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Pumps for Marine Service.

READ AT A MEETING OF THE JUNIOR SECTION

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On Thursday, November 9th, 1933, at 7 p.m.

THIS paper endeavours to give a general survey of the various pumps that are used for marine work, reference being made only to those commonly installed on board steam or motor ships. Special pumping units, such as those used for dredgers, fire fighting vessels, docks, etc., are not included. No attempt is made to go into any great detail of design; indeed, this would be impossible within the limits of this paper and detailed information on this point can always be obtained from manufacturers' publications.

As far as can be ascertained, very little has been published in the way of a general survey of this very important subject, and it is often found that papers written on ships' auxiliaries in general make only a meagre reference to the pump installation. This certainly should not be so, as the pumps form a very important part of the ship and engine room equipment, as it is hoped this paper will reveal later on. To a large extent the safety of passengers and crew depends on pumping machinery, as for example when a fire or collision occurs, whilst the proper functioning of the main and auxiliary engines is dependent upon a number of different types of pumps for various duties. It will be appreciated, therefore, that the pumping installation is of vital importance and absolute reliability must be the fundamental principle of design.

The earliest marine pumps were those used on sailing ships for pumping out bilges or holds, these being manually operated by the ship's crew, and have formed a favourite subject for artists' pictures (probably labelled "All hands to the pump" or some such title) depicting the crew frantically pumping to save their vessel from sinking.

With the advent of steamships, mechanically-operated power pumps came into use, these being of the reciprocating or plunger types, the majority worked by levers from the main propelling engine. Some of course operated independently, as for example the boiler feed pump, mention of which immediately conjures up visions in the mind of any old sea-going engineer of our old friend the direct-acting feed pump. This wonderfully-reliable and widely-used pump must surely take a first place in our list! Their characteristic drawn out wail rising from a low to a high note must have soothed many thousands of marine engineers to sleep—when not on watch, of course!

The use of independent steam reciprocating pumps rapidly grew, modified and improved forms being still widely used on board ship for a variety of purposes.

Owing to the reciprocating pump being limited in its capacity and the progress made in the development of the steam engine, the centrifugal type became general during the second half of last century for supplying the large quantities of cooling water necessary for condensers and, except in very small installations, this type is now invariably used for this purpose.

Up to comparatively recent years, the above mentioned pump units (with of course constant improvements, chiefly in the way of higher efficiencies and running speeds) continued to be used; but with the advent of the motor ship, the electrically-driven pump was introduced. This was found to have many advantages over steam drive so that to-day, not only do Diesel engine-propelled vessels have their pumps necessarily driven by motors, but most of the larger steamships adopt the electric drive. This is made possible by the large generating sets which are fitted on board providing an ample supply of electric power.

The design of any particular pump depends to a large extent on the kind of prime mover used for driving it. Perhaps this can be best understood by reference to Fig. 1, which gives in tabulated form some of the chief types of pumps used on ships and the means of driving them.

TABLE SHEWING TYPES OF PUMPS WITH VARIOUS KINDS OF DRIVE.

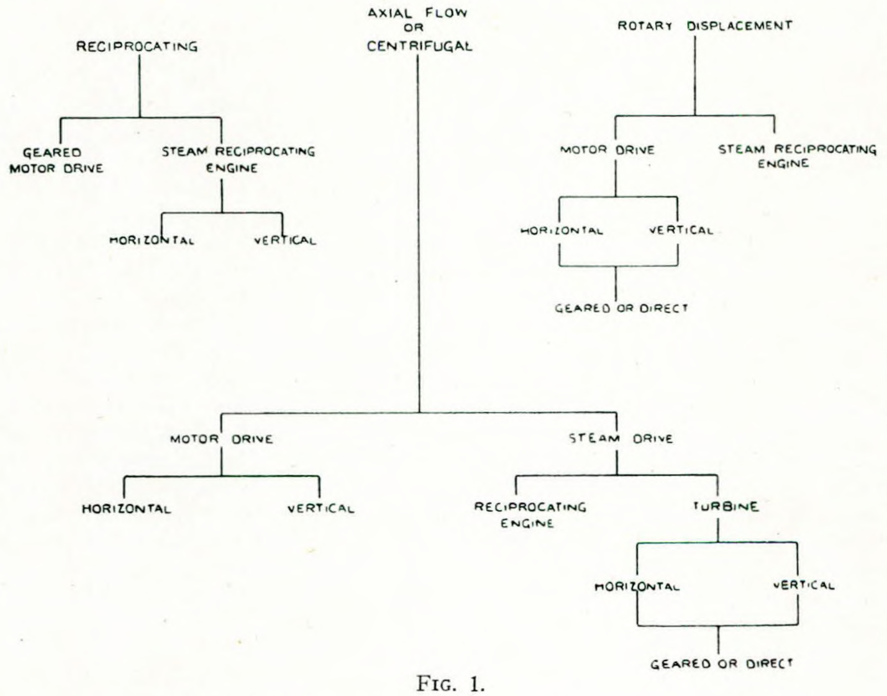


FIG. 1.

A rough guide as to which of these are generally adopted is as follows :—

On small steamers.—A steam engine-driven centrifugal circulating water pump. Direct-acting pumps with steam drive.

On large steamers.—A steam engine, steam turbine, or motor driven circulating pump for the condenser. Motor-driven centrifugal, reciprocating, positive displacement, or steam reciprocating pumps for other purposes.

On motor ships.—Motor-driven centrifugal, reciprocating, or positive displacement pumps.

It will be noted that the drive is always either by steam or electric motor. There is no record yet of a Diesel engine being used, but it is possible this may come some day. Belt or chain drive is occasionally used for small units.

In order to give some idea of what the total complement of pumps consists of, Fig. 2 gives a list of all the principal pumps installed on a large steamship and a motor ship. The "Strathnaver" or "Strathaird" of the P. & O. Company, propelled on the steam turbo-electric system, and the motor ships "Georgic" or "Britannic" of the White Star Line have been taken as examples. All these vessels are new and the installations represent thoroughly typical and modern practice. It will be noted that similar pumps are required for either type of vessel, the steamers having in addition pumps for dealing with boiler feed and condensate. The figures given under the column headed "B.H.P." represent the total horse power required to drive each set of pumps at their rated full load output. In practice there is usually a margin allowed, so that each pump normally runs at a lower output and the horse power absorbed is less than that stated. Furthermore, there is a number of standby pumps so that only a proportion of each class of pump is run at the same time. Taking an average diversity factor, it is probable that the actual horse power required for the whole of the pump installation when the vessel is running at full power is from a half to two-thirds of the total given; even so, the power required is a very respectable figure and represents a large proportion of the ship's auxiliary load. On larger liners, like the "Empress of Britain", where the s.h.p. is 60,000, the number and power of the pumps are greatly increased. The total horse power installed for the main circulating pumps alone is over 1,000, and the total number of pumps on board is nearly 100.

Types of Pumps.

It is now proposed to examine the various types of marine pumps and the functions they perform. Fig. 3 shows in diagrammatic form some of those which are more commonly used. The liquids that require pumping are water (salt and fresh), brine for refrigeration work, fuel and lubricating oil, whilst in connection with the condenser on a steamer, there are air and vapour to be dealt with.

The various functions or duties are split up into groups, each of which requires a somewhat different design. Circulating water pumps for supplying the cooling water to condensers on steamships or to the jackets of Diesel engines on motor-ships, etc., require to deal with large quantities of water, hence the almost universal use of a centrifugal type of pump. The next group are general service pumps, etc., which require varying quantities, depending on the size of vessel, with moderate discharge heads. Like the circulating pumps, sea water is dealt with and as there is a positive head on the suction side the pumps are always primed when starting up. For bilge, ballast, and fresh water work the pumps have a negative head on the suction side, as the supply comes from some point (bilges or ship's tanks) situated below the level of the pump, so that some means has to be introduced for priming a centrifugal pump before it can commence operations. A reciprocating pump is, of course, naturally self-priming. The boiler feed pump has to deal with high pressures on the delivery side and varying quantities. The extraction pump for the condensate has a high suction lift, due to the vacuum in the condenser, against which it has to work.

Dealing with media other than water, cold brine has to be circulated round the insulated holds and the various cold cupboards for stores, etc. Fuel oil, especially when very cold, is difficult to deal with, and whilst centrifugal pumps have been successfully used, one or other of the alternatives mentioned is usually employed. Transfer pumps lift the oil from the ship's storage tanks to the daily service tank, whilst pressure pumps create the necessary head at the furnace oil burners.

Quite a different problem is involved with cargo oil pumps. These are used for pumping out a cargo of oil (frequently crude oil) from the holds of a tanker, and as a supply of steam is necessary, even on a motor tanker, for warming up the oil before pumping, a direct-acting steam-driven reciprocating-type of pump is extensively used. A positive displacement pump can also be employed for this duty.

For supplying lubricating oil to a Diesel engine or steam turbine a moderate pressure head has to be maintained and all types of pumps can be utilized; each of these has its own special merit, though the quantity and other conditions often govern which is the best type to use.

Coming now to the last item on the list, namely, air, an entirely different medium has to be dealt with. The air and non-condensable vapours in a condenser have to be extracted and got rid of, and modern practice is to use a steam ejector.

Detailed particulars and illustrations of these various types of pumps will next be given.

TABLE SHEWING TOTAL COMPLEMENT OF PUMPS
INSTALLED ON TYPICAL STEAM & MOTOR SHIPS

	S/S "STRATHNAVER" OR "STRATHAIRD" 22500 TONS. 28000 S.H P			M/R "GEORGIC" OR "BRITANNIC" 27750 TONS 20000 S.H P		
DUTY	DRIVE	Nº OFF	TOTAL B.H P	DRIVE	Nº OFF	TOTAL B.H P
MAIN CIRCULATING (SALT)	MOTOR	4	620	MOTOR	4	148
" " (FRESH)	—	—	—	"	2	64
AUX CIRCULATING (SALT)	MOTOR	2	146	"	2	74
" " (FRESH)	—	—	—	"	4	40
EMERGENCY BILGE	MOTOR	1	42	"	1	25
FIRE AND/OR BILGE	"	4	69	"	2	52
FIRE AND/OR BALLAST	"	1	52	"	3	111
SANITARY AND/OR BATH	"	2	124	"	2	90
HOT SALT BATH	"	1	11	"	2	20
FRESH WATER	"	5	39	"	3	33
MAIN ENGINE LUBRICATING OIL	"	4	64	"	6	408
OIL FUEL TRANSFER	"	2	24	"	6	52
REFRIGERATION BRINE	"	4	53	"	4	31
" CIRCULATING	"	2	20	"	1	9
OIL FUEL PRESSURE	MOTOR & STEAM	5	17	"	—	—
MAIN BOILER FEED	STEAM TURBINE	2	110	"	—	—
AUX. " "	STEAM RECIPROCATING	2	20	"	—	—
EXTRACTION	MOTOR	5	74	"	—	—
TOTAL		46	1485		42	1157

FIG. 2.

Circulating Cooling Water Pumps.

These comprise the largest class of marine pump. As previously mentioned, it has been the practice for many years to have them of the centri-

TABLE SHEWING TYPES OF PUMPS USED FOR DEALING WITH VARIOUS KINDS OF LIQUIDS & AIR.

MEDIA	FUNCTION	TYPES OF PUMPS USED.
WATER	COOLING WATER (CIRCULATING PUMP)	CENTRIFUGAL AXIAL FLOW
	GENERAL SERVICE FIRE SERVICE SANITARY BATH SWIMMING POOL	CENTRIFUGAL (NON SELF PRIMING) RECIPROCATING
	BILGE BALLAST FRESHWATER	CENTRIFUGAL (SELF PRIMING) RECIPROCATING
	BOILER FEED	CENTRIFUGAL RECIPROCATING
	EXTRACTION (CONDENSATE)	CENTRIFUGAL RECIPROCATING
BRINE	CIRCULATING	CENTRIFUGAL
FUEL OIL	TRANSFER PRESSURE	CENTRIFUGAL RECIPROCATING POSITIVE DISPLACEMENT
	CARGO	RECIPROCATING
LUBRICATING OIL	CIRCULATING	CENTRIFUGAL (SELF PRIMING) RECIPROCATING POSITIVE DISPLACEMENT
AIR	EXTRACTION	STEAM EJECTOR

FIG. 3.

fugal type. Fig. 4 shows a section drawing of a double suction centrifugal pump. In this type the water enters on opposite sides of the impeller and thus theoretically the pump is self-balancing. Actually, centering collars are fitted to the shaft, to ensure that the impeller will assume its correct position in relation to the casing. With a single-suction pump some form of thrust bearing has to be introduced. Each type has its own special advantages and it cannot be said that either is inherently superior to the other.

Fig. 5 shows a typical set of characteristic curves for a non-overloading centrifugal pump at constant speed. As is well known, centrifugal pump design is governed by the following fundamental laws :—

1. The quantity varies directly as the speed.
2. The head generated varies as the square of the speed.
3. The power absorbed varies as the cube of the speed.

It will be noted that three curves are plotted, *viz.*:—

Head curve labelled (A).
Efficiency curve „ (B).
Power „ „ (C).

The design duty of the pump was 14,500 gallons per minute with a total head of 31ft. The efficiency was 80 per cent. at full load. From curve (A) it is seen that as the head diminishes the quantity automatically increases and *vice versâ,* until with zero quantity (*i.e.,* the delivery valve closed) a maximum head of 40ft. is generated. The efficiency curve (B) shows that with a well-designed pump the apex of the curve is flattened over a range of head and quantity readings, although this range is somewhat limited in a non-overloading type of pump. It will also be observed from curve (C) that the power absorbed at the "cut-off" point is 100 h.p., or approximately 59 per cent. of normal full power; this energy represents friction and churning losses in the pump.

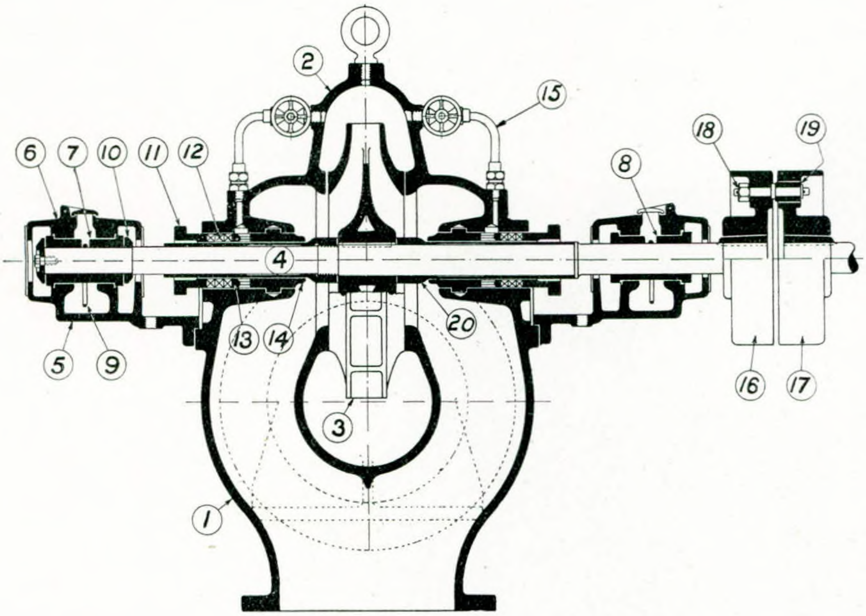
Up to about twenty years ago the steam-operated reciprocating engine was exclusively used for direct coupling to centrifugal circulating pumps, the "open" engine being the first type, followed by the "enclosed" forced-lubrication engine. Both types are still extensively employed to-day, especially in the smaller class of steamer, and adapt themselves extremely well for the slow-running pump.

During recent years, steam turbines have been used a good deal, these forming a light and compact unit. In order to get a good steam economy it is necessary to run the turbine at a high speed. Gears are introduced between the turbine and pump to obtain the efficient lower running speed of the latter. A modern example is given in Fig. 6, which shows a horizontal set. Limitations of floor space sometimes preclude this arrangement, in which case a vertical unit can be used and is particularly favoured for naval work.

With electric motor drive the motor is usually directly connected to the pump and Fig. 7 shows a good example of a large vertical set. This particular pump delivers 15,000 gallons of water per minute against a head of 17ft.

Another illustration is given in Fig. 8 showing a horizontal motor-driven pump.

Variations in speed on circulating pumps should be allowed for, as the quantity of water they have to deliver varies according to the load on the main



Item	Description
①	Casing (Bottom Half)
②	Casing Top Half
③	Disc
④	Spindle
⑤	Bearing Body
⑥	Bearing Cap
⑦	Bearing Bush (Thrust)
⑧	Bearing Bush (Journal)
⑨	Oil Ring
⑩	Thrust Collars. (1 Pr.)

Item	Description
⑪	Gland
⑫	Packing
⑬	Lantern Bush
⑭	Dummy Bush
⑮	Water Sealing Pipes
⑯	Pump Half Coupling
⑰	Motor Half Coupling
⑱	Coupling Bolt.
⑲	Coupling Bolt Bush.
⑳	Spindle Liners

FIG. 4.—Section through a double suction centrifugal pump.

engine and also to the sea-water temperature.

Immense quantities of water are required on large vessels for cooling purposes. Some pumps have recently been made in this country each of which will be capable of delivering 10,000 tons of sea water per hour. These will probably be the largest single pumps afloat used for condenser circulating.

A comparatively recent development is the "axial-flow" pump, a horizontal steam turbine-driven example of which is shown in Fig. 9. This pump is extremely simple to construct and consists of an impeller, shaped on the lines of a ship's propeller, running with large clearances inside the casing. Guide vanes are used to direct the flow of water past the impeller. The efficiency is about the same as a centrifugal radial flow pump. Two special advantages accrue with this pump for ship work, one being that it can be run at much higher speeds than the centrifugal type for corresponding duties, thereby requiring a smaller driving unit, and the other is that the shape of the casing together with the inlet and outlet branches allow of a very nice layout in a ship and obviate awkward bends in the run of the circulating water piping. Actually, the pump casing is only slightly larger in diameter than the connecting suction and discharge branches, whilst the axial length is less than the diameter with consequent saving in weight and space. The illustration shows a steam turbine drive directly connected to the pump. Other forms have gearing introduced between them, whilst a motor drive may be substituted for steam. The axial-flow pump is only suitable for low heads and approximately constant quantities if run at constant speed, as unlike the centrifugal type it cannot be made non-overloading and, consequently, when the quantity of water

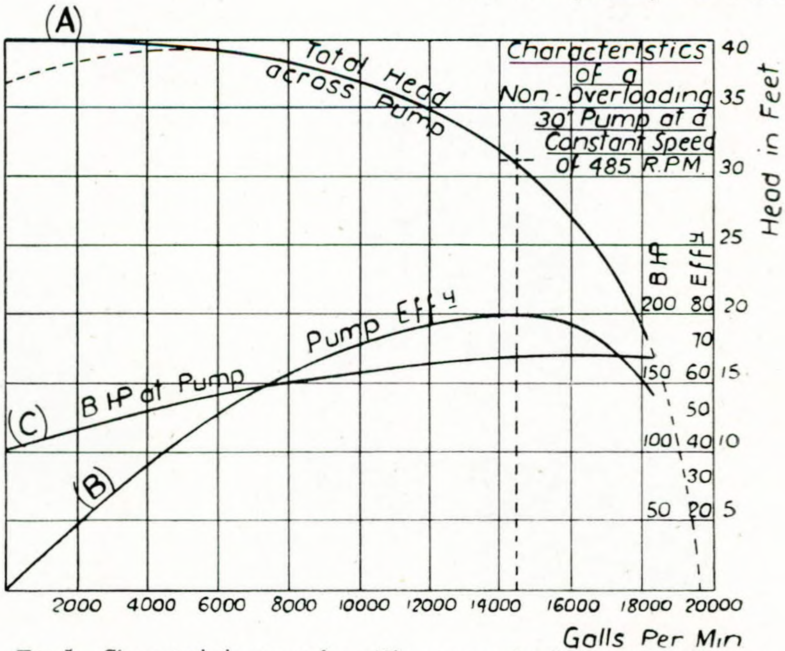


FIG. 5.—Characteristic curves for a 30in. non-overloading centrifugal pump.

