of the discovery of the prime mover. To-day, in factories, industrial undertakings and electricity supply undertakings in this country, steam reciprocating engines and steam turbines develop more than 20,000,000 h.p. On such a basis, every man, woman and child in this country has, on an average, ten slaves working for him in the factory and power stations. In addition, probably another 20,000,000 h.p. are produced on the railways for the transportation of people and goods, and we must add to this the power of internal-combustion engines, of which a total of 27,000,000 h.p. are used in motor vehicles alone. This account of the prime mover is, of course, totally inadequate. Many of the men I have talked about are not even classified as engineers, while some of the really great engineers, like Boulton, Stephenson, Otto and Daimler, have not even been mentioned. As some form of compensation, I propose to sound a note of praise about the latest large power station which the engineer has erected. I refer to the Battersea power station, which is one of the bright spots in our industrial England, inasmuch as coal is burned and power produced practically without smoke. In fact, if I were asked to-night where the application of science to engineering has reached its highest stage of development, I should instance the Battersea power station. Here, indeed, is a fine example of the engineer's service to man.

To pass from the prime mover to food, the prime necessity of life, may seem a very big step. Indeed, so far as our food supply is concerned, many of you may wonder what particularly notable achievements, apart from transport, are to be credited to the engineer. But it is justified, since from the same principle of the convertibility of heat into work and the realisation that heat was a mode of motion, it followed that if vapour given off by water was continually removed it would not only cool, but would freeze owing to the loss of energy which had occurred. As in the steam engine the first refrigerating machine was an atmospheric one, and in the same way as the development of the steam engine was in the direction of increased pressure, so was that of the refrigerating machine. The application of this principle in the hands of the engineer and biologist has revolutionised the feeding of the people, until every day, on an average, each person in this country consumes 6oz. of food which has been subjected to refrigeration. In ships alone the freezing space carrying cold-stored produce to this country amounts to about 100,000,000 cub. ft., and the capacity of the public cold stores of Great Britain is about one-half of this. Half a million tons of ice are made by engineers for domestic and commercial land purposes, and 750,000 tons are made for the sea-fishing industry. There is, however, an even more interesting feature of food preservation than refrigeration. To preserve apples the external conditions must be such as not to stop them taking oxygen from the air and giving out carbon dioxide and other products. If the atmosphere surrounding the apple contains too much carbon dioxide it will decay, but this change can be delayed by maintaining the carbon-dioxide content at a rather higher value than that of the normal atmosphere. The fruit subject to a certain amount of refrigeration is therefore contained in an atmosphere with a certain percentage of carbon dioxide, the exact percentage varying for different kinds of apples. The carbon dioxide and heat is produced by the apples themselves; both must be removed by appropriate ventilation if suffocation is to be prevented. Similarly, beef can be preserved for a long enough time to bring it from Australia by storing it in a chilled atmosphere containing 10 per cent. of carbon dioxide.