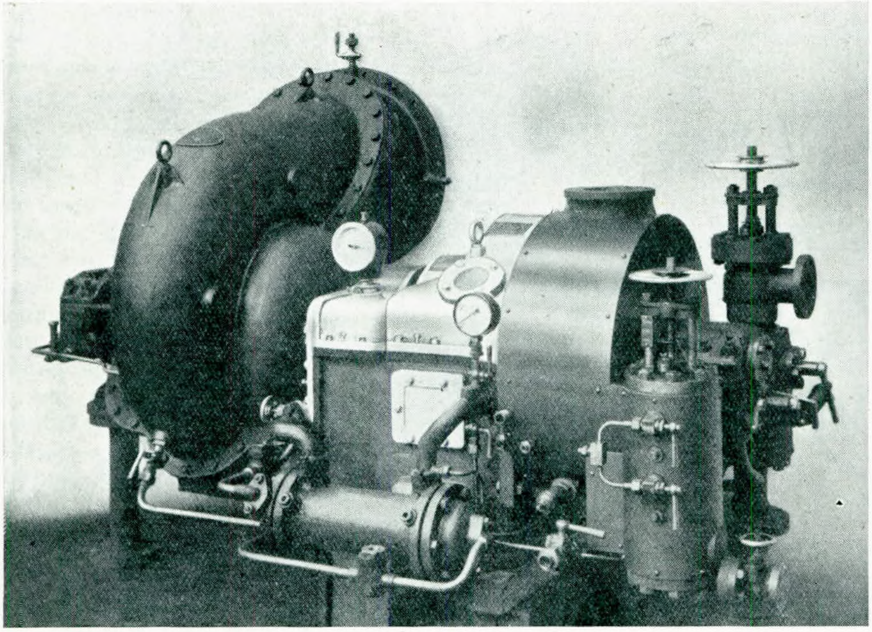


FIG. 6.—Horizontal geared turbine-driven centrifugal circulating pump.

delivered is reduced by throttling, thereby increasing the head, the power required at constant speed for driving also goes up. It will be appreciated, however, that for condenser circulating purposes, where a steady load operates for long periods, this type of pump is particularly applicable.

General Service, Sanitary, Bath and similar duty Pumps.

These pumps, which obtain their supply direct from the sea, are usually of the centrifugal type for large units, but for smaller capacities and when an electric supply is not available, a reciprocating pump is used.

Fig. 10 shows a vertical motor-driven centrifugal pump which is supplied for these services. The same design is also used for jacket circulating or piston cooling on Diesel engines, the head required then being approximately two or three times that required for circulating water through a condenser.

Fig. 11 shows an electrically-driven two-throw general service pump. As will be seen, the set is mounted vertically with the motor on top driving the double-acting pump through reduction gearing. Another type of pump for these duties is steam driven and reciprocating. This design follows the same lines as the direct acting feed pump as illustrated in Fig. 14.

Bilge, Ballast and Freshwater Pumps.

The design requirements of these pumps are similar to those just mentioned. They differ, however, in that instead of having their suction "drowned" or positive, they have to draw from the

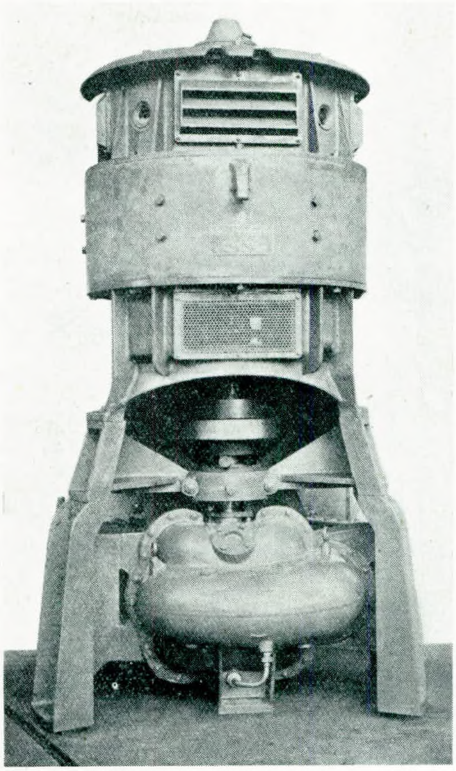


FIG. 7.—Vertical motor-driven centrifugal circulating pump.

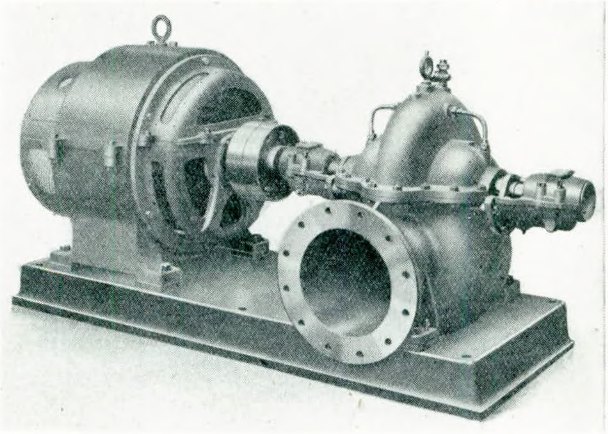


FIG. 8. Horizontal motor-driven centrifugal circulating pump.

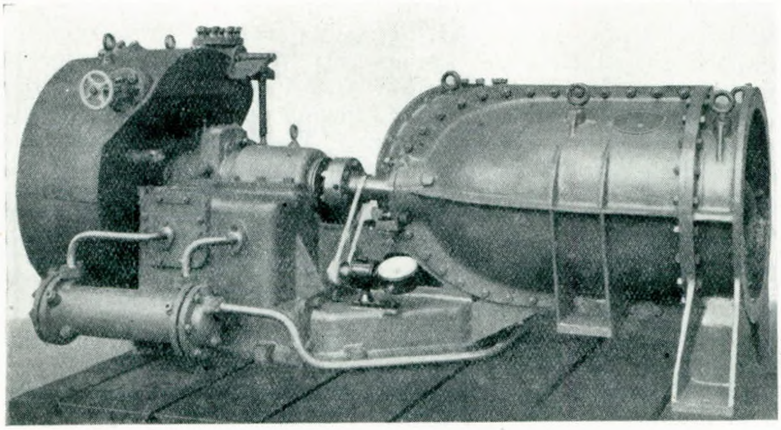
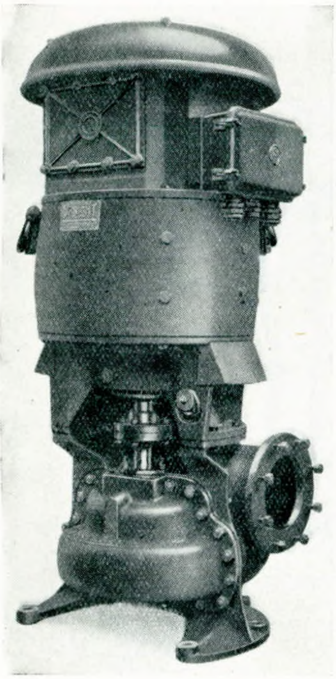


FIG. 9.—Horizontal direct-coupled turbine-driven axial-flow circulating pump.

ship's bilges or tanks. This means that there is a suction lift or negative head. A reciprocating pump, either steam or electrically driven, is suitable without modification, but the centrifugal pump has to be provided with some kind of priming apparatus.

Fig. 12 shows a form of pump which is primed by means of a small auxiliary two-cylinder single-acting air pump driven through worm reduction gearing from the main pump spindle. When starting up, the air in the suction pipe is withdrawn by the auxiliary pump until the main pump is primed; a float operated valve is provided which prevents water reaching the air pump. Another form of self-priming pump works in a similar manner to that just described, but the air pump in this instance is of the rotary type directly coupled to and driven by an extension of the motor shaft.



10.—Vertical motor-driven centrifugal pump.

The Board of Trade have a rule applicable to passenger-carrying vessels which states that: "In addition to the ordinary bilge pump (which may be worked from the main engine) two independent power bilge pumps have to be provided. Sanitary, ballast and general service pumps are accepted as independent power bilge pumps if fitted with necessary connections to the bilge pumping system. Of these two pumps, one at least has to be available for pumping any compartment, even though the compartment in which the pump is situated is flooded". This latter pump is generally referred to as the "emergency bilge" or "S.O.S." pump.

It is also decreed that main circulating pumps on steamships have to have direct suction connections to the engine room bilges. There is also a specified formula which gives the size of bilge suction pipes for any size of vessel. Lloyd's Register of Shipping have similar regulations to the above.

Fig. 13 shows a motor-driven emergency bilge pump. It should be noted that the pump is really identical with an ordinary self-priming bilge pump, but as it has to be capable of working submerged the motor is placed in an air bell. When working normally as

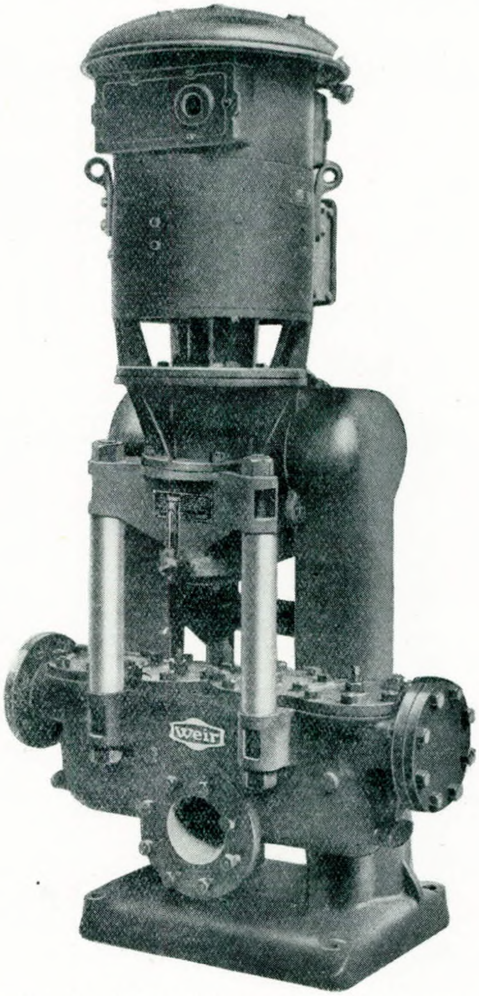


FIG. 11.—Motor-driven reciprocating pump.

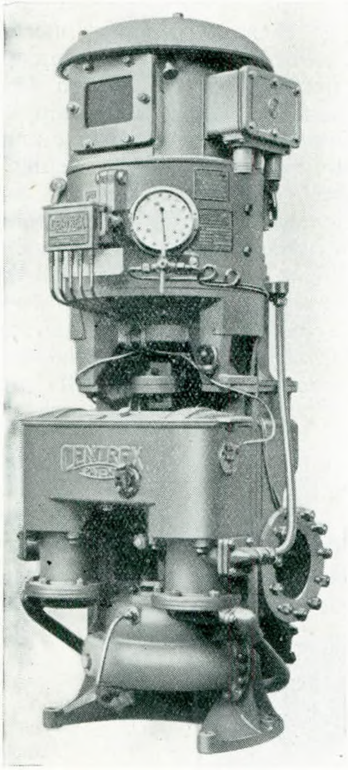


FIG. 12.—Motor-driven self-priming centrifugal pump.

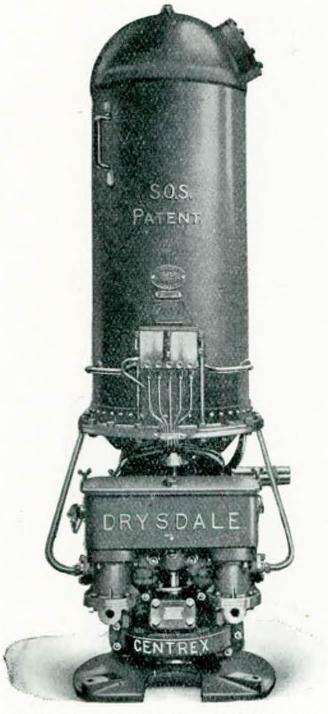


FIG. 13.—Emergency bilge pump.

a bilge pump air freely circulates inside the motor for ventilating purposes, but when submerged the water is prevented from reaching the motor windings by the air pressure created in the air bell. Another design uses a totally-enclosed watertight motor in place of the open-type motor contained in the air bell.

It is not the function of an emergency bilge pump to endeavour to pump out a compartment which has been badly holed (unless the hole can be fitted with an efficient temporary patch), but to overcome in adjacent compartments leakage which may be caused by strained bulkheads or leaky rivets. As, however, the compartment in which the pump is placed may be the one which is badly holed, the pump should be capable of working when completely submerged, and of continuing to pump out the leakage entering adjoining compartments. It must be self-priming and capable of overcoming a reasonable amount of air leakage into the bilge pipe system. It must also be capable of being driven by the emergency lighting and power set which is placed high up and above the water line of the ship.

Fire Pumps.

The bilge or ballast pumps, on account of their capacities, are very often used as fire pumps on a vessel by having a suction connection direct to the sea and by speeding up in order to increase the delivery pressure. The Board of Trade have another regulation which says that on ships of less than 4,000 tons gross, there shall be two, and on larger ships at least three fire pumps, capable of supplying powerful jets of water for dealing with fires.

Boiler Feed Pumps.

Earlier reference was made to the direct-acting

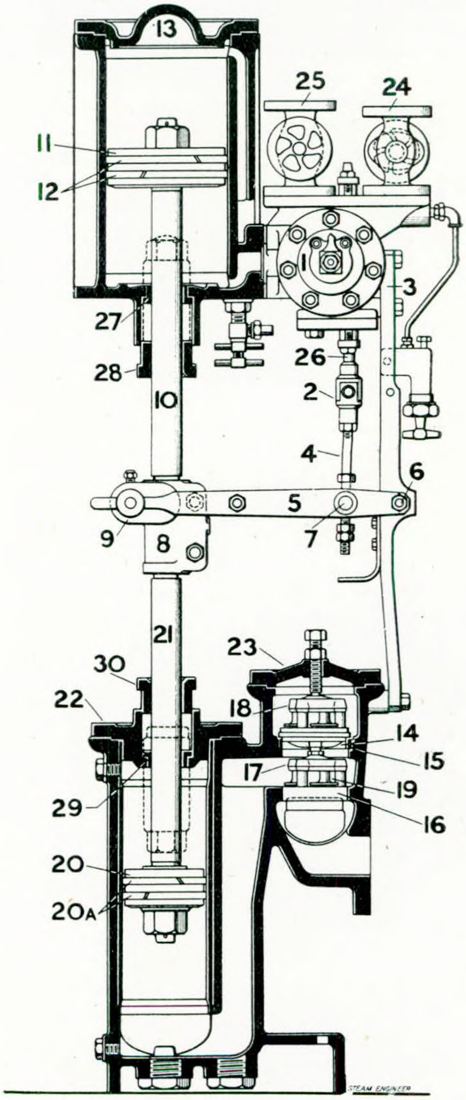


FIG. 14.—Reciprocating feed pump.

1, steam slide valve chest; 2 double joint; 3, front stay; 4, bottom spindle; 5, valve gear levers; 6, front stay bush; 7, ball crosshead; 8, main crosshead; 9, crosshead pin; 10, piston rod; 11, piston body; 12, piston rings; 13, cylinder cover; 14, discharge valve seat; 15 discharge valve seat ring; 16, suction valve seat; 17, suction valve guard; 18, discharge valve guard; 19, water valves; 20, bucket; 20A, bucket rings; 21, pump rod; 22, pump cover; 23, valve chest cover; 24, steam stop valve; 26, auxiliary valve spindle; 27, cylinder neck ring; 28, cylinder gland; 29, pump neck ring; 30, pump gland.

feed pump, one of the first power pumps to be used in marine service and still extensively employed to-day.

Fig. 14 shows one in section with a list of parts. Whilst this type is admirable for small and medium sized steam ships, the large quantity of feed water required for a modern liner, combined with high steam pressure, has brought into use the rotary feed pump. The choice between the direct-acting and rotary feed pump has resolved itself practically into a matter of size. Approximately 7,000 gallons per hour is the lower limit for the rotary type and 10,000 per hour the highest for direct-acting pumps, although both types are manufactured in sizes beyond these limits as modifying circumstances dictate.

A good example of a steam turbine driven rotary feed pump is shown in Fig. 15. It will be noted that the centrifugal pump running at a high speed makes an extremely compact machine. It is automatic in action and is capable of discharging against the highest boiler pressures.

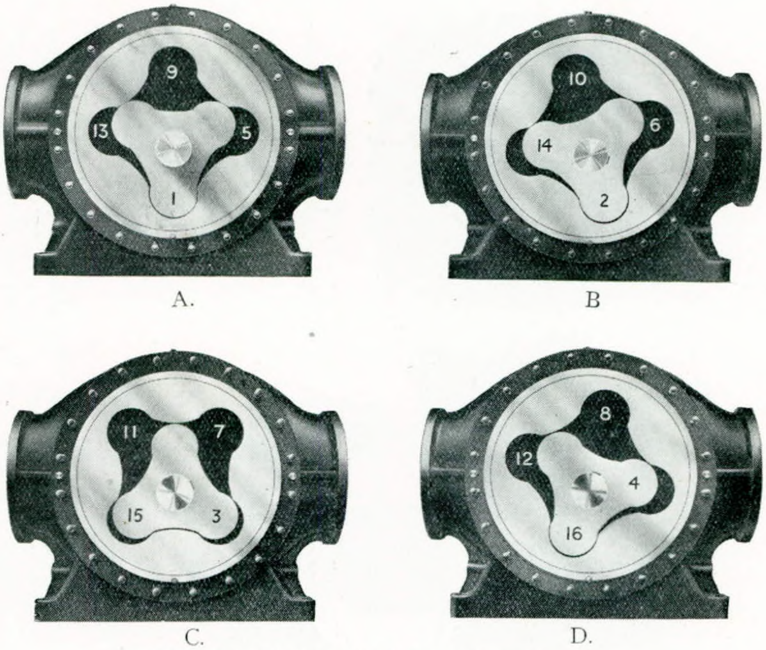


FIG. 16.—Positive displacement pump.

The principal parts of the pump are body, body liner, gland and inspection covers, inner rotor keyed to shaft, and outer rotor.

The inner rotor is held in position by its bearings in the pump covers, whilst the outer rotor is supported by the pump body and covers. The centres of the two rotors are eccentric one to the other.

A, B, C and D illustrate the rotors in sequence of positions during one revolution, one lobe of the inner rotor being marked on the illustrations with similar marking on the outer rotor to show the relative positions of the two members during one revolution. Reference to A shows the lobe 1 of the inner rotor completely filling a recess of the outer rotor, and by following the numbers in sequence in the successive figures A, B, C and D, it may be seen how this lobe during a complete revolution moves forward to the next recess in the outer rotor, creating while so doing a pocket of gradually increasing capacity up to the position 9, A, and from there onwards to 16, D, gradually decreasing until the pocket is again filled by the next lobe as in 1, A.

The fluid is drawn into the pump through ports of the outer rotor while the pocket is increasing and forced out of the opposite side of the pump during the last half revolution when the pocket is decreasing.

Centrifugal boiler feed pumps are made in both single and multi-stage designs, an advantage of the latter being that the pump can run at a lower speed, as the total pressure head is divided into two or more stages. Furthermore, a minimum of internal leakages arise and moderate water velocities are assured. Occasionally the drive is by electric motor instead of steam turbine.

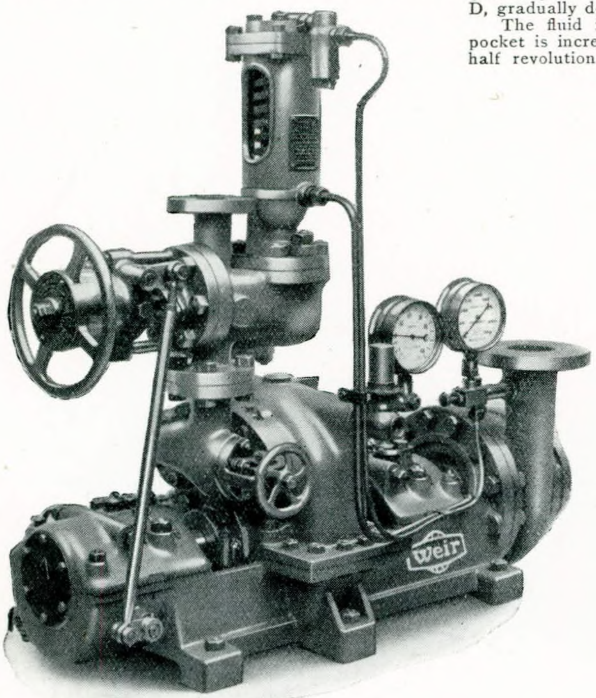


FIG. 15.—Turbine-driven feed pump.

Brine Pumps.

There is nothing particularly novel in the design of pumps used for circulating brine. Small motor-driven units are generally used in modern refrigerated ships. A comparatively low head is sufficient for circulating round the insulated cargo holds, but a high pressure pump is required for dealing with the various cold cupboards and stores, etc., found on a passenger liner. The pump is usually situated inside the evaporator room and is connected by an extended shaft through an insulated bulkhead to a motor outside.

Fuel Oil Pumps.

This class of pump has been greatly developed during recent years with the increasing use of fuel oil both on steam and motor ships. Some fuel oils, especially when cold, are very viscous and therefore difficult to pump. Whilst the centrifugal pump is capable of dealing with fuel oil if not too viscous,

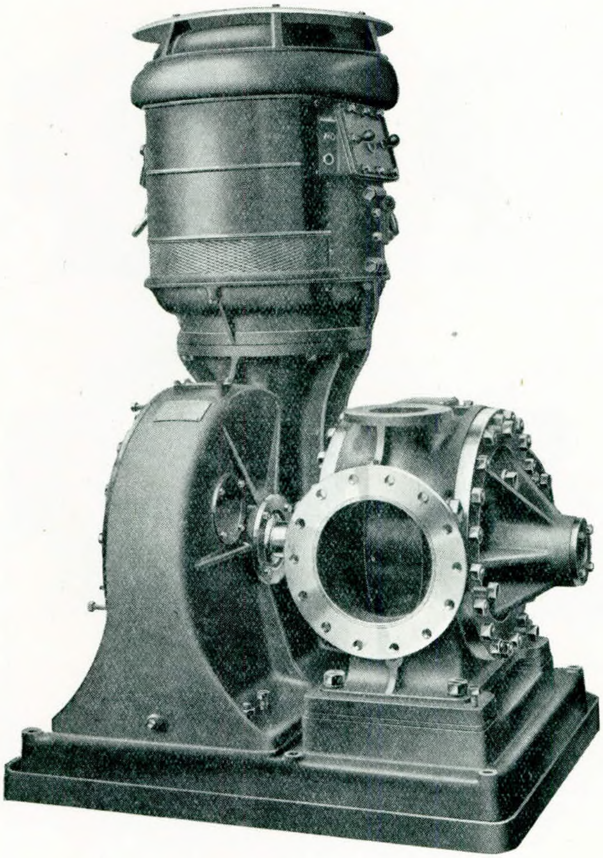


FIG. 17.—Motor-driven positive displacement fuel oil pump.

a steam or motor driven reciprocating type is often used.

An entirely different design of pump is shown in Fig. 16. This is generally described as a positive rotary or positive displacement pump. It has the characteristics of a reciprocating type, but rotates when working and can be driven either through gearing or direct from the prime mover. The figure and accompanying letterpress describe the action. A later development of the same make of pump has an inner rotor of seven lobes engaging with an outer rotor of eight lobes, otherwise the action is exactly similar to that mentioned above. The later type is capable of being run at higher speeds compared with those employed for the earlier type, and can therefore in the majority of cases be direct coupled to an electric motor or vertical steam engine without the use of gear transmission.

Fig. 17 shows an electrically-driven positive displacement fuel oil transfer pump installed on the "Empress of Britain" which has a capacity of 150 tons per hour.

Gear wheel pumps are also used, especially for smaller capacities. The rotors in these pumps consist of two helical shaped toothed wheels meshing inside a casing. Two or more stages can be used when high pressures are required.

Cargo Oil Pumps.

An illustration of a steam reciprocating pump for this duty is shown in Fig. 18. This is a duplex type and has a capacity of 270 tons per hour. Another type is the positive displacement referred to above.

Lubricating Oil Pumps.

The types used are similar to those for fuel oil transfer, centrifugal and rotary displacement predominating. An interesting feature of the latter is that it can be arranged to have a unidirectional flow. The pump is usually driven from the crankshaft of a Diesel engine for supplying the forced lubrication, and the flow is maintained in one direction with both the forward and reverse directions of rotation of the engine. This is done by having an eccentric liner which can be carried round on reversal through a path of approximately 180 degrees.

Another arrangement which is installed on a large number of motor vessels is diagrammatically shown in Fig. 19. A multi-stage vertical spindle motor driven centrifugal pump, very similar to a borehole pump, is suspended from a circular pedestal mounted upon the oil tank top. The pump itself is submerged in the oil in the tank, so that

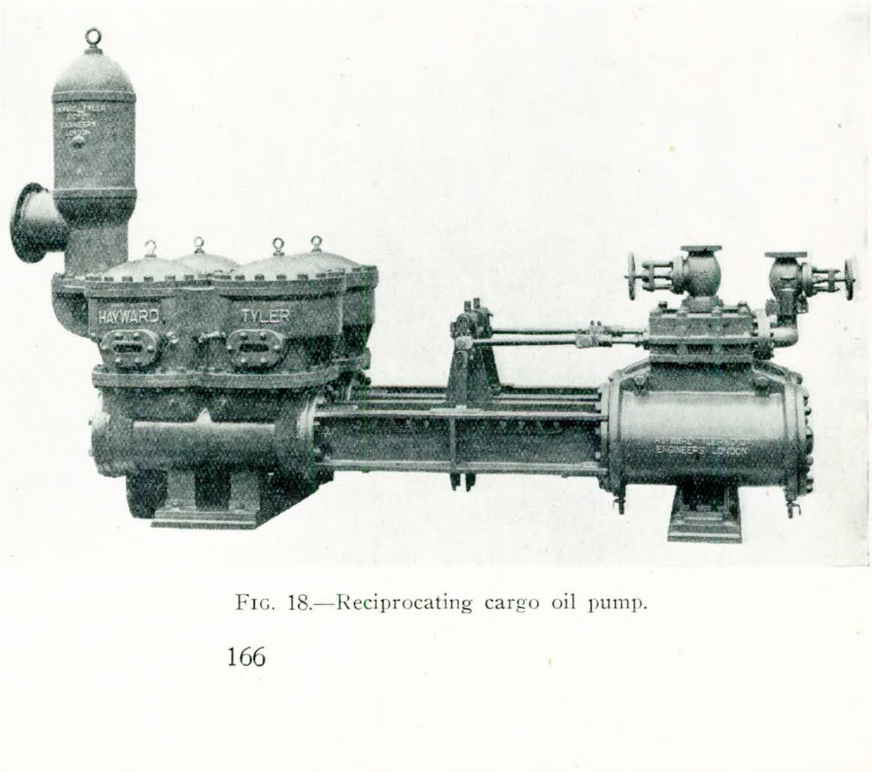


FIG. 18.—Reciprocating cargo oil pump.

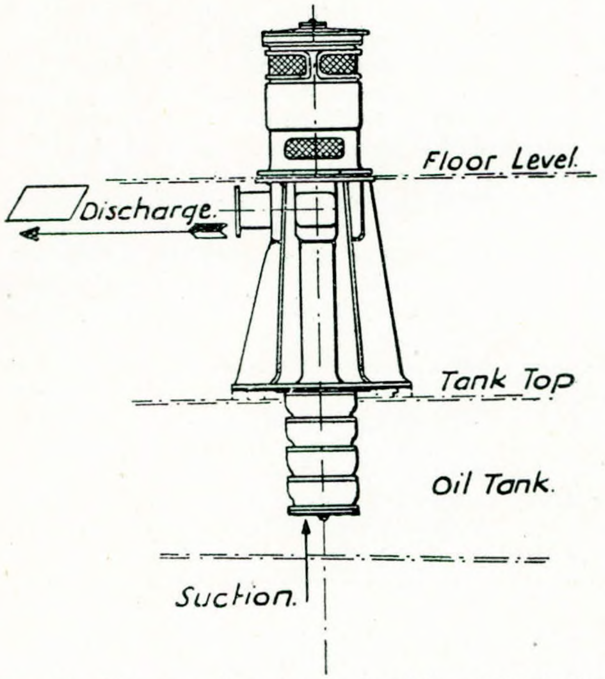


FIG. 19.—Diagrammatic arrangement of forced lubricating oil pump.

no priming apparatus is necessary. The hydraulic thrust is taken on a Michell thrust bearing at the top of the pump shaft. The pedestal also carries the motor, which is placed level with the engine room floor so that it is easily accessible.

As lubricating oil has usually to be lifted from a storage tank, back to which it gravitates after passing through the main engines, a centrifugal pump, other than the type described above, has to be fitted with a self-priming arrangement such as that described under the heading of bilge pumps.

One point to be borne in mind with regard to forced lubricating oil pumps is the fact that when first starting up with cold oil the power absorbed by the pump is considerably more than when the oil has been warmed up, and it is advisable for the driving motor to be designed for considerable speed variation in order to meet the fluctuating demands occasioned by the variations in the viscosity of the oil to be dealt with.

Air Pumps.

Until comparatively recent years the universal method of extracting the air and vapour from a condenser was by a reciprocating type of pump. The low vacuum conditions under which the main reciprocating engines in a steamer worked allowed of a twin barrel beam type of pump being used, which dealt with the whole of the air, water and vapour from the condenser. The higher vacuum conditions required by the marine steam turbine necessitated separate pumps for the air and condensate and the dry air pump was evolved. The air dealing capacity of the reciprocating pump is limited by its size and speed, whilst its valves and passages impose resistance to the flow of gases. Modern practice is to use a steam jet ejector which has a large air dealing capacity and is capable of creating a pressure difference at a very low absolute pressure. Fig. 20 shows a combination pumping unit which has been widely used and is a compact arrangement.

The air and non-condensable gases are extracted from the condenser by means of a steam ejector and the reciprocating pump withdraws the condensate. The steam ejector air pump is now almost

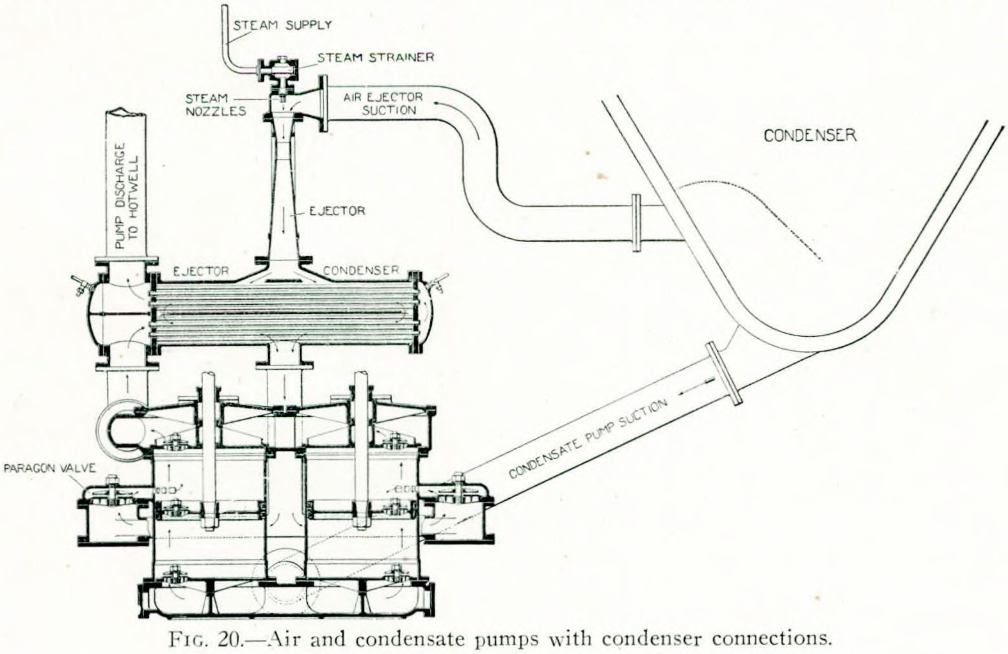


FIG. 20.—Air and condensate pumps with condenser connections.

LIST OF MATERIALS USED IN PUMP MANUFACTURE WHEN DEALING WITH VARIOUS KINDS OF LIQUIDS

MEDIA	CASING	IMPELLER	SHAFT
SEA WATER	GUNMETAL OR CAST IRON	GUNMETAL	MILD STEEL WITH G M SLEEVES OR STAINLESS STEEL OR FORGED BRONZE
FRESH WATER	CAST IRON	CAST IRON	MILD STEEL OR STAINLESS STEEL
BRINE	GUNMETAL OR CAST IRON	GUNMETAL	MILD STEEL WITH G M SLEEVES OR STAINLESS STEEL OR FORGED BRONZE
FUEL OIL	CAST IRON	CAST IRON	MILD STEEL OR STAINLESS STEEL
LUBRICATING OIL	CAST IRON	CAST IRON	MILD STEEL

FIG. 21.

universally used and as there are no moving parts its maintenance is negligible. It also has the advantage of being cheap, lightweight, and occupies a very small space. For large installations, air ejectors work in conjunction with rotary condensate extraction pumps instead of the reciprocating type of extraction pump shown.

Pump Materials.

In conclusion, the question of the durability of materials against the erosive and corrosive effects of the various media with which they are in contact will be briefly dealt with.

Fig. 21 gives a list of metals that are usually used in the manufacture of the principal parts of a centrifugal pump.

Sea water and brine are the most difficult liquids to deal with. When sea water enters a space that is below atmospheric pressure, a certain amount of the air which it contains is liberated. Released air is exceedingly destructive to metals and this condition often occurs in a pump particularly when there is a negative head on the suction side. Furthermore, the effect of throttling causes "cavitation" in the pump and consequent erosion of the metals. It is for these reasons that the supply of water to a pump should never be throttled on the suction side, any throttling being done on the delivery or pressure side. Gunmetal or bronze is extensively used, but has the disadvantage of being expensive and as it is comparatively soft is ill-fitted to withstand erosion. Cast iron is much harder and should be correspondingly superior in this respect, but it is unfortunately very liable to corrosion caused by the chemical action of the water, and the same remark applies to mild steel. For sea water it is usual to provide a gunmetal impeller and a steel shaft fitted with renewable bronze sleeves where it passes through the water spaces. Stainless steel has also been used for impellers and, when trouble has previously occurred through electrolytic action, has been most successful.

The effect of erosion or corrosion on an impeller is, of course, much more serious than on a casing, as a change of shape of the blades and the increased clearances very soon cause a very serious falling off in efficiency. The casing is thick and it therefore takes a long time before the thinning down causes any serious consequences, and consequently, common practice is to use gunmetal for the impeller and cast iron for the casing.

Various alloys have been evolved, the most successful being those having cast iron as a base with the addition of nickel, copper and chromium and suitable proportions. These are not only less expensive than gunmetal but also much harder and therefore better able to resist the effects of erosion.

Fig. 22 shows the results of some interesting experiments that were carried out to determine the relative corrosion of different metals in aerated sea

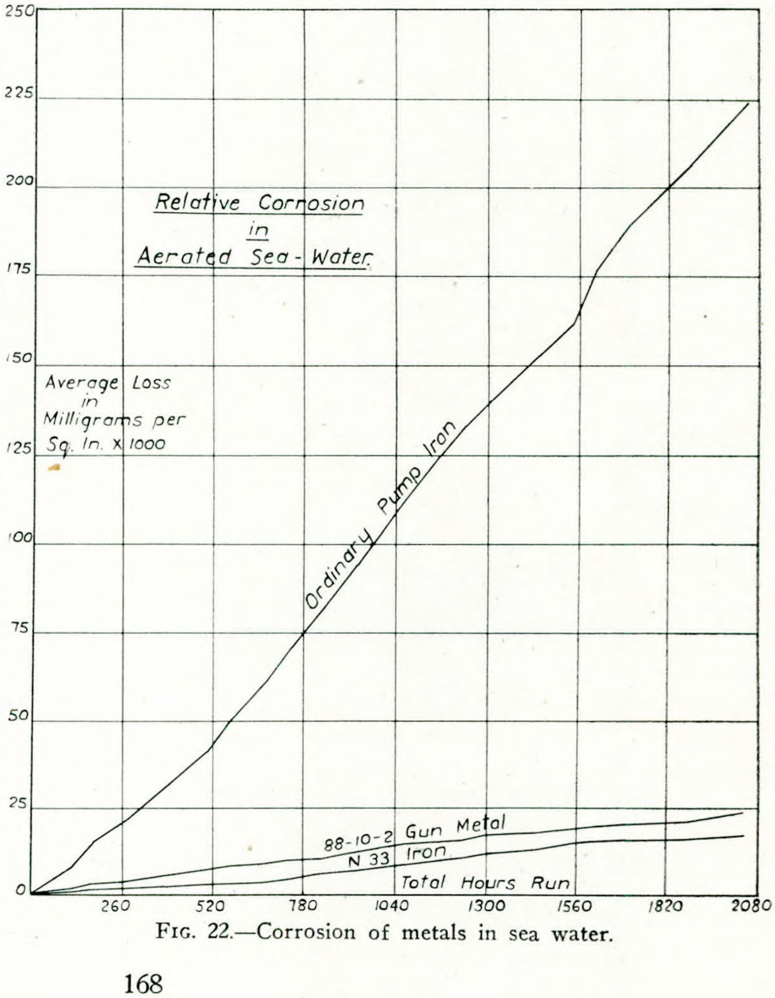


FIG. 22.—Corrosion of metals in sea water.

water. The relative corrodibility in these tests was as follows:—

Ordinary iron—109. Gunmetal—12. Alloy—9.

The N.33 alloy referred to is a special austenitic iron.

A further cause of trouble is sometimes due to electrolytic action, and is often caused by stray electric currents. This is particularly liable to take place on a ship unless precautions are taken to see that no "earths" occur in the electrical installation.

It must be clearly understood that the various types of pumping units mentioned in this paper do not by any means cover the complete range used in marine work. Only those which, up to the present time, have been commonly used have been described, and there are of course many others which owing to limitations of space cannot be dealt with here.

Thanks are due to the following firms for loaning illustrations, etc.: Messrs. G. & J. Weir, Ltd., Drysdale & Co., Ltd., Hayward Tyler & Co., Ltd., Stothert & Pitt, Ltd., and W. H. Allen, Sons & Co., Ltd.; also the P. & O. Company and the White Star Line for permission to use the data regarding the pumps on their vessels.

Some Diesel Engine Lubrication Difficulties and their Remedies

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THE authors of the paper "Some Observations on Fuel for Heavy Oil Engines" recently read before this Institute raised so many interesting points in connection with the effect of the nature of both fuels and lubricants on engine performance and wear that the writer is glad to have the opportunity of making a few comments in addition to those contained in his written contribution to the discussion which followed the above paper. He would also like to refer to some of the matters raised in the very interesting paper on the lubrication of Diesel engines read by Engr. Lt.-Com'r. H. J. Nicholson before The Institute in April, 1932.

The selection of suitable lubricants for Diesel engines offers considerable difficulties, since in many cases entirely opposing requirements must as far as possible be satisfied. Thus, the lubrication of cylinder liners demands the use of oils having great "oiliness" as the conditions are severe and the feed of lubricant comparatively sparing. It would therefore appear advantageous to use compounded oils for cylinder lubrication, more particularly because the addition of even as little as 3 to 5 per cent. of a fatty oil (such as cocoanut) not only materially increases the "oiliness" of the lubricant (*i.e.,* its capacity for providing reasonably satisfactory lubrication under "boundary" or "greasy" as distinct from perfect fluid film conditions) but also greatly reduces the tendency for sticky asphaltic deposits to form on the rubbing surfaces of the piston and behind the rings. This second property of suitably compounded "cylinder" oils is most important, and in the opinion of many lubrication technologists far outweighs the increase in "oiliness" obtained by the addition of fatty oil. The asphaltic deposits are often largely derived from incomplete combustion of the fuel (even when the engine is giving a perfectly clean exhaust) and are also formed by the oxidation of the lubricating oil in the strongly oxidising conditions which are characteristic of Diesel engine combustion chambers. At first the asphaltic matter derived from the partially oxidised fuel and lubricating oil remains in solution in the remainder of the lubricating oil, and only results in the darkening and thickening of the latter. During this stage the "oiliness" of the lubricant and its friction-reducing power may be actually increased to a marked degree, as the oxidation products are strongly "polar" bodies, which helps the oil to adhere to the metallic rubbing surfaces. Unfortunately, the oxidation and other chemical changes which take place in the oil as the result of heat, contact with air and unburnt fuel, frequently do not stop there, but proceed further with the precipitation of sticky asphaltic deposits insoluble in "straight" mineral oils. The formation of these deposits leads to the sticking of piston rings (often followed by breakage), heavy liner wear, lack of piston seal, and severe piston drag. A remarkable improvement can often be brought about in the cylinder lubrication of internal-combustion engines by substituting for straight mineral oil a compounded oil containing about 5 per cent. to 10 per cent. of a suitable non-gumming fatty oil such as lard or cocoanut. This is standard practice in the case of the cylinder lubrication of gas engines running on an impure suction or pressure producer gas carrying tarry matters in suspension. Pale-coloured non-sludging compounded oils will show marked superiority over dark-red straight mineral oils as regards clean lubrication, the rate of formation of carbonaceous deposits in the piston ring grooves being greatly reduced. This phenomenon is often attributed to the burning of the carbon by the oxygen in the fatty matter present in the compounded oils (animal and vegetable oils and fats contain some 9·5 per cent. to 12·5 per cent. by weight of combined oxygen). This explanation is, however, probably quite erroneous, as the oxygen content of fixed oils is insufficient for their own complete combustion, and, therefore, oxygen is obviously not available for the burning-off of extraneous carbonaceous matter. The correct explanation is that fatty or "fixed" oils and fats, especially when hot, have a marked solvent action on tarry, asphaltic and carbonaceous deposits, and are able to confer this property on compounded oils even when the proportion of fatty matter is as low as 5 per cent. Straight mineral oils and even petrols lack this solvent property, which is often of great importance in internal-combustion engine cylinder lubrication. A homely example of the superior solvent powers of fatty bodies for tarry substances is afforded by the familiar practice of the housewife of removing tar stains from cloth by applying butter and allowing this to absorb the tar, prior to cleaning with petrol or other fat solvent in the usual manner. This is far more effective than trying to remove the tar with petrol alone, as neither tar nor asphalt is readily and completely soluble in this liquid.

The "oiliness" (and possibly also the asphalt solvent power) of compounded oils can be still further increased if a portion of the fatty matter (say about 1 per cent. calculated in the compounded oil as a whole) is present as free fatty acid. So small a proportion of, say, stearic or oleic acid is insufficient to cause corrosion, but materially increases the "oiliness" or adhesiveness of the lubricant to metal, free fatty acids being strongly "polar" bodies.

While the compounding of cylinder oils is attended with excellent results in the case of internal-combustion engines such as gas and petrol engines, great caution must be exercised when adopting this procedure in the case of vertical Diesel engine cylinder lubrication, owing to the possibility of some of the compounded cylinder oil working its way down into the crank-chamber and causing the bearing oil to emulsify with water. This may occur even with compression-ignition engines in which the crank-chamber is entirely isolated from the cylinders, with the piston rods passing through glands at the bottoms of the cylinders and top of the crank-chamber. What happens in this case is that some of the cylinder oil splashes on to the piston rod during the upstroke of the piston and on the downstroke gets carried right through the glands down into the crank-chamber. Most of the oil in the piston rod is naturally wiped off by the glands, but a thin film of it adheres so strongly to the rod that it is able to resist the scraping action of even a tight packing. Particularly is this true when the oil is compounded and also contains free fatty acid, its adhesion to the rod being thereby much increased. Once in the crank chamber some of the film of compounded oil on the piston rod becomes washed off by the sprays of bearing oil which fill the chamber, and more and more fatty oil is thus introduced into the bearing oil circulation system. Now, modern lubrication practice favours the use of oils for the crank case which are not only resistant to oxidation but also demulsible, so that any water leaking into the bearing oil circulation system may be shed as quickly as possible. Many modern Diesel engine bearing oils are "circulation oils" and, in fact, to all intents and purposes resemble turbine oils except in that they have a higher viscosity in order to withstand the higher bearing pressures encountered. It is often impossible to prevent a certain amount of water leaking into the crank-chamber from the cooling systems of cylinders, pistons, or crosshead guides, and it is important that the crank-chamber or bearing oil should be of such a nature that the water will separate out from the oil as rapidly and completely as possible. If this does not occur, the oil and water will emulsify to form a thick sludge and dangerous deposits will form on the oil strainers and in various portions of the lubricating system. Unfortunately, the crank chamber oil, although initially possessing a good demulsibility, often deteriorates rapidly as the result of oxidation brought about by heat and atomisation and the picking up of powerful oxidation catalysts and emulsifying compounds such as iron oxide, so that its power of shedding water may in severe cases be reduced to a degree which renders even centrifugal treatment ineffective.

One of the greatest advances made in recent years in the manufacture and refining of mineral lubricating oils is the introduction of what are called "solvent extraction" processes for producing non-sludging (non-oxidising) oils for the lubrication of steam turbines and Diesel engines. These oils are not only resistant to oxidation but have a high degree of demulsibility, both initially and after lengthy and severe service. The best qualities are comparable with even transformer oils in resistance to oxidation. Briefly, the manufacture of these oils (usually distillates) involves the introduction of an additional stage in the usual process of refining the "raw" lubricating distillate: the latter is intimately contacted with a large volume of some selective solvent (such as liquid sulphur dioxide) at low temperatures, and the two liquids are then allowed to separate. The liquid SO_2 or other solvent dissolves out the higher gravity, more unstable portions of the lubricant (known as the "extract"), leaving behind as an upper layer the lower gravity, less readily oxidisable fraction of the oil (known as the "raffinate"). The latter, after removal of a small proportion of dissolved SO_2, only requires a light chemical and fuller's earth treatment to produce a pale-yellow high-grade oil of remarkable chemical stability. Other solvents or mixtures of solvents are rapidly being developed as additions to or in replacement of the earlier "Edeleanu" liquid SO_2 processes.

It is important not to confuse these pale non-sludging oils of low to moderate specific gravity with the pale high-gravity lubricating oils derived from asphalt-base crude petroleums by the older refining methods. The latter oils have a very bad demulsibility and poor resistance to oxidation, hence they are not to be recommended for circulation systems. Moreover, although initially giving very low coke values in carbon residue tests, after several hours severe oxidation, the coke test figures increase to a marked degree, so that in certain types of engine they are unsuitable even as cylinder lubricants. A further point is that their pale colour is only obtained by subjecting them to very heavy treatment with concentrated sulphuric acid followed by fuller's earth, so that there is considerable likelihood of some of the more valuable "oily" or "lubricative" hydrocarbons having been destroyed. The pale-coloured oils obtained by treatment with liquid SO_2 or other solvents, on the other hand, have suffered little chemical attack, as these solvent extraction processes act in a purely physical manner. Some emphasis should be laid on this point, since there is a fixed idea in the minds of many chemists and engineers that because an oil is pale in colour it lacks "oiliness" or "adhesiveness". Actually, colour alone is no guide to oiliness; an extreme example of this is pure castor oil, which, although one of the most efficient lubricants obtainable (from the point of view of friction-reducing power under conditions of high temperature and pressure) is nevertheless often extremely pale.

In view of the care taken to choose non-emulsifying straight mineral oils for the lubrication of Diesel-engine bearings, it will be obvious that the compounding of the cylinder oil requires careful consideration, for if considerable quantities of the latter oil are carried down into the crank-chamber, the demulsibility of the bearing oil may be reduced to a point where water entering the system refuses to separate at all. Thus the beneficial effects of clean lubrication and decreased friction resulting from the compounding of the cylinder oil must be balanced against the possibility of serious sludge formation in the bearing oil. This may vary with different engines, even of the same make and type; also with the same engine at different periods of its life. This much is certain—that the heavy compounding of the cylinder oil is inadvisable and that the incorporation of fatty matter, if practised at all, must be undertaken very cautiously, starting with a small percentage—say not more than 3 per cent.—and gradually increasing this to 5 per cent. or even 10 per cent. only if frequent sampling of the crank chamber oil at the lowest point clearly indicates that serious emulsification is not occurring. Thus, the compounding of the cylinder oil in the case of engines hitherto operated with straight mineral cylinder oils should most definitely be regarded as a large scale experiment to be carried out gradually and with caution, and not as a change to be lightly introduced, say, in a large number of engines simultaneously. These remarks apply even more forcibly to the smaller-sized engines fitted with trunk-type pistons. Here, owing to the fact that the bottom of the cylinder is open to the crank-chamber, the leakage of cylinder oil into the bearing oil circulation system takes place to a much greater degree, with a consequent more rapid diminution in the demulsibility of the bearing oil. It will be obvious that in those engines where the same oil is used for both cylinder and bearings the addition of fatty matter, if practised at all, must be carried out very cautiously indeed. It is significant that most Diesel cylinder and bearing oils marketed are not compounded, even in the case of those engines where the same oil is used to lubricate the air compressor (which demands a compounded oil whenever the design of the lubrication system permits this).

Cylinder Oils.

Apart from the incorporation of fatty matter in cylinder oils to increase oiliness and dissolve asphaltic matter derived from the fuel, oxidation of the more unstable constituents of the mineral oil, etc., the nature of the hydrocarbon or mineral portion of the cylinder oil require careful consideration. Here again the modern tendency appears to be to use either straight pale-yellow non-sludging distillate oils (up to about 175″ Redwood viscosity at 140° F.) or, especially in the case of higher-viscosity oils, blends of these with filtered low cold test steam cylinder oil (bright stock). Non-sludging oils have the important advantage of combining minimum coke-forming tendencies at very high temperatures (550° C.) with minimum asphalt-forming tendencies at lower temperatures (say 150-250° C.). Thus, they are less apt to form asphaltic deposits on the piston walls and in the ring grooves, and they continue to remain fluid and pump freely round the rings even under severe operating conditions. This is an important advantage. The rings are able to move freely in their grooves, thus giving less friction and liner wear, the gas seal is improved, and the tendency for rings to stick and break is greatly reduced. In addition, the reduction in the formation of sticky asphaltic matter reduces liner wear because these tarry bodies are very abrasive; they absorb and hold mineral abrasive matter and hard abrasive coke derived from the fuel, and thus act as lapping compounds for the liner. On the other hand, if the oil remains fluid and continues to flow freely round the rings and over the piston and ring surfaces, the asphaltic matter and abrasives are washed away as rapidly as they are introduced, the presence of fatty matter in the cylinder oil assisting this solvent action.

It is obviously desirable to use as low a viscosity oil as consideration of gas seal and film formation allows, since not only will such oils be more readily distributed over the cylinder walls from the oil inlet ports by the piston rings, but their washing and cleansing action will be increased and their inherent coke-forming tendencies at a minimum. This brings us to the vexed problem of the advisability of incorporating "bright stock" in the lower viscosity Diesel cylinder oils and the proportion to be added.

If operating conditions demand cylinder oils having a viscosity higher than about 175-180″ Redwood at 140° F., most lubrication technologists are agreed that the addition of "bright stock" is necessary, since the viscosity curve of the oil is otherwise too steep. Points about which strong differences of opinion exist are (*a*) whether the addition of "stock" to the lower viscosity Diesel oil is advisable and (*b*) the amount of "stock" to be incorporated in the higher viscosity oils. The presence of stock in a Diesel oil is immediately rendered evident by the darker colour of transmitted light (deep red) and the pronounced green "bloom", "cast" or fluorescence. Stock is added for the following reasons:—

(1) To increase the viscosity of the oil (the viscosity of "neat" bright stocks may be 500″ Redwood or over at 140° F.).

(2) To avoid any possible danger of "drying-up" at the top of the liner due to the volatilisation of the larger portion of any purely distillate lubricating oil.

(3) To improve the "oiliness" of the cylinder oil without unduly decreasing its demulsibility. (It is disputed by some petroleum technologists whether the addition of stock improves the "oiliness" of distillate mineral oils, but there is a good deal of reason to believe that it does so, although admittedly not to the same extent as fatty oils containing free fatty acids).

The presence of stock in a lubricant also often has a psychological effect on the consumer, since it gives the lubricant a rich oily appearance and because he has been accustomed to oils of such appearance.

The disadvantage of using Diesel cylinder oils containing high percentages of stock is that the tendency for coke and asphalt formation is thereby considerably increased. Cylinder stocks are high flash-point residues from the distillation of suitable types of crude petroleum, and cannot be further distilled or evaporated without undergoing extensive chemical decomposition with formation of heavy carbonaceous deposits. Thus, the very property of non-volatility which renders stock of value in preventing a "dry" piston, on the other hand leads to an increased tendency to carbon formation. In addition to this, cylinder stocks, even when highly filtered, are much more prone to oxidise with formation of asphaltic deposits than the specially refined non-sludging distillate oils already referred to. Clearly, if the stock is to be added to all, it must be limited in amount and the distillate portion of the blend should be as viscous and non-sludging as possible.

The addition of stock to bearing oils would appear unnecessary except where increased load-carrying capacity is required, or where the same oil is to be used for both cylinders and bearings, and the presence of stock is considered desirable for the lubrication of the cylinders. It will appear evident that the selection of lubricants for Diesel engines is largely a matter of compromise, as opposing requirements must be carefully balanced one against the other. In these circumstancces it is hardly surprising that perfectly sincere differences of opinion exist between different oil companies as to the best blend of oils suitable for a particular type of engine and set of operating conditions; moreover, it is not uncommon to find entirely opposite views held by experienced lubrication technologists in the same company.

Colloidal Graphite in Cylinder Oils.

An interesting alternative to compounding as a means of reducing friction, liner wear, and the sticking of piston rings is the addition to the cylinder oil of a very small proportion of the purest silica-free colloidal graphite. Both laboratory tests and a considerable amount of practical experience have shown that the addition of as little as 0·1 per cent. to 0·2 per cent. by weight of this material to either straight mineral or compounded lubricating oils improves their lubricating properties to a very marked degree under certain severe operating conditions, such as a combination of very high local pressures (due perhaps to lack of alignment), high temperatures and starved oil feed. Some tests carried out on a Diesel ship's propulsion engine of Continental manufacture some time ago showed a very striking reduction in liner wear as the result of adding a very small proportion of colloidal graphite to the cylinder oil. On two successive voyages to the East the average liner wear reached the very high figures of 0·015in. and 0·012in. respectively, also every cylinder except one contained broken piston rings. This one cylinder had been lubricated with the same oil as the others except that it contained a little colloidal graphite. In this cylinder the liner wear had been reduced to 0·008in. and no piston rings were broken in spite of the fact that the oil was unsuitable. At the end of the voyage when the cylinders were opened up, the engineer in charge reported that the condition of the walls of this particular cylinder was better than any he had seen before.

The explanation of such rather remarkable improvements in lubrication has been shown by careful scientific tests to lie in the fact that the continued rubbing of a film of graphited oil between loaded metallic surfaces causes a portion of the colloidal graphite to leave the oil and attach itself very firmly to the metal. It there forms an extremely thin but nevertheless strongly adherent and continuous film, which actually penetrates into the pores of the metal to an appreciable depth and gives a highly polished and very frictionless surface. The physic chemical attraction between the iron and graphite is akin to the formation of an iron carbide, and is so powerful that the graphite can only be removed by grinding away the metal as well. As long as this so-called "graphoid" surface is lubricated with oil containing colloidal graphite, any graphite-cum-metal worn off by abrasion is replaced at an equal rate by fresh graphite up to a certain film thickness. The "graphoid" surface also has the valuable property of being readily wetted by oil, which spreads over its surface with greater rapidity than over a plain metal surface.

Beneficial though the friction and wear-reducing properties of colloidal graphite may be, its addition to marine oil engine lubricants must still be regarded as in the experimental stage, and the incorporation of *relatively large* amounts of colloidal graphite would be not only superfluous but also dangerous, in view of the possibility of choking of oilways with separated graphite. Large scale experiments on the lubrication of marine oil engines with colloidally graphited oils should, however, prove to be extremely interesting, and the writer hopes that these few lines may induce some enterprising engineer to carry out full-scale research on the problem. Some further hints and precautions may be useful in this connection: colloidal graphite is commonly obtainable in the form of a stable "suspension" of extremely finely divided graphite in a moderately high-viscosity straight mineral oil (viscosity about 190″ Redwood at 140° F.). The graphite content of this mixture is of the order of 10 per cent., so that not more than 1 per cent. or 2 per cent. need be added to the ordinary cylinder oil to obtain the required graphite content of 0·1 per cent. to 0·2 per cent. More than this is superfluous, since all that is necessary is to have sufficient graphite present to "saturate" the metallic surfaces.

The second important precaution is either to select such cylinder oils as have good colloidal graphite "suspension" properties or, alternatively, to fit the reservoirs of the ordinary mechanical lubricator with some simple mechanical stirring device which will automatically bring back into suspension any flocculated graphite which may have settled out while the lubricator was idle. The first method is naturally preferable and there is no difficulty in obtaining high-grade Diesel engine lubricants which have excellent "suspension" properties. (The SO_2-treated non-sludging Diesel oils fall into this class). The advice of the colloidal graphite manufacturers should be sought in this connection, as they have complete data available concerning which types of oil maintain colloidal graphite in suspension and which are apt to precipitate this material.

The colloidal graphite used must be as ash-free as possible (a trace of ferric oxide ash, being non-abrasive, does no harm) and must be absolutely free from silica or other abrasive matter. A very useful and simple test for the latter is to rub the moistened ash between two flat glass plates and examine the latter for minute scratches. These should be absent.

Colloidal graphite may be defined as graphite which has been ground as finely as possible and then sub-divided still further by treatment with certain colloids until the graphite particle size is so small that it no longer sinks when suspended in liquids, such as oil or water. The "protective colloid" not only serves to subdivide the graphite particle but also to prevent the extremely minute particles resulting from this sub-division from re-joining or coalescing to form particles sufficiently large to be affected by gravity. If the lubricating oil contains traces of certain acids and electrolytes (either intially present, formed by oxidation, or picked up in use) it destroys the film of protective colloid surrounding each graphite particle, and so allows flocculation followed by sedimentation to take place. It follows, therefore, that although an oil may not flocculate the colloidal graphite when unused, it may do so when it becomes subjected to oxidation and contamination with products of combustion in the cylinders. By this time, however, the graphite will already have done much good; flocculation is by no means instantaneous and the graphite, even after flocculation, is still extremely finely divided—more so than is possible by grinding.

There is still the important matter of the possible blockage of the oilways, piston ring grooves, etc., by the flocculated graphite to be considered. Whether such obstructions are likely to take place can only be ascertained by actual full-scale trials—no amount of arguing one way or the other from laboratory experiments carried out in test tubes are of much assistance here, and the practical test is the only one of any real value. However, the fineness of even the flocculated graphite, the fact that even ungraphited lubricating oils accumulate appreciable amounts of finely divided amorphous carbon in use without apparent blockage of oilways, and the present widespread and ever-increasing use of colloidally-graphited oils as "running-in compounds" during the first 500 or 1,000 miles running of new and rebored automobile engines, all suggest that possibly very small amounts of colloidal graphite could be added to Diesel cylinder oils without harm ensuing and with, perhaps, considerable reduction in friction and wear. The writer has added colloidal graphite not only to the crank-case oil but to the motor spirit of his cars over a number of years, and has yet to experience an engine failure due to stoppage in either the lubrication or fuel system with graphite. Moreover, the graphite was used not merely during the running-in period but for many thousands of miles running of each engine without any blockage occurring. It is, however, admittedly undesirable to apply to large oil engines, without some reserve, experience gained in the lubrication of relatively small petrol engines, especially as the method of cylinder lubrication is so different in each case. The rate of flow of oil along the cylinder walls in petrol engines is relatively high, and the pump circulating system universally adopted for both bearing and cylinder lubrication is a great aid in keeping the flocculated graphite in suspension and on the move.

One final precaution necessary to bear in mind when experimenting with colloidally-graphited oils for Diesel engine lubrication, is that the addition of even small quantities of colloidal graphite reduces the demulsibility of the oil to a very marked degree, the colloidal stabilising material being presumably the chief offender. If, therefore, considerable quantities of the graphited cylinder oil work their way down into the crank-chamber, there is a possibility that the demulsibility of the bearing oil may be reduced to a degree sufficient to cause serious thickening and sludging. Here again, only actual trial will indicate whether this takes place to a serious extent, but it is a condition concerning the appearance of which vigilance should be exercised. Engines in which comparatively little cooling water leaks into the crank-chamber and in which a centrifugal purifier is included in the oil circulation system, are naturally the least likely to give trouble in this respect, even if leakage of graphited cylinder oil into the crank-chamber occurs.

Effect of Abrasives in the Fuel.

It is interesting to observe that the great increase in liner wear resulting from the presence of abrasive mineral matter in the fuel is also commonly experienced with gas engines running on blast-furnace gas. It is found that if the impurities are more than 0·05 gram per cubic metre of gas, the latter is dangerous for the engines and will cause deposits and excessive wear of piston rings and cylinder walls. The impurities here include lime dust, fine iron oxide, coke dust, tarry matter, etc., and are markedly abrasive. Dirty intake air is also a fruitful cause of heavy wear, which in some cases may be as high as 0·7mm. per annum. In such cases deposits taken from the piston commonly contain free silica, silicates and iron oxide (the latter partly due to wear), in addition to oil and bituminous matter. In marine Diesel engines the intake air is nearly always pure, but it has been known to carry with it fine sea-water spray in suspension into the engine, producing salt deposits and rapid wear, quite apart from the crank-chamber corrosion referred to in a recent paper.

The Effect of Sulphur in the Fuel.

The presence of even relatively high percentages of sulphur in the fuel does not appear to have any effect whatever on the lubricating oil, nor, *as long as these are maintained at a temperature above the dewpoint,* on the metallic surfaces with which the products of combustion come into contact. At lower temperatures, as has already been pointed out in recent papers and discussions, both corrosion and wear may be very marked indeed. This has for a long time been realized in connection with gas engines running on gaseous fuel containing excessive amounts of sulphur. In such cases corrosion is often entirely prevented, or at least greatly minimized, by allowing the jacket cooling water to run through the engine at temperatures as high as 160° F. The wear is chiefly on the piston rod, but only on that part which is rubbing in contact with the rings in the metallic packing. The greatest wear is where the rod is coolest, *i.e.,* where the water enters. The rod does not get pitted, but wears uniformly, maintaining a bright polished surface, with dark coloured patches showing here and there.

If a piston rod gets splashed with water outside the cylinder, it will wear rapidly if the gas contains an excessive amount of sulphur. A water leak from the cylinder head into the metallic packing will have a similar effect. In the case of a porous cylinder, allowing cooling water to leak into the cylinder, sulphur in the fuel will cause extremely rapid wear.

A simple calculation shows that a Diesel engine of 2,500 h.p. consuming, say, ten tons of fuel oil per twenty-four hours produces no less than 896lb. of sulphur dioxide during this period if the fuel oil contains 2 per cent. by weight of combined sulphur (by no means an unusual figure). This quantity of sulphur dioxide is equivalent in iron-consuming power to about 1,370lb., or approximately over 0·6 ton of concentrated oil of vitriol. Since this quantity of acid would be capable, even when cold and highly diluted, of attacking and dissolving as much as 780lb. (or roughly one-third of a ton) of steel or iron, it might at first sight appear surprising that an engine running on a fuel of 2 per cent. sulphur content would be able to complete a single voyage! Fortunately, corrosion of the crank-pins and other working parts can be very simply and cheaply prevented, so that, provided certain simple precautions are taken, the sulphur content of the fuel is relatively unimportant.

Crank-Chamber Corrosion.

It is a curious and at first sight apparently paradoxical state of affairs that a Diesel engine lubricated in the crank-chamber with a rather poor quality bearing oil, may be perfectly free from corrosion troubles, even when running on a fuel oil of relatively high sulphur content, yet on changing to a high-grade non-sludging demulsible circulation oil for bearing lubrication may suffer from very severe corrosion indeed. It is a mistake, however, to assume that the oil itself is corrosive, or in any way attacked by sulphur acids. All that has happened is that the oil, being demulsible, causes any water with which it becomes contaminated to form large drops. As Messrs. Le Mesurier and Stansfield have shown, large drops of acid water suspended in oil cause much more pronounced corrosion than small drops —perhaps partly because the large drops can more readily span the oil film and so form electrolytic cells between the metallic rubbing surfaces, and partly on account of the greater tendency for large drops to rupture the thin oil film adhering to each metal surface (*c.f.,* the effect of *large* as compared with *small* air bubbles in condenser tube erosion). This formation of large water drops is characteristic of mixtures of water and high-grade demulsible oils; the water drops may be initially small, as the result of mechanical atomisation, but owing to the absence of impurities in the oil which act as protective colloids, the very small water droplets rapidly run together to form larger drops until in a short time, wherever the oil is left comparatively undisturbed, the water separates out almost completely.

In the case of oils of poor demulsibility, the initial small water droplets become covered by very thin envelopes of impurities from the oil (which act as "emulsifying agents") and remain small and therefore relatively harmless until the oil leaves the bearings and reaches the settling tanks; in fact, the emulsion may be permanent and the water never form large globules at all. It would be a mistake, however, to jump to the conclusion that oils of poor demulsibility are therefore the correct lubricants for the bearings of Diesel engines running on high-sulphur fuel; while crank-pin and centrifuge bowl corrosion may thus be prevented without the necessity for the installation of even the simplest of washing devices, there is still the awkward problem of asphaltic oil-water sludge formation to contend with, and the formation of such dangerous deposits can *only* be prevented by the use of non-oxidising circulation oils. The latter appear almost invariably to show considerable resistance to emulsion, but for Diesel engine lubrication this may almost be regarded as incidental. The correct procedure then, is to eschew oils of poor demulsibility (where circulation oiling is employed) use only the best non-sludging oils, and to wash these thoroughly with water (preferably condensed water). The simplest and most effective way of doing this is perhaps to bleed continuously a little hot distilled water from the steam service, not only into the lubricating oil as it enters the centrifugal purifier (if fitted) but also into the crank-chamber. The settled acid water may be drained off regularly at intervals, or may be allowed to discharge itself automatically through a syphon. The advantage of using crank-chamber oils of high demulsibility here becomes apparent, for the wash water will be found to separate out rapidly and completely with the minimum amount of emulsion "mush".

Testing of Oil for Acidity.

It is important to draw off samples of the crank-chamber oil periodically and test these for both inorganic and organic acidity. In addition to the older method of shaking out a known amount of the oil with hot water and testing the aqueous extract for inorganic acidity by titration with dilute standard alkali solutions in the presence of methyl orange, it is often useful to supplement this test with an electrometric titration of the water, so that the hydrogen ion concentration (PH value) of the aqueous extract may be determined. Since, broadly speaking, the corrosiveness of the water is directly proportional to the H ion concentration, irrespective of the nature of the salts or acids present, this is a very rapid and useful method and avoids the necessity for determining the sulphurous and hydrochloric acids separately.

The writer has also found that useful information is afforded by determining the "organic" as well as the "inorganic" acidity of the aqueous extract of the used oil, since the water-soluble organic acids formed by the oxidation of the oil, although not as corrosive as mineral acids, are nevertheless far more so than petroleum acids and fatty acids of higher molecular weight. In a thorough investigation it is even desirable to distil the oil with steam and determine the total organic acidity of the distillate, as oil acids volatile in steam are corrosive.

Extreme Purity of Fuel.

In conclusion the writer would like to lay emphasis on the extreme degree of purity (as far as abrasive matter is concerned) involved in reducing the content of suspended matter to as low a figure as one gram per barrel. Assuming that the specific gravity of the oil is approximately 0·9, the weight of forty gallons of oil is 163,000 grams, so that the one gram of suspended matter expressed as a percentage by weight is only 0·0006 per cent. It is interesting to observe that many "fine chemicals" used in medicine, analysis, and research do not attain this standard of purity, even though graded as "chemically pure".

INSTITUTE NOTES.

VISIT TO FALMOUTH.

At the invitation of Mr. John H. Silley, O.B.E., the new President, Members of Council and the London Vice-Presidents of The Institute visited Falmouth during the week-end, May 25th to 27th.

Reserved carriages were provided on the 3.30 p.m. train from Paddington on the Friday, the guests being accommodated at the Falmouth and Bay Hotels.

On Saturday morning the shipyard and works of the Falmouth Docks and Engineering Company were inspected, when the excellent facilities for dry-docking and repairing vessels up to 25,000 tons greatly impressed the visitors. It was learnt that no fewer than 358 ships had thus been dealt with during the past twelve months, an extraordinary development since the small yard of Cox & Company was taken over by Messrs. R. & H. Green & Silley, Weir, Ltd. only fifteen years ago. Mr. John H. Silley is, as is well known, Chairman and Managing Director of the firm.

After lunch the party boarded the "Gerrans" for a trip up the River Fal, passing pathetic groups of moored ocean-going vessels patiently awaiting the dawn of better days. On arrival at Truro, a fleet of cars conveyed the visitors across country, past many relics of centuries-old steam pumping plants of disused tin mines, to the Treloyan Hotel, St. Ives, where tea was served on the lawn overlooking the Bay.

The return journey was made via Mount's Bay, affording fine views of coastal scenery and the romantic island fortress—St. Michael's Mount. Nearing Falmouth, the Company's housing estate at Swanvale was visited and admired. This is a development which the President has very much at heart. Ten cottages are already occupied and plans are ready for another forty. Employees can retire from work on attaining the age of 65 and live in ideal surroundings at an inclusive rental of 2s. 6d. per week, the houses as completed being handed over by trust deed to the Corporation. It has been well said that Falmouth seems to be pioneering an effort of national importance.

In the evening Mr. Silley entertained his guests to dinner at the Falmouth Hotel, when the Chairman of Council and a senior Vice-President expressed the thanks and appreciation of all present for the delightful holiday enjoyed. In response to the toast of his health, which was accorded musical honours, the President outlined his ambitions to extend the activities and raise the status of The Institute of Marine Engineers during his year of office, making particular reference to the reconstituted Guild of Benevolence now in process of being placed on a wider and firmer basis.

The party returned to London on the Sunday afternoon, having been favoured by remarkably fine weather throughout the trip.

At the Shipyard of the Falmouth Docks & Engineering Company. Mr. John H. Silley is seen near the centre, under the flag. The Chairman of Council is on his right.

The party on board the "Gerrans" at the commencement of the trip up the River Fal. The President (in soft hat) is standing by the base of the funnel between two well-known Vice-Presidents, Mr. J. M. Dewar and Mr. R. S. Kennedy).

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, June 4th, 1934.

Members.

Matthew Blackwood Aitken, 151, Kingswood Drive, King's Park, Glasgow, S.4.

William Arthur Clarke, 16, Grosvenor Road, Highfield, Southampton.

Arthur Rowland Darbyshire, 13, Church Road, Manchester, 13.

George Gordon Hay, Mazagon Dock, Bombay, India.

William Humphreys Hooper, c/o Port Office, Cochin, S. India.

Thomas Henry Hunstone, Galatea, Stream Road, Kingswinford, Dudley.

John David Lewis, St. Ives, New England Road, Haywards Heath, Sussex.

David Arthur MacFarlane, c/o Whangpoo Conservancy Board, Customs Buildings, Shanghai.

George William Pollard, 51, Oak Avenue, Cleadon Estate, South Shields.

Charles E. Stuart, China Navigation Co., c/o Messrs. Butterfield & Swire, Hong Kong.

George William Terry, 18A, Pierremont Crescent, Darlington.

Robert Munro Young, 3, West Drive, Seedfield, Bury, Lancs.

Associate Members.

Cyril Gordon Crawford, Leamington, 4th Avenue, Belleville, St. Michael, Barbados, B.W.I.

George Ellis, 77, Sudbury Heights Avenue, Greenford, Middlesex.

ADDITIONS TO THE LIBRARY.

Purchased.

Reed's Extra First Class Engineers' Guide Book, by W. H. Thorn. T. Reed & Co., Ltd., Sunderland. 18s. net.

King's Regulations and A.I. Amendments (K.R. 3/34). H.M. Stationery Office. 3d. net.

Final Report on the Fourth Census of Production (1930). Part II. The Iron and Steel Trades, the Engineering, Shipbuilding and Vehicle Trades, the Non-Ferrous Metal Trades. H.M. Stationery Office, 7s. 6d. net.

The William Froude Laboratory. Abstract of Results published on a Methodical Series of Resistance Experiments on Ship Models, and their Use in Design. By G. S. Baker and A. W. Riddle. H.M. Stationery Office. 6s. net.

"The Directory of Directors, 1934". Thomas Skinner & Co. 25s. net.

"The Superintendent Engineers' Pocket Data Book", compiled by the Superintendent Engineer of the Royal Mail Steam Packet Co. James Munro & Co., Ltd. 5s. net.

Presented by the Publishers.

Nickel Bulletin on "An Historical Survey of Alloy Steels", by Professor Sir Harold Carpenter, D.Sc., F.R.S.

Rensselaer Polytechnic Institute Bulletin No. 46 on "Reinforced Brickwork", by H. Duff Williams, C.E.

"Piston Material and Design". Paper read at the Diesel Engine Users' Association by H. J. Maybrey.

"A Manual of Foundry Work", by J. Laing and R. T. Rolfe. Chapman & Hall, Ltd. 276pp., 15s. net.

The value of metallurgical control in foundries is more fully recognised and appreciated to-day than ever before, and this book is a praiseworthy effort to link up the scientific principles of foundry work with the art of the moulder.

The claim is made in the preface that it is intended for all connected in any capacity with the foundry industry, for while the basic principles have been dealt with fully the work proceeds to a comprehensive study of the advanced technique. The claim is made good in so far as moulding is concerned, but much prior knowledge is assumed as regards metallurgy in general, and metallography in particular. For this reason the book will prove of greater benefit to the student or metallurgist who seeks to enlarge his knowledge of foundry technique, than to the foundryman who may have only a limited scientific training.

Chapters 1 to 7 are devoted to moulding and core making in sand and loam, and contain, besides much useful information as to its use, a comprehensive description of the tackle. The 6th chapter on moulding and running in relation to design, is worthy of special mention as it deals in a lucid manner with one of the problems arising daily in foundries where a range of castings is being handled, and should help the designer to realize some of the difficulties which beset the moulder.

The next three chapters deal with ferrous alloys, followed by a chapter (of fifteen pages only) on non-ferrous alloys. The authors say of these alloys that on account of diminished thickness, moulding requires greater care, but owing to the lesser variation in size and shape of the casting it scarcely requires the same initiative. Actually, these variations are as great as in ferrous alloys, and in view of their variety and importance, and the special foundry technique and skill required for most of them, more attention might with considerable advantage have been devoted to them.

No mention is made of die casting or centrifugal casting, and the scope of the book is confined to a consideration of British methods.

As an introduction to the study of foundry practice, and moulding in particular, the book should prove valuable; it is clearly printed and the diagrams, illustrations, and microphotographs are exceptionally good.

"The Motor Boat Manual". 11th Edn. Temple Press, Ltd., 5-15, Rosebery Avenue, London, E.C.1. 1934, 5s. net.

Since the previous edition of this book was published, three years ago, there has been perhaps more progress in the design and manufacture of marine motors—particularly of high-speed Diesel engines—than during the preceding ten years. As a result, very extensive modifications and additions have been made in the new edition of this now well-known and valuable work. Many chapters have been completely re-written; the remainder have been thoroughly revised with a view to bringing the work up to date and increasing its usefulness.

The following list of contents is perhaps the best indication of the comprehensiveness of the book, viz., boat construction; hull design; practical details of boat-building; metal hulls; typical displacement craft designs; high-speed motor boats; some notes on sailing and sail plans; propulsion systems; how the marine motor works; carburetters, vaporizers and heavy-oil injection systems; engine lubrication, the cooling-water system, silencers and electric lighting sets; clutches, reverse gears, reduction gears, vee drives and reversing propellers; care and maintenance of machinery; installation; petrol and paraffin engines; heavy-oil engines; high-speed Diesel engines; outboard motors; outboard motor boats; motor boat clubs and associations; and international regulations for preventing collisions at sea.

"The 'Stand-by' Nautical Telegraph Code". Compiled by Capt. C. H. Noel. Brown, Son & Ferguson, Ltd., 52-58, Darnley Street, Glasgow, S.1. 5s. net.

The importance of telegraphic codes is already generally recognised and there are now several different examples of this type of aid to rapid transmission of messages in accepted use on shore.

Captain C. H. Noel, Master Mariner, has compiled a complete code for five-letter combinations suitable for the construction of long messages in the simplest and most definite form, and of such a character that the code is not only easy to use in the deciphering of a message, but also reasonably easy to use when one is faced with the need to break the message up into its proper parts when preparing the radio telegram.

This is the first edition of a work upon which Captain Noel has obviously spent a tremendous amount of time, and it can be said that there is every indication that the book should prove itself as invaluable to sea travellers as other codes have proved themselves in the commercial world.

It would appear to be well worth the time of the average sea-going engineer officer to inquire as to what the book can offer, and also that at least one copy should be available on board for the general convenience of the officers and crew. For the full value to be obtained from the service the book offers, it should be pointed out that access to a copy must be easily obtainable by the recipient of the message.

The Institute's copy will be placed in the Reading Room so that Members may have access should they have occasion to refer to it.

"A Five Year Bibliography of the Theory of Refrigeration, Refrigerants and Appliances. 1929-1933". Compiled by H. T. Pledge, B.A. Price 2s. net (post free 2s. 3d.) and 2s. 6d. net (printed on one side only) (post free 3s.). Published for the Science Museum by His Majesty's Stationery Office, Adastral House, Kingsway, W.C.2.

A complete list of all references to articles, papers and books on every branch of refrigeration would fill a book of such vast proportions that it would defeat its own object. For this reason and because of the rapid developments in recent years the Science Library of the Science Museum, when preparing a bibliography on the subject, decided to limit its scope to the five years, 1929 to 1933. Part I, which is devoted to the Theory of Refrigeration, Refrigerants and Appliances, has now been published and is recommended to those firms and individuals who wish to know the British, European and American sources of information on the subject. Part II, which will deal with the Effect of Refrigeration on the Bacteriology and Biochemistry of Foods, etc., and on the Applications of Refrigeration (except where the papers describe appliances), is expected to be ready shortly.

No such complete bibliography on refrigeration has hitherto been compiled; its appearance is of special interest in connection with the Refrigeration Exhibition open to the public at the Science Museum until the end of August.

The references are classified under the Classification Décimale Universelle and the book under review is divided under the following headings: treatises on refrigeration; refrigeration in general, refrigerants; general works on refrigerating plants as a whole and individual refrigerating plants; refrigeration in various industries; principles of plant construction, insulation, etc.; general works on refrigerating units and parts of plant; theory of refrigerating machines; various methods of refrigerating; parts of machines, compressors, condensers, absorbers, etc.; domestic refrigerators, ice chests, etc.; ice manufacture; and refrigeration in air conditioning.

Notable exclusions are patents, all purely commercial matters, accident prevention, Diesel and electric drive, corrosion, welding, suproconductivity, air conditioning except as to the cooling of air lubrication, insulating materials except in specific reference to refrigeration and plant for constituents of ice cream other than ice. Bibliographies on lubrication and heat transmission have previously been prepared by the Science Library and a complete list of all the bibliographies, 120 in all, prepared by this institution, is given at the end of the book. Copies of the earlier bibliographies can only be obtained from the Science Museum.

In order to keep down the cost of the book the present bibliography has been prepared in mimeograph form. Printed on one side of the page the cost is 2s. 6d. (post free 3s.) while a cheaper edition, printed on both sides, is available at 2s. (post free 2s. 3d.). Copies may be obtained direct from the Science Museum, South Kensington, London, S.W.7, or from His Majesty's Stationery Office.

"Guide to the Refrigeration Exhibition at the Science Museum". By T. C. Crawhall, M.Sc., and B. Lentiagne, B.A. Price 6d. net, 7d. post free (Science Museum handbook published by His Majesty's Stationery Office, Adastral House, Kingsway, W.C.2.

The title of this small handbook gives only a slight indication of its contents. It seems to imply that the book may be used with advantage only when visiting the Refrigeration Exhibition at the Science Museum, South Kensington, whereas this is far from being the case.

The exhibition, which is open to the public free of charge until the end of August, consists of models, small-scale working plants, charts and diagrams, designed to illustrate the principles of refrigeration, results of research, and the industrial applications of this branch of science and engineering. In the Guide the authors have taken the opportunity of giving short treatises on each of the principles concerned, and subsequently described each exhibit in detail; the book is in effect a text-book in miniature. Moreover, the exhibition represents the most up-to-date practice and, in consequence, the book contains accounts of refrigerating machines and appliances which will not be found in the most modern textbook. One of the outstanding examples of this is the device known as a cold multiplier, which makes use of solid carbon dioxide in a machine operating on the absorption cycle.

A useful feature of the book is a chart giving the precise temperatures at which all forms of foodstuffs should be stored. This alone is worth more to those who are in any way concerned with food preservation than the cost of the publication. The chart supplements a chapter on the uses of refrigeration.

Apart from food preservation, refrigerating machinery is now very widely used in industry, e.g., brewing, margarine manufacture, the de-waxing of oil, and the sinking of mine shafts, in addition to the better-known applications to ice manufacture, ice-cream manufacture, skating rinks, etc. These and other applications are carefully described.

The refrigeration industry has developed along scientific lines in a compartively short space of time and it is interesting to read a brief account of its historical development. Unnecessary details have been eliminated, leaving only the essential features in a manner which cannot fail to interest.

The book is recommended to students of the subject, for whom it will form a useful introduction, and to all those whose affairs bring them in contact with the problems of refrigeration.

It may be obtained direct from the Science Museum, South Kensington, London, S.W.7, or from His Majesty's Stationery Office.

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 17th May, 1934 :—		
Hall, Edward R.	2.C.	London
Holmwood, John F.	2.C.	"
Milne, Alexander O.	2.C.M.	"
Willoughby, Leonard A.	2.C.M.	"
Crockett, Hector B.	2.C.	Glasgow
McDougall, Donald G.	2.C.	"
Mann, George	2.C.	"
Rough, Arthur	2.C.	"
Bowering, Percival S.	2.C.	Liverpool
Chesters, Philip F.	2.C.	"
Gorst, William S.	2.C.	"
Redfearn, Godfrey F.	2.C.	"
Reid, William T.	2.C.	"
Wootton, Eric A.	2.C.	"
Tughan, Basil W.	2.C.M.	"
Frost, William B.	2.C.	Cardiff
Brown, Charles H. W.	2.C.	London
Dobson, Charles V.	2.C.	Newcastle
Dodd, Charles G.	2.C.	"
Douglas, George	2.C.	"
Quenet, Leslie R.	2.C.	"
Swinburne, Albert H.	2.C.	"
Thompson, William W.	2.C.	"
Andrew, John W.	2.C.M.	"
Sutton, Alexander G.	2.C.M.E.	London
Spring, Stanley R.	2.C.M.E.	"
For week ended 24th May, 1934 :—		
Archer, Norman	1.C.	Newcastle
Chapman, John H. P.	1.C.	"
Henderson, Richard W.	1.C.	"
Newhouse, George A.	1.C.	"
Robson, Edmund V.	1.C.	"
Laws, Walter	1.C.M.	"
Porter, James W.	1.C.	London
Whincop, George F.	1.C.	"
Anderson, Edward F.	1.C.M.	"
Kessick, Herbert S.	1.C.M.	"
Mackie, James E.	1.C.M.	"
Cadger, Robertson	1.C.	Glasgow
McArthur, William	1.C.	"
Macintosh, James L.	1.C.	"
Stuart, John G.	1.C.	"
Wotherspoon, John	1.C.	"
Drummond, Robert	1.C.M.	"
Axten, Frederick T.	1.C.M.	"
Baxter, William	1.C.	Liverpool
Binks, Bertram M.	1.C.	"
Haggitt, Walter	1.C.	"

Name.	Grade.	Port of Examination.
Morris, Reginald H. C. ...	1.C.	Liverpool
Nunn, Harry	1.C.	,,
Richardson, George H. ...	1.C.	,,
Rothwell, Edward O. C. ...	1.C.	,,
Routledge, James	1.C.	,,
Shroff, Ratansha B. ...	1.C.	,,
Porter, George	1.C.M.	,,
Seed, John B.	1.C.M.	,,
Smith, Harold R.	1.C.M.	,,
Robb, Douglas	1.C.M.E.	,,
Ross, Charles E.	1.C.M.E.	,,
Wright, Edward	1.C.M.E.	,,

Name.	Grade.	Port of Examination.
Christian, Charles H. ...	1.C.S.E.	Liverpool
Horn, James	1.C.S.E.	Glasgow
Youldon, Joseph S. H. ...	1.C.M.E.	London
Lobban, Alfred A. C. ...	1.C.M.E.	,,
Spray, James	1.C.M.E.	,,

BENEVOLENT FUND.

The Committee gratefully acknowledge receipt of the following donations:—"10-37", £1; J. V. Delves (Member), 10s.

ABSTRACTS.

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

Power from Sewage Gas.

Discussing the Utilisation of Sewage Gas for Power Development, with Warming of Sludge by Exhaust heat.

"Internal Combustion Engineering", March, 1934.

One of the most interesting developments in the power field during recent years has been the systematic utilisation of sewage gas on a large scale. Successful installations have been established in this and various other countries, including Holland, Germany and the United States, and there can be no doubt that others will follow. According to Obering. Franz Fries, writing in *Gesundheits Ingenieur,* the first sewage clarifying plant in Germany with gas-recovery equipment was that at Essen-Rellinghausen, which has recovered and utilised all its sewage gas since 1924. Since then, sewage gas recovery has been introduced in 40 German towns with a total population of 4,500,000; and in eight cities, with 2,100,000 population, the gas is utilised in power plant.

The average composition of sewage gas is 70 to 85 per cent. methane (CH_4), 9 to 30 per cent. carbon dioxide (CO_2), $1\frac{1}{2}$ to $7\frac{1}{2}$ per cent. nitrogen, and traces of hydrogen and oxygen. Generally, the gas can be used as it leaves the fermenting tanks, purification to remove sulphuretted hydrogen being necessary only in exceptional cases. The value of the gas is determined by its methane-content, a rising percentage of the other constituents, particularly carbon dioxide, reducing its effective value. Methane is explosive in almost any mixture with air and the risk is one to be specially considered in arranging the gas collecting devices. The gas itself being odourless, additions are commonly made to render its leakage apparent.

The quantity of gas obtainable from the sludge depends upon the amount of organic matter present. According to the degree of decomposition, which depends on the temperature in the tank, the theoretically obtainable amount of gas varies up to about 13·8 cub. ft. per lb. of decomposable material present. In practice, the gas yield ranges from 0·2 to 0·9 cub. ft. per head of population per day according to the composition of the sewage.

Collection of Gas.

The main consideration in the collection of gas is the provision of a gastight cover over the fermenting chamber. In double-deck installations, the partitions act as gas covers. In other cases special covers are provided, either as fixed covers below or above the level of the sludge or as floating covers. A fixed submerged collector avoids the risk of explosion but involves a sacrifice of effective fermenting space. Fixed covers above the sludge eliminate this loss and provide space for mixing gear, but special seals are required to avoid the risk of explosion. In this respect, floating covers offer obvious advantage, the gas being necessarily under pressure (and therefore leaking outwards if at all) unless the cover is resting on the sludge. According to Herr Fries, experiments with floating gas covers of sheet metal were made at Aachen as

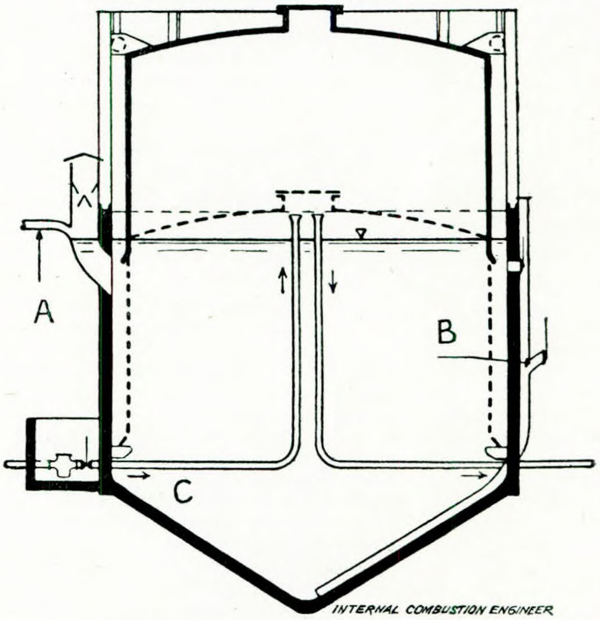

FIG. 1.—Sewage tank with gasometer collector as used at Essen-Rellinghausen.

early as 1922, but the first practical installation was at Birmingham (England) where large open tanks were fitted with Whitehead's floating collectors of reinforced concrete. Somewhat similar collectors of sheet iron were adopted in Holland by Kessener; and large tanks in America have been fitted with lattice-braced floating covers, in accordance with Downes' recommendations.

Going a step further, the floating gas cover becomes a gasometer, this arrangement being specially useful in gas-power plants where the rate of generation of gas is fluctuating. The sludge itself forms the seal of the gasometer (see Fig. 1), the sludge inlet and outlet being at *A, B* respectively; and, if the supply of sewage gas is inadequate, it can be supplemented by town gas admitted at *C,* the gas bell itself ensuring good mixing of the two gases. In this connection, it may be mentioned that Prof. Fischer and his collaborators at the Coal Research Institute, Mülheim, have found that, when coal gas is passed through fermenting sludge, the carbon monoxide is converted more or less completely to methane; and Imhoff and Hilgenstock have proposed (German Patent No. 411,926) the treatment of mixed gas with fermenting sewage in order to secure conversion of the hydrogen. It is possible, says Herr Fries, that the gasometers of gas works could be used economically as sewage tanks in some instances.

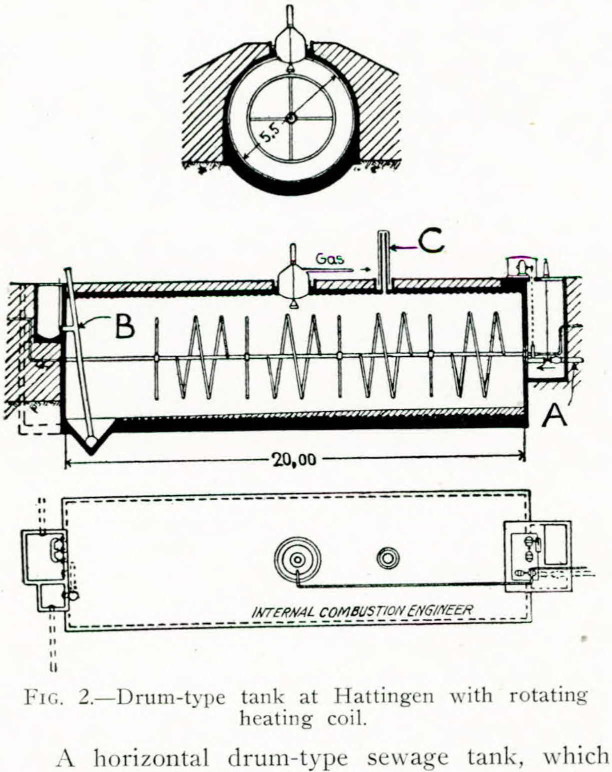

FIG. 2.—Drum-type tank at Hattingen with rotating heating coil.

A horizontal drum-type sewage tank, which considerably simplifies the collection of gas, has been in use at Hattingen for a long while. As shown by Fig. 2, a drum of corrugated iron, about 20m. long by 5·5m. diameter (65½ft. by 18ft.), is set in reinforced concrete and heated by a rotating coil. The sludge inlet and outlet are at *A, B;* gas is drawn off at the dome shown, and a safety valve is provided at *C.*

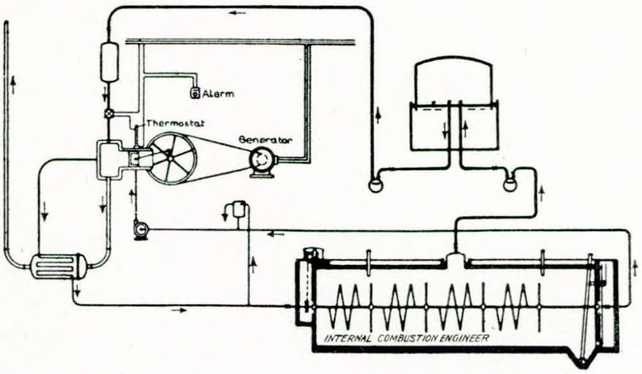

FIG. 3.—Lay-out of sewage gas power plant.

Utilisation of Gas.

The utilisation of sewage gas depends on local circumstances. The simplest application is for lighting purposes, in conjunction with town gas, and no special equipment is needed for this purpose, with the possible exception of a compressor to overcome the pressure of the main system. Of recent years, however, sewage gas has been used to an increasing extent for power purposes, this development being favoured by improvements in gas engines and by the increasing mechanisation of sewage disposal works, offering a ready outlet for the almost cost-free power.

Experience indicates that from 14·3 to 17·9 cub. ft. of sewage gas is required per h.p. hour; hence, from a sewage plant for 100,000 population yielding about 49,500 cub. ft. of gas per 24 hour (at 7·4 cub. ft. of gas per lb. of organic material in the fresh sewage), it is possible to generate about 2,760 h.p. hour per 24 hour, or say 1·15 h.p. continuously per 1,000 head of population. This is based upon using only the sludge of a preliminary purifier. If rain-water sludge and final-purification sludge, particularly activated sludge, also enter the fermenting tank, twice as much power can be obtained and this will generally suffice for the full biological purification of the sewage.

The general lay-out of a modern sewage gas power plant is shown in Fig. 3. Gas from the sewage tank is taken to a gasometer through a meter, and thence through a check meter and a receiver to the gas engine, which is arranged for waste heat recovery. The jacket water flows through an exhaust boiler to the heating coil of the sewage tank and thence back to the circulating pump, an expansion tank being provided on the hot-water line as shown. A thermostat rings an alarm bell and closes the engine stop valve if the temperature of the jacket water reaches a predetermined limit. The use of a rotating heating coil in the sewage tank is specially advantageous because it prevents the formation of crusts, even when the water is at 200° F., and permits a heat transmission rate of 74 B.th.u. per sq. ft. per hour.

The heat balance of a sewage gas power plant is approximately as follows, taking the energy content of the gas as 100:—

Brake h.p. of engine	26
Belt and bearing friction ...	6
Loss in electric generator ...	3
Exhaust	35
Cooling water	30
	100
Recovered by heating sewage ...	54
Net loss (=100−26−54) ...	20

This shows that 26 per cent. of the energy in the gas is converted to mechanical energy, 54 per cent. is utilised in heating the sewage, and only 20 per cent. is lost. The economic advantage of combining the power and heating services in this way is obvious.

Horizontal engines are generally used in Germany, and the largest sewage gas-power plant there working is the 1,750 h.p. installation at Berlin-Stahnsdorf. The use of such plant is likely to become standard practice in the majority of towns in view of the advantages offered and the increasing importance of complete and economical treatment of sewage. A further interesting possibility, pointed out by Beinhauer, is that of using sewage gas as a fuel for motor vehicles. This application deserves to be borne in mind, though it is probable that the works power and heating requirements will generally be the more useful outlet.

The Principles of Refrigeration.[*]

By Sir William Bragg.

"The Engineer", 11th May, 1934.

In these days it is obvious that the discoveries of science are exercising a tremendous effect upon our affairs—individual, national, and international. Certain applications of discovery are to our advantage, as, for example, the plentiful provision of food, clothing, leisure, and other necessities, though it is to be admitted that distribution is badly at fault. On the other hand, science can be so applied as to cause painful dislocations in peaceful industry, and utter misery in war. The question at once arises—can the applications of scientific discovery be put under control, either by law, or by any form of common consent? It is impossible to put any real check on the urge to acquire new knowledge, but perhaps an understanding watch may be kept upon the progress of discovery, and upon the uses that men of all sorts are finding for it, so that abuses may be stopped in time, while beneficial applications may be encouraged.

It must be an understanding watch, because action must needs be quick to be effective. Weeds had better be discovered at once and pulled up while their roots are feeble. But, it may be argued, science is so far advanced that experts alone can understand its thoughts and its deductions. If this were true such lectures as that which I am to give this evening would be in vain. But it is not true. One may distinguish between the broad principles of science which gradually become clear in the course of years or centuries, and the complicated deductions which men derive from those principles in order to satisfy their keen desires. The difference is like that which exists between strategy and tactics in a military campaign. A layman may follow the former, and only a trained soldier may comprehend the innumerable details of the latter.

The immense and still growing refrigeration industry will serve as an excellent example. It springs directly from a very few fundamental principles of Nature which are readily understood. The construction of its machinery requires the highest technical skill and most ingenious and painstaking scientific research. Its strategy is simple; its tactics are exceedingly complicated. It is exercising a great influence on the health and comfort of the nation, and is a matter of the greatest importance to our trade and to our relations with foreign countries. This is well illustrated by a table published in connection with the present Refrigeration Exhibition in the Science Museum in South Kensington. In 1932 we imported 1½ million tons of meat, half a million tons of cheese and butter, 70,000 tons of fish, about 400 million eggs, while the fruit filled 500 ships. All this food was brought to the country by the aid of refrigeration. It works out at about 5 oz. a day for every person in the country. If we try to comprehend this vast movement, and to forecast its future, we may be helped from a knowledge of the fundamental principles, while we leave the details of the machinery to the experts among the scientists and the engineers.

Of these elementary considerations the most important is that which shows us the activities of the world, including all its life, as dependent on two opposing tendencies in Nature. The atoms and the molecules of which we and our surroundings are made are drawn together by forces which, if given their full influence, would bind them into a single lump, motionless and dead. The opposing tendency is that energy of motion which, in various forms, and particularly that of heat, keeps the atoms and molecules continually on the move. If the heat tendency is in the ascendant, atoms and the molecules fly apart in complete disorder and form a gas, as happens, for example, in the air where the molecules of nitrogen and oxygen move to and fro with intense rapidity, never entering into combination with each other because their lively motions so far overpower their relatively feeble attempts to hold together. It should be remembered that the atoms are like the letters of the alphabet, limited in

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[*] Abstract of a lecture, given under the auspices of the British Science Guild, on Wednesday evening, May 2nd, in the Lecture Theatre of the Royal Institution.

number, whereas the molecules are like words that can be made of the letters. The number of possible combinations of atoms is infinite, and all the processes of Nature, animate and inanimate, depend on the continual resolution of molecules into atoms and their recombination in fresh forms, just as type is distributed by the compositor and set up in words of new meaning.

Now heat may encourage the processes on which life depends by shaking up the atoms and molecules of a body so that they are continually presented to each other in different ways, so favouring the combinations that Nature must bring about. In liquids there is much freedom, though the forces between the molecules have so far the upper hand that they do not easily break away from each other. Life, in fact, is mainly carried on in substances which contain much liquid as the body tissues or the stalk of a plant or the flesh of a fruit. If heat is relatively so feeble that the molecules draw finally together and lose all power of shifting their places with respect to each other, the life of that body has ceased. When Nature finally lays the molecules to rest in this way, there is usually a beautiful order in their arrangement, which displays itself in the perfect symmetry of its outward form; the substance is now, as we say, a crystal. There is a certain amount of crystalline arrangement in every body, because rigidity is useful as in the bones and the teeth, and even in the tissues there is some attempt at arrangement, because living bodies cannot be made of liquids only.

When we want to preserve meat and fruit for our use, we must check as far as is necessary the constant tendency of molecules to break up and re-unite, whether as part of the natural change of the body itself, or as a consequence of living forms imported from outside. That is the essence of refrigeration. Our machines must slow down the individual motions of the molecules of the substances which we wish to preserve from change. How can we get at those invisible motions?

The methods of refrigeration, like the occasion for it, depend on simple fundamental principles, one of which we learnt in the cricket field. When we wished to make a catch we found that we had to draw our hands back quickly as the ball entered them. If we held our hands firmly in place, it hurt, and the ball generally jumped out again. It was because the hands retreated before the ball that the latter lost its speed. In a cylinder containing air or any gas, the molecules are continually bombarding the piston and being reflected therefrom. It is this bombardment which constitutes pressure. If, now, the piston is allowed to be driven forwards, the molecules that strike it all lose way like the cricket ball. Their motion is diminished, heat is lost, the gas cooled. Whenever a gas is allowed to expand against pressure, it loses heat. Conversely, if it is compressed it becomes warmer, as everyone knows who has handled a bicycle pump. Here is our refrigerating engine. First, compress a gas, such as the air, take away the heat thus put into it by bathing its container in running water at normal temperature, and then allow the compressed air to expand. It is chilled in consequence, and may then be allowed to circulate in or round the chamber containing the substances to be refrigerated. This is the essential operation; the refrigerating machine is its elaboration by the engineer along scientific lines. The method was actually used in 1881 to bring home from New Zealand the first consignment of 5,000 lambs.

There is a second method of arresting motion, more easily handled than the first. When molecules on the surface of a liquid break away as they do sometimes, the liquid which has expelled them has lost energy and heat. We are familiar with the chill due to evaporation. A wet hand feels cold when winds blow over it; a water holder of porous earthenware or canvas is chilled when it is placed in a draught, all the better if the wind is hot and dry. So most machines to-day cause ammonia to evaporate by drawing away the vapour as fast as it is formed. This is the essential feature of a machine which skilful design, based on much research, has brought to a high state of efficiency.

Thus, the skill of the engineer-scientist has given us a means of controlling to a large extent those natural processes which cause deterioration in our foods. When their machines are put into use, it is found that there is still further work to be done, very important and very interesting. Apples, for example, do not cease to develop when they are gathered; they must be treated as living organisms. The temperature must be nicely adjusted. It must be cold enough to hinder change, yet not so cold as to cause crystalline arrangement. Even its atmosphere must be regulated; not too much oxygen, or it will live too fast, nor too much carbon dioxide, or it will be suffocated and develop "brown heart". The proper treatment of one kind of apple differs from that of another. A whole new and most interesting world of research opens out before the keen workers at Cambridge, at East Malling, at Aberdeen, at Teddington. One thinks with amazement of the rapid growth of a marvellous industry, and realises that there is far more to come. What will be the consequences if, for example, it is proved, as seems to be certain, that chilled meat can now be brought from Australia, provided a certain proportion of carbonic acid is added to the air in the ship's hold? What is to be the effect when the word "perishable" disappears from the food label? And when the element of chance and choice in the housekeeper's shopping lies not in the degree of freshness of a limited number of foods, but in the variety of foods all of one high standard of excellence?

The vigorous progress of this already vast movement is no matter of surprise when we realise that on the one hand it is directed towards the fulfilment of primitive and urgent desires, and that on the other it depends on the application of fundamental principles which scientific research has laid bare. The desires are permanent; research, physical, chemical, and biological, gains strength every day, and so the movement is sure also to grow in volume and in power.

Geared Turbines to Diesel Engines.

Extra Speed—One-third Fuel Consumption.
Non-stop Run of 49 Days.

"Journal of Commerce", May 24th, 1934.

Engine conversions may not always be a practical proposition, but their value in some instances may be realised by the performance of the Italian motorship "Riv", of the Societa Commerciale di Navigazione. This ship, which was built in 1921 by Messrs. Armstrong, Whitworth & Co., as the steamer "Montgomeryshire", has just completed a very long trip through Europe and the Far East, in which she has covered a total distance of over 35,000 nautical miles, with very few and short port calls.

After the voyages Venice—Novorossisk, Novorossisk—London, London —Novorossisk, the "Riv" started from this latter port up to Vladivostock, the extreme Russian harbour on the Yellow Sea. On the return journey, the ship travelled to Stettin (Germany) and Gdynia, and reached Venice on May 7th.

These runs total to a distance which is equal to 2½ times the circumference of the earth. When it is realised that the Fiat Diesel propelling machinery is reported to have been kept running continuously (that is, with only a stoppage of a few hours at the Suez Canal) for 46 days in the journey from Novorossisk to Vladivostock, and for 49 days from Vladivostock to Stettin, it forms a very valuable tribute to the reliability of the machinery. It is stated that, notwithstanding the extremely low temperatures experienced at Vladivostock (33 degs. Fahr. below zero), the engines have not given the least trouble, and when the ship arrived back in Venice she was ready to start another trip immediately.

The hull of the "Riv" was built on the longitudinal framing system, and the ship carries general cargo in six holds, including a deep tank. No important structural modifications have been required, but the insulated space for cargo, provided on behalf of her previous owners, was taken out, and there has been a complete new engine seating laid on the tank top in the machinery space.

The New Machinery.

The new main engine in the "Riv" is a four-cylinder Fiat two-stroke unit rated at 2,400 b.h.p. when running at 110 r.p.m. It has four cylinders, drives its own scavenging air pump, and has a compressor for blast-injection of fuel, and was fitted on board in the early part of last year. It is a fully standardised unit with a bore of 750mm., or about 29½in., the stroke being 1,250mm., which corresponds to practically $49\frac{3}{16}$in.

Salt water is used for cooling the jackets and pistons. The piston cooling pipes have their glands external to the crankchamber, so that in the event of leakage the water drains clear of the crankcase and the lower part of the cylinders. Steel tie-bolt construction is employed.

Steam auxiliary machinery is used (the winches, windlass, steering gear and engine-room pumps being those originally fitted); none of the three boilers was retained. A new cylindrical marine boiler has been fitted. This is oil-fired, and there is also a large Cochran vertical exhaust gas and oil-fired boiler with separate combustion chambers, so that the exhaust gas from the main engine enters by an inlet pipe in the upper part and has its own discharge pipe to the funnel, whereas there is another uptake from the oil-fired section.

The amount of steam generated by the exhaust gas is sufficient for all requirements under way; all the accommodation is steam-heated, moreover, and as a further step towards economy a main shaft-driven dynamo provides current for lighting when the ship is at sea.

The new auxiliary machinery comprises a two-cylinder Fiat two-stroke high-pressure Diesel-engined air compressor with a capacity of 400 cubic metres per hour. The engine develops 100 b.h.p. at 350 r.p.m., and is of the two-stroke blast air-injection type, driving a scavenging pump.

Fuel Consumption.

There is also an interesting high-speed set for emergency purposes. The engine is one of the latest Fiat design with two cylinders, running at 800 r.p.m. employing solid injection, with Bosch fuel pumps and atomizers. It is coupled to an 11·5 kW. dynamo, and there is a friction clutch, operated by a wheel, in order to drive a small air compressor, which pumps up to 60kg. per sq. cm., or about 850lb. per sq. in. The maximum pressure of the large set, also that of the main engine compressor, is 70kg. per sq. cm., corresponding to about 1,000lb. per sq. in., and it may be added that starting air is supplied from the high-pressure air bottles. The main shaft-driven dynamo is a 90-ampere machine, and there is also a steam-engine-driven 110-volt dynamo of 12 kW., running at 370 r.p.m.

In order to maintain 10 knots when loaded, the "Montgomeryshire" burned 35 tons of oil a day. As the "Riv", the vessel uses between 9 and 10 tons daily, and her speed is 11½ knots when fully loaded. Thus, an extra 1½ knots has been gained at a saving of not less than 25 tons of fuel per day.

The time taken for conversion of this ship is a matter of interest, it being just two months from when she was docked until the sea trials with the new machinery completed. The work was undertaken at the Monfalcone yard of the Cantieri Riunti dell'Adriatico.

Heat Transfer between Metal Pipes and a Stream of Air.*

By Ezer Griffiths, D.Sc., F.R.S., and J. H. Awbery, B.A., B.Sc., of the National Physical Laboratory.

"Ice and Cold Storage", January, 1934.

The technical importance of data on the design of heat transfer appliances has resulted in a very large number of investigations.

Earlier workers who attempted accurate measurements concerned themselves with observations of heat transfer between the fluid inside and that outside the pipe, thereby obtaining the total resistance to the heat flow. This coefficient is a complex one, for it is built up of the surface resistance between fluid and solid at each side of the dividing wall as well as the resistance of the material of the wall. Recent workers on the subject, following Stanton, have tended towards a simplification of the problem by making a study of each of the fluid-solid resistances separately.

The authors devoted attention solely to the transfer between the external surface of a pipe, usually constituting one of a bank, and the stream of air sweeping past, the transfer being reversed in direction according as the pipe is hotter or colder than the air. The data were required in the design of air-cooling batteries for refrigeration work, but the conclusions arrived at are of general application in the design of heat transfer equipment.

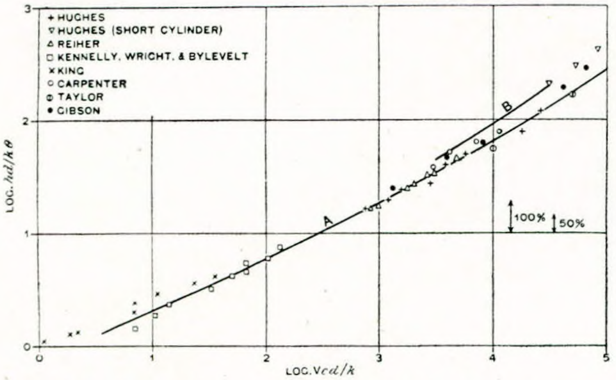

FIG. 1.—Single pipes: comparison with other observers. Curve A taken from Fishenden and Saunders's book (Fig. 22).
Curve B based on author's experiments.

The pipe temperatures have ranged from about 90° C. down to a few degrees below the freezing point of water and the velocity of the air stream from about 30ft. per sec. (*i.e.,* 20 m.p.h.) down to free convection.

The experiments were made with the pipes installed in a closed-circuit wind tunnel.

For adjustment of the humidity, trays of calcium chloride or water were inserted in the lower section of the tunnel. Baffle plates were installed to ensure uniformity in the distribution of the air flow.

The quantity of heat transferred from pipe to air or air to pipe was determined by two alternative methods: (1) the dissipation of electrical energy in a heating coil; or (2) the change in temperature of a stream of liquid circulating in the pipe. The electrical method was applicable only in the case when the pipe was hotter than the air, and was the more convenient of the two.

The temperature of the pipe surface was obtained by means of copper-constantan thermo-elements.

Whilst the present investigation was primarily concerned with banks of piping, in the course of it two entirely separate series of experiments were carried out on single pipes set with axes perpendicular to the direction of the air stream. The pipes ranged in external diameter from $1\frac{1}{4}$ to $3\frac{1}{4}$in., and were of copper or iron.

Method of Representing the Results.—Whilst it is a simple matter to draw a curve connecting heat loss and temperature excess for any given pipe at a given air velocity, or conversely to draw one connecting heat loss and air velocity at a given temperature excess, the information derivable from such a curve is very restricted. Matters are improved by drawing a family of curves, but it is difficult from such a family to interpolate for a set of conditions lying between two of the curves. Moreover, the family represents the facts strictly for one particular air temperature, and, is, of course, restricted to one particular pipe diameter.

Some conciseness is possible, at a slight loss of accuracy, if instead of heat loss, the quantity "heat loss per degree" is used.

By use of the principle of similitude a family of curves can be reduced to a single one, and the principle has the further advantage of being based on physically sound arguments. It takes into account variations in the air temperature, and does not depend on an approximate numerical law. To apply the principle, we set out below the physical quantities which affect the problem, with the notation used herein.

The quantities a and g can only affect the heat flow in so far as warm air, being lighter, sets up convection currents. The moving force (the buoyancy) will be proportional to a and to g, and therefore to their product.

There are four fundamental units, namely, mass, length, time, and temperature. Consequently, it must be possible to select six independent dimensionless quantities, any one of which is, by the principle of similitude, a function of the other five. The selection is partly a matter of choice, since if two quantities xy and xz are dimensionless, it is clear that y/z and x^2yz are also dimensionless; and any two of the four could be chosen. As a

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*A Report to the Engineering Committee of the Food Investigation Board.

starting point, the six variables set out below are selected.

(1) $H/k\theta$ (2) Vd/v (3) gda/σ

(4) θ/θ_0 (5) $k/\rho\sigma v$ (6) $\dfrac{y^2g^2a^2}{\theta_0\sigma^3}$

This formidable array of symbols is an indication of the complexity inherent in the subject of convective heat flow in its most general form. In the present case, however, the number can be reduced considerably. By the kinetic theory of gases, $k/\rho\sigma v$ is a constant independent of pressure and temperature, and may therefore be left out of account. Again, variables (3) and (6) in which the product ag occurs, can only enter the problem when free or natural convection is in question.

The deduction from the theory is, therefore, that $H/k\theta$ is a function of Vd/v and θ/θ_0. Experiment shows that the effect of the variable θ/θ_0, in the range covered, is negligible. This is not the same as saying that H at a given excess is independent of air temperature. If so, H/θ would be constant at a given value of Vd/v whereas actually it is $H/k\theta$ which remains constant, and it must be remembered that k varies appreciably with temperature as shown in the accompanying table.

Kinematic Viscosity and Thermal Conductivity of Air.

Mean Temperature, deg. C.	Kinematic Viscosity v, C.G.S. units.	Thermal Conductivity $k\times10^5$, C.G.S.-calorie units.
−10	0·122	5·10
− 5	0·127	5·25
0	0·132	5·32
5	0·136	5·40
10	0·140	5·48
15	0·145	5·56
20	0·150	5·64
25	0·155	5·71
30	0·159	5·78

In order to facilitate comparison with other recent work on the subject, the logarithms of the variables $hd/k\theta$ and Vcd/k have been used in Fig. 1 together with the points given as due to other recent observers in the book by Fishenden and Saunders.* The line which those authors give as best representing the results available at the time, when the present results are taken into account, might reasonably be drawn somewhat higher at values of Vcd/k above about 2·5. The alteration may at first sight appear trivial, but it is to be remembered that the scale is logarithmic.

Effect of Turbulence.—With a view to studying the increase in heat transmission due to a turbulent air stream, a state of eddy motion was set up by a framework of horizontal wooden laths placed in the wind tunnel. The velocity observations were made in the undisturbed part of the air stream. The results are seen in Fig. 2 which shows the effect on sections A and B. The greatest effect is in section A, nearest the air inlet, for which the heat transfer is more than doubled. For section B, which initially had a smaller coefficient than section A, the increase is somewhat less than twofold, so that the disparity is increased.

Heat Transmission of a Pipe constituting an Element in a Bank.—An important practical case occurs in pipes arranged in banks, the individual pipes having their axes transverse to the air stream. The number of different configurations which could be studied under this heading is almost unlimited. The only generalization possible is provided by the principle of similitude, which shows that if two banks differ only in scale then $H/k\theta$ will be the same function of the two variables Vd/v and gda/σ in the two cases.

To keep the investigation within reasonable bounds, work on banks of pipes has therefore been restricted to the use of pipes of a diameter commonly used in refrigeration work, nominally $1\frac{29}{32}$in. externally, these being built into banks of the two commonest forms. These are the square formation with a spacing of 3·18in. between successive parallel rows of pipes, and the same formation rotated through 45° with respect to the wind stream, so that the appearance becomes that of similar vertical layers $2\frac{1}{4}$in. apart, the pipes of alternate layers being raised $2\frac{1}{4}$in. above the level of the others.

For square formation the mean coefficient in B.T.U. per hour per foot run of $1\frac{29}{32}$in. pipe per degree Centigrade as a function of air velocity is quite well represented by the formula

$$\text{Coefficient}=1{\cdot}24+0{\cdot}977\,V^{0\,89} \quad . \quad . \quad . \quad (1)$$

where V is the air velocity in feet per second.

The formula

$$\text{Coefficient}=1{\cdot}55\,V^{0\,76} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

also fits the observations in an air stream nearly as well, and is of a somewhat simpler form, but it is of course inapplicable for the free convection results, or at low air speeds.

The agreement of the two formulæ with the observations may be seen below.

Air Velocity, ft. per sec.	0	5	10	15	20
Coefficient observed ...	1·25	5·33	8·88	12·12	15·28
Calculated, 1st formula ...	1·24	5·34	8·82	12·13	15·33
Calculated, 2nd formula...	(0)	5·28	8·94	12·18	15·18

For diagonal or staggered formation the corresponding coefficients were found to be :—

Air Velocity, ft. per sec.		0	5	10	15	20
Mean heat transfer coefficient	First layer	0·96	4·48	6·94	9·02	10·79
	Third layer	0·96	7·29	11·54	15·00	17·74

In the first layer, these are fairly well represented by the equation

$$\text{Coefficient}=0{\cdot}95+1{\cdot}071\,V^{0\,743}$$

and in the third layer by

$$\text{Coefficient}=0{\cdot}96+2{\cdot}054\,V^{0\,705}$$

Pipes below 0°C.: Staggered Formation.—The diagonal formation of transverse pipes, besides being the one which shows the highest efficiency, is

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* *"The Calculation of Heat Transmission"*, Fishenden and Saunders, 1932 (H.M. Stationery Office).

also the one commonly used in refrigeration practice. Consequently this formation, using the standard iron pipes of rather more than 1⅞in. diameter, has been studied at temperatures below 0° C.

Measurements were confined to a single pipe in the third layer of the bank, it being assumed, from the results of the work with heated pipes, that conditions in the third row were typical of those in all succeeding rows.

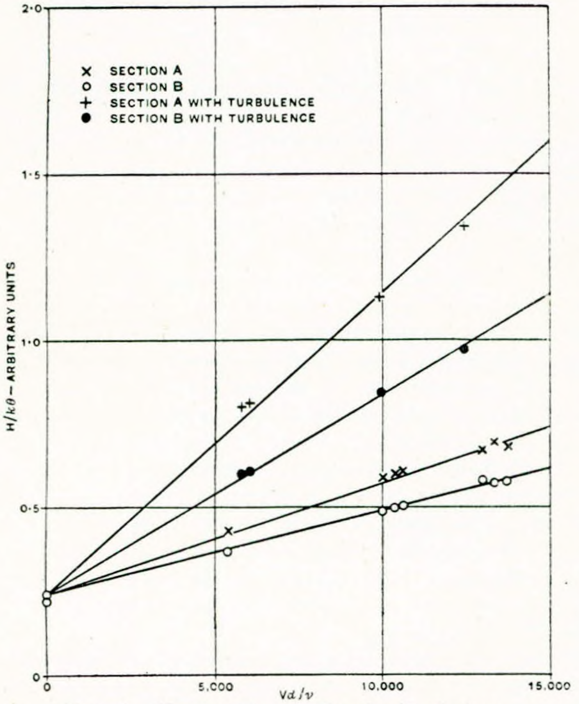


Fig. 2.—Heat exchange, longitudinal pipe.

The experiments with cooled pipes fall into two groups: (1) those in which the humidity was kept sufficiently low to prevent any deposition either of dew or of frost, and (2) those in which such a deposit was formed. The results for the first group are shown as crosses in Fig. 3, where, for the cold pipes, the results are shown individually; the continuous line and the circles represents the corresponding heat loss from hot pipes.

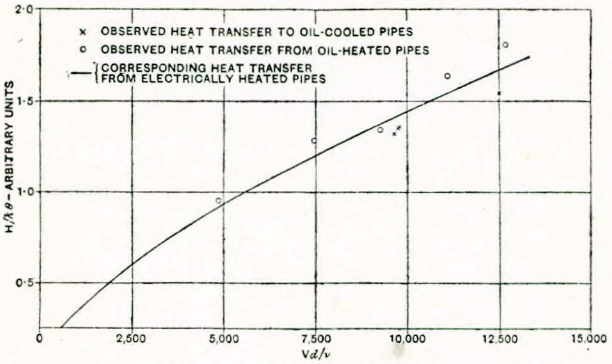


Fig. 3.—Heat transfer for dry pipes (cold).

The results of frosted pipes agree quite well with those for dry pipes, the presence of the ice or snow hardly affecting the heat transmission. This may be due to the well-known effect whereby a layer of insulation, by increasing the area available for heat transmission, will sometimes actually increase the latter.

It is noteworthy that the three lowest results refer to experiments in which the ice was dry, whilst for the two highest water was dripping from the pipe. This water in condensing from the atmosphere would liberate a considerable amount of latent heat, and evidently this is the cause of the high rate of heat transfer. It is clearly desirable in practice to aim at this condition, which can increase the heat transfer by about 30 per cent., *i.e.* an increase which would require 50 per cent. increase in air velocity to attain.

Foreship Remodelling and Hull Form.

Speed Increase and Fuel Economy.

By a Naval Architect.

"Journal of Commerce", 1st February, 1934.

The present economic crisis has brought forth the necessity of the severest economy in all operating costs. For shipping companies, one of the most important items is the cost of fuel, which constitutes up to one-third of the total expenses. It therefore follows that the reduction of fuel consumption is one of the most acute problems of shipping management.

New ships are now being constructed in which the most up-to-date mechanical improvements and better ship forms are found, so as to permit the ships being run at higher speeds under more economical conditions.

Many solutions have been proposed and applied with success, tending to increase the engine power, so as to allow of vessels obtaining higher speeds with a relatively lower fuel consumption. The most successful has been the modernising of ships carried out in Germany, Sweden, Norway and Holland. Higher steam pressures, superheat, air pre-heating, etc., are the outstanding features of the modernisation of the propulsive machinery. Low-pressure Bauer-Wach turbines are frequently added to the existing engines to utilise the residuary energy of the steam from the reciprocating engines. In some instances the refitting of the machinery is decided upon by replacing the existing steam engines and boilers by Diesel motors, and by these means the original engine power can be increased by 20 per cent. to 30 per cent.

The necessity of better sea performance of ships is so urgent that even a comparatively great outlay of money is often allowed, on the understanding that the expense will be recovered by a better return from faster and more economical ships.

It will be evident that if the ship's hull has harmonised with the former power of the engines, this harmony will not exist after the power is increased by the modernisation of the machinery. It is known that, in every case, beyond a certain value of the speed-length ratio $\frac{V}{\sqrt{L}}$ the ship's resistance to forward motion in standard hull forms grows so quickly, that even a considerable increase of the power will only result in a restricted increase of speed. This is due to the fact that for the speed-length ratios, say, exceeding 0·7, the residuary resistance grows much more quickly than the frictional resistance, so as to become equal, if not greater than the latter, because even a slight increase of the speed occasions considerable loss of energy in wave-making.

If the speed increase aimed at is not very considerable, a more economical solution can sometimes be found in remodelling the hull, so as to reduce the resistance, instead of a costly alteration of the machinery. But if modernisation of the machinery is desired, a simultaneous remodelling of the hull becomes absolutely imperative and in conjunction with the former it is often the best solution of the problem. Some such improvements of machinery combined with remodelling of the hull have been recently carried out in Holland and in the United States of America, where shipowners have expended considerable funds in order to raise the efficiency of their fleet.

This large outlay of money can be avoided, if the remodelling of the ships is carried out in accordance with some novel methods resulting from recent model tank tests. To quote one example, a cargo vessel of 3,600 tons displacement for the French Navy, originally ordered 268ft. long, but finally altered to have a length of 275ft., which resulted in a reduction of the effective horse-power of nearly 13·5 per cent. at the designed speed of 13·5 knots. It is obvious that such reduction of the power could not have been obtained by merely lengthening the ship by 7ft., what would, with the normal ship form only, be capable of reducing the resistance by, say, 4 per cent. or 5 per cent. The great success of this forward end remodelling is due to the adoption of the novel Yourkevitch patented ships' low resistance form, which consists of a hollowness of the waterline at a very distinct spot of the bow lines.

A further tank test experiment enables us to examine with more detail an example of remodelling of a ship of 9,250 tons at a service speed of 16 knots, and for which an increase of speed up to 17·5 knots was required. The principal dimensions of the ship are as follow :—

Length between perpendiculars ...	370ft.
Beam, moulded	61ft.
Draft	21ft.
Block coefficient	0·675

The power diagram derived from the tank test shows that the speed of 16 knots ($\frac{V}{\sqrt{L}}$=0·825) is obtained with 3,930 E.H.P. If the speed of 17·5 knots ($\frac{V}{\sqrt{L}}$=0·910) is to be obtained by alteration of the engines only, the power would have to be increased up to 5,240 e.h.p., or an increase of 33 per cent. Alternately, a very slight remodelling of the fore end according to the Yourkevitch method, even without improving the propulsive machinery, will by itself result in an immediate increase of the speed by 0·65 knot.

If both an increase of the power by 15 per cent. and a simultaneous remodelling of the hull was made, this combined transformation gives a further gain of 0·85 knot, and a speed of 17·5 knots. Thus, an increase of the power by 15 per cent. results in a gain of only 0·65 knot, while a further gain of 0·85 knot can be obtained by a form remodelling. On the other hand, it is beyond doubt that such a moderate increase of power as 15 per cent., accompanied by a remodelling of the hull according to the Yourkevitch lines, will cost considerably less than refitting of the boiler and engine plants with an equivalent increase of the power by about 33 per cent.

In reconstructing any vessel, every effort must be made in order to restrict the alteration to a minimum extension. The Yourkevitch method of foreship remodelling has proved to be most efficient, and a very considerable gain of power, varying from 7 per cent. to 14 per cent., can be obtained by rebuilding only a very restricted portion of the forepart not exceeding 10 per cent. to 15 per cent. of the total length, and resulting in a final increase of the ship's length by only some 2 per cent. to 2·5 per cent.

In fact, for the ship under consideration, the only remodelling would consist in replacing the existing foreship on a length of about 40ft. by a new fore-end of special pattern, and about 50ft. long, so that the final length of the vessel will be increased by only about 2·5 per cent. This hull reconstruction would amount to a weight of metal of about 65-70 tons, the cost of which at 60s. per cwt. will be £4,200. On the other hand, since this reconstruction is equivalent to a reduction of the power from 5,240 e.h.p. to 4,520 e.h.p., *i.e.*, to a gain of 720 e.h.p. (16 per cent.), or 1,440 s.h.p., admitting a propulsive co-efficient of ·50, the annual saving for 180 days of steaming time, is as follows :—

$$\frac{1{,}440\times180\times24\times1{\cdot}4\times2}{2{,}240} = \pounds7{,}750$$

—approximately, allowing 1·4lb. of coal per h.p. and per hour at a cost of, say, £2. Thus the cost of the hull's reconstruction will be covered in less than seven month's time.

It is to be noted that the alteration outlined above is far from exhausting all the possibilities opened for improvement. For example, it would be advantageous to change the propellers, which would certainly result in a further increase of speed. The rudder could also be replaced by a "streamlined" pattern, and the bosses could be remodelled so as to further improve the performance. These various improvements of the hull and machinery can result in a gain of the power of about 25 per cent. and over.

Oil Engine Cooling-water Systems.

Provision for the Continuance of Circulation after Engines are Stopped.

"The Motor Ship", April, 1934.

It would perhaps be of interest to those concerned with the installation of plant in motor vessels to draw attention to what the writer considers a serious omission in a large number of such ships with regard to cooling-water systems.

One of the fundamental rules that the newcomer to Diesel-engine practice early acquires is that the cooling water must continue in circulation for 20 minutes or half an hour after stopping an engine, in order to abstract the heat from the metal of the liners, covers, pistons, etc. Further, in cases where a hot-water circulation is provided it is of great benefit to leave this in operation for a few hours, gradually reducing the temperature meanwhile, in order that sudden heat stresses in the metal shall be avoided as far as possible.

It is somewhat remarkable to note that, in many cases, no provision is made in this direction for the involuntary stoppage of the main engines at sea, due to a sudden failure of the electrical supply. This applies wholly to the all-electric auxiliary class of vessel. In ships with steam-driven pumps, naturally, the cooling water continues circulating automatically after the main engines are stopped.

The only provision made in the event of sudden failure of the main electric current is, in some instances, the installation of a standby battery, whereby a certain number of lights throughout the vessel remain in operation. This is, however, primarily intended for use in the event of the ship being *in extremis,* and only sufficient current is available for lamps.

The load conditions may sometimes be such that it is the usual practice for two machines to be running in parallel. It is then quite probable that, in the event of a sudden breakdown occurring on one generator, the total load will be in excess of the maximum for the other. The switches of the latter will then trip automatically, stopping all the pumps. The obvious procedure is then to stop the main engines as expeditiously as possible, to prevent overheating and consequent damage. In this particular case all that requires to be done is to bring the load below the maximum for the generator which is still running, replace the machine on the switchboard and again start the cooling pumps—possibly a matter of seconds only.

Should, however, only one generator be in commission, in similar circumstances the position is naturally intensified; up to 15 minutes may be required in which to start up another machine. As it may be impracticable for the ship to remain stopped for the length of time necessary to allow the cylinders and pistons, etc., to cool off, the risk of allowing cold water to come into contact with hot metal must perforce be accepted.

Defects caused by the above procedure may not at once be apparent. Many cases of cracked covers, liners and pistons could possibly be traced to their source in the minute flaws occurring on such occasions. Where the engine cylinder covers are below the water level, and remain flooded even should the flow of cooling water cease, the position is alleviated. In the majority of large two-stroke single-acting and double-acting engines, however, the covers and liner tops are above the water line. The cooling water will then commence draining away from the hot surfaces directly the flow ceases.

To overcome the difficulty some form of automatic device is a virtual necessity. For example, the standby battery could be of sufficient power to carry the load of one cooling pump, which could then continue in operation automatically.

An alternative in vessels fitted with exhaust-gas boilers would be to install a small steam-driven standby cooling-water pump. This pump would be fitted with a stop valve, electrically controlled by the main-engine fuel levers, the current being supplied by the emergency battery. L.J.H.

Avoiding Piston Rod Corrosion.

"The Motor Ship", March, 1934.

There is no doubt that the free discussion on the subject of piston rod corrosion of double-acting two-stroke engines which followed the paper delivered by Dr. S. F. Dorey has had satisfactory results. The problem may, perhaps, not be solved in its entirety, but at least no shipowner need now fear that piston rod corrosion will cause him any serious trouble. But it is curious that the matter is handled so differently by various manufacturers. In the Burmeister and Wain double-acting two-stroke engine, of the type which will be installed in the Union Castle liners and one of the new Blue Star cargo ships, lubricating oil is employed for piston cooling, and some engineers consider this the most satisfactory method of avoiding all possibility of corrosion. Others, however, take the view that the amount of lubricating oil needed in circulation is excessive, and that the employment of an inhibitor, such as potassium chromate or the new non-corrosive oil produced in Germany, presents the most satisfactory solution. This is being adopted in M.A.N. and Stork-A.E.G. engines. Finally, we have the method employed in the 7,600 b.h.p. Japanese-built Sulzer engine described in this issue, in which two small annular spaces are formed by means of tubes outside the piston rod and within the hole bored in it. Lubricating oil is circulated in these spaces, so that there is a similar effect to that obtained when oil is the cooling medium.

A paper embodying the results achieved with the three systems would be extremely helpful after a year's experience has been gained. Some details were published in "The Motor Ship" a short time ago regarding the trouble that had been experienced with the piston rods of double-acting two-stroke engines, but these did not cover engines in which every expedient mentioned was used.

Divergent Views on Motor Ship Problems.

"The Motor Ship", March, 1934.

Somewhat surprisingly, Mr. R. S. Dalgliesh, who is the owner of several motor ships, remarked during the course of a discussion on Mr. Runciman's paper on tramp ships, that his experience had taught him that it is not advisable to carry Diesel oil in the double bottom. He therefore suggested that in motor tramp ships there should be four separate tanks in the thwartships bunker, carrying, say, 600 tons to 700 tons of oil, which would keep a ship of 8,000 tons going for some 80 days to 100 days. Mr. Runciman, however, took the view that double-bottom tanks are preferable to deep tanks, if only on the ground of better cubic capacity for cargo.

It is interesting to have these directly opposing views from two motor ship owners, and we have heard equally divergent opinions from other owners of experience. The general custom is, of course, to carry the oil in double-bottom tanks, and if reasonable care be exercised, there seems to us no objection to this system, damage to the double bottom being the major risk to be considered. It would be valuable to have expressions of opinion from those who oppose it, especially if it is based on some experience which is not generally realized.

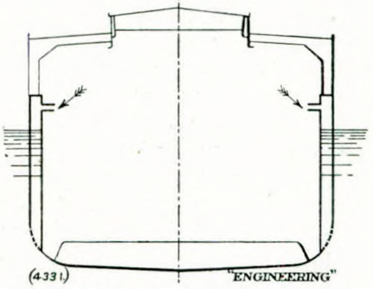
Whilst Mr. Dalgliesh, on the one hand, is emphatic in preferring electrically driven winches, Mr. Runciman believes in steam auxiliaries, although he admitted that if there is a prospect of much winch work, or of the ship being used on a line, electrically driven winches may be preferable. Mr. Dalgliesh's remarks are worth quoting. He said: "I will have nothing else but electrically driven winches, windlass, steering gear and cooking on the next Diesel-engined vessel we build".

Mr. Runciman was supported by Dr. Ing. E. de Vito, of the Ansaldo shipyard, who suggested that exhaust gas donkey boilers with supplementary burners and steam winches may be found preferable on Diesel-engined tramp ships. Incidentally, he made a notable comment on the question of the speed of tramps. As the speed of recent cargo liners has gone up and is tending, in his opinion, towards 16 knots or 18 knots, he thought that, for the future, tramps should be designed for speeds of from 12 knots to 14 knots at least.

The Flamm System of Stabilising Ships.

"Engineering", 27th April, 1934.

The checking of the rolling and pitching of ships has been discussed recently in "Schiffbau, Schiffahrt und Hafenbau", by Engineer W. Kohrs, who states that the efforts hitherto made in this connection have been mainly directed to counteracting rolling. Two systems have been applied to this end, one involving the movement of a mass from one side of the ship to the other, and the second the installation in the ship of a gyroscope. In the case of the former, the mass has usually consisted of a quantity of water or oil, contained in two tanks in communication with each other, and located one on either side of the vessel. To be really effective such tanks have to be of very considerable dimensions, but the provision of the large volumes and of the heavy weights involved, at the broadest, therefore, the most valuable part of the ship, is a matter of grave concern to the ship designer. In the case of ships employing oil firing, oil is commonly used in the anti-rolling tanks, an extra quantity always being carried as a reserve; the space taken up, even in this case, remains a drawback.



With a view to getting over these difficulties, while at the same time securing a satisfactory anti-rolling effect, coupled with the minimum of space and weight, Mr. Kohrs has carried out, in Professor Flamm's laboratory at the Berlin Technical High School, a series of experiments upon a new method, these experiments being followed up by trials on a tugboat. The system tested consists in developing impulses within the ship and causing them to act upon the outside surrounding water, resulting in a reaction upon the ship tending to stabilise it. In this instance, use is not made of a statical effect, due to the movement of a mass inside the ship, as in the methods hitherto followed; pressures are actually generated to oppose forces which develop outside the ship.

The laboratory experiments referred to were made with a model, 3m. (9ft. 10in.) long, of the steamer "George Washington", the scale being 1 : 75. The model had a displacement of 0·1 cub. m.

(3·5 cub. ft.). For checking the rolling, a vertical tube was fitted on one side amidships, where the breadth was greatest. The lower end of the tube was open to the water outside, communication being through the ship's bottom. The upper end was closed by a cover which, in the model, took the form of a movable plug that could be adjusted to any position vertically. The tube was of glass, so that the water level could be watched; it was 27 m.m. (1·063in.) in diameter inside. The water level in the tube corresponded with the water level outside. The tight-fitting plug in the upper part of the tube was adjusted to about 10 m.m. (⅜in.) from the water level and then fixed, there being thus an air space ⅜in. high above the water column in the tube. A small pipe through which air could be blown made connection with the air space in the tube. When the model was set rolling, the motion could be damped by injecting short blasts of air at the moment when the side of the model at which the pipe was fixed was descending. This had the effect of accelerating the downward movement of the water column, with a consequent upward reaction on the plug. As this was fixed in reference to the hull of the model a stabilising force was introduced, which checked the rolling.

In tests with the model, it was set in oscillation and then left to itself when it was found to make about 20 oscillations before coming to rest. It was then given the same angle of inclination as before and released, but in this case when the side of the model at which the pipe was situated was descending a short air blast was injected into the tube. It was then found that the model came to rest after three oscillations. It was not possible to measure the quantity of air used, nor the pressure, but an approximate idea of the requirements in this direction is given by the fact that for a model 9ft. 10in. long, and weighing 220lb., stabilisation was obtained simply by the operator blowing through the connecting pipe and without exerting himself in any way.

Following the tank experiments, trials on a larger scale were carried out with the tug "Fortuna"; this was 14m. (46ft.) long, 3·7m. (12ft. 2in.) in breadth, and 1·9m. (6ft. 3in.) in depth, and had a displacement of 53 tons. This vessel was fitted on each side with a vertical tube 150mm. (5⅞in.) in inside diameter and 2m. (6ft. 6in.) in length, the lower, open end being in communication with the surrounding water, while the upper end was made air and water tight 120mm. (4¾in.) above the water level. Pipe connections were arranged to deliver steam from the boiler to the upper part of both tubes, and to admit it to or cut it off from, either tube, by operating a steam cock by hand. A pressure gauge in the cover of each pipe, close to the steam inlet, gave the pressure at every steam impulse. A piston-shaped float in each tube distributed the steam pressure evenly over the whole water area of the tubes. Steam was employed for the reason that it was available on board; it has, moreover, the advantage that it condenses in the tubes after having done its work, and does not entail the provision of discharge piping. The float was 130mm. (5⅛in.) in diameter, and was guided inside the tube by rods 5mm. ($\frac{3}{16}$in.) in diameter. The essential features of the arrangement are indicated in the accompanying diagram.

When the boat was made to roll round about 7° on each side, and was then left to itself, the time of oscillation was about 65 seconds. But when, in similar conditions, the steam-checking device was brought into operation, the boat came to rest in 12 seconds. Trials were made while the boat was travelling as well as when it was at rest. The control of the steam impulses was carried out by hand by opening the steam cock for about ¼-second. The steam pressure at the inlet in the top of the pipes was two atmospheres.

The effect taking place is comparable to the expansion of steam in the cylinder of a steam engine, the water surface representing the moving piston and the pressure on the fixed plug the pressure on the underside of the cylinder cover. When the steam impulses were timed so that water in the pipe on the side of the boat which was moving down ward received an impulse, then a damping effect was produced, the effect of which is indicated by the times of free and damped rolling given above. Unfortunately the arrangements available did not permit the steam consumption to be measured, but it was evidently small, since there was no drop in boiler pressure after many tests, although no special firing was carried out. Further experiments made on the "Fortuna" by Professor Flamm showed that the steam consumption was about 12 grammes (0·42oz.) of saturated steam for each impulse, the steam pressure at the steam cock being about three atmospheres. Only two steam impulses were required to bring the ship to rest after rolling about 7° on each side. In the case of six complete oscillations per minute, 720 steam impulses would be required per hour, which would equal a steam consumption per hour of no more than about 9kg. (about 19lb.).

This system of ship stabilisation occupies but little space. The pipes which are of relatively small diameter, can be built into the hull between two frames, as shown in the diagram, so that they do not occupy valuable space. Their weight is insignificant and the power consumption small. The system has the additional advantage that it is operative even if the ship has a permanent list, while the stabilising effect can be regulated to suit the prevailing conditions by varying the steam pressure. It would also appear possible to employ the system for neutralising pitching by providing a ship with tubes of this type placed fore and aft.

Two Very Large Helical Gear Wheels.

"The Engineer", 13th April, 1934.

In the two photographs reproduced herewith we illustrate two very large double helical gear wheels which have just been made. It is probable that nothing of their kind of greater dimensions has been manufactured before in this country. That shown in Fig. 1 was made by David Brown & Sons (Huddersfield), Ltd., Huddersfield, and in the finished condition weighs over 24 tons and has nine pairs of channel section arms. The central boss as cast in one piece is provided with three small gaps to relieve contraction stresses and is machined to accommodate turned steel hoops, which are shrunk on finally after the slots have been filled or otherwise spaced. The double helical teeth, 203 in number, were cut from the solid; the face width is 3ft. 4in. and the overall diameter about 13ft. 7½in. This wheel was machined and cut from a casting supplied by the English Steel Corporation, and it is now being incorporated in a 91in. single reduction gear for a rolling mill drive overseas. Its normal running speed will be about 35 r.p.m. and the peak loads likely to be encountered will be in the neighbourhood of 10,800 horse-power. It is believed to be the largest wheel of its kind ever cast in one piece.

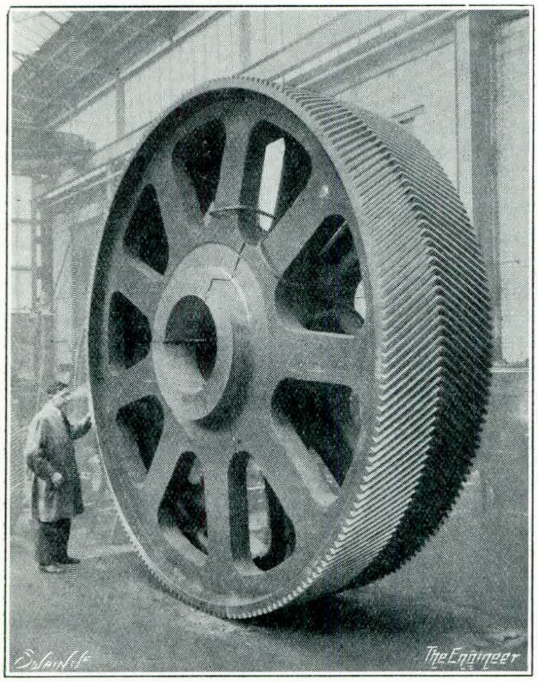


FIG. 1.—24-ton gear wheel—Brown.

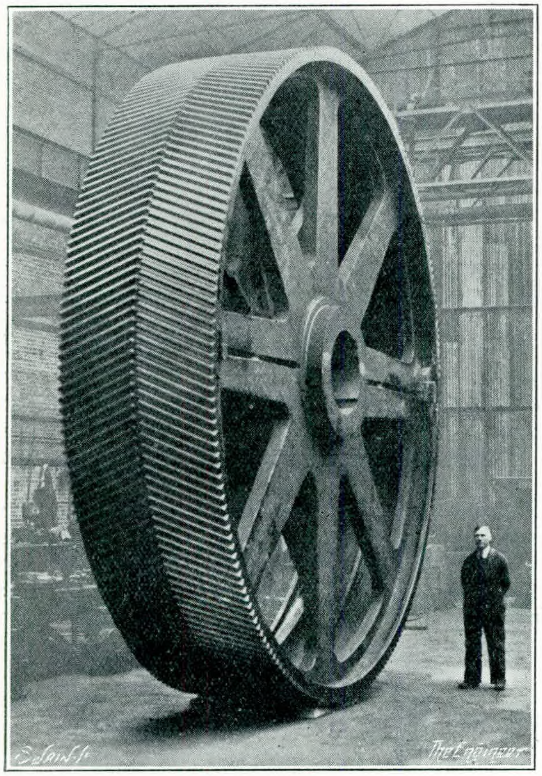


FIG. 2.—19-foot gear wheel—power plant.

The other wheel—Fig. 2—was manufactured by the Power Plant Company, Ltd., of West Drayton. It has a diameter of 19ft. and a face width of 50in., and was made in halves. It has 222 teeth in all and is designed to transmit 16,000 h.p. in a new sheet mill in Australia.

Main Factors in Modern Diesel Engine Construction.

By Dr. H. H. BLACHE (Director, Burmeister and Wain)*
"The Motor Ship", May, 1934.

The introduction of the Diesel engine and the steam turbine took place at about the same time, in the middle of the 'nineties. But only one decade later the "Mauretania" and "Lusitania", fitted with Parsons turbines, were built, holding the blue ribbon of the North Atlantic until a few years ago.

Steam turbine construction has since practically consolidated into certain uniform types. The development taking place in steam plant is mainly due to the progress in the design of high-pressure boilers, superheaters, air pre-heaters, mechanical firing, etc.

Steam engine construction has also for a number of years been suffering from almost complete stagnation. It is only during the latter years that new types have been introduced with a view of utilizing the progress in boiler construction.

Diesel engine construction exhibits, on the other hand, *important departures,* characterized by the diversities in the design of the production of the three leading firms in the world, viz., M.A.N. and Sulzer on the one side, and Burmeister and Wain on the other, thus indicating that the development in Diesel engine construction has not yet culminated.

It is mainly the piston, the piston rings, the cylinder liner and the cover which are exposed to the high-pressure combustion gases. The piston

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* Extracts from a Lecture before the Polytechnic Association in Oslo.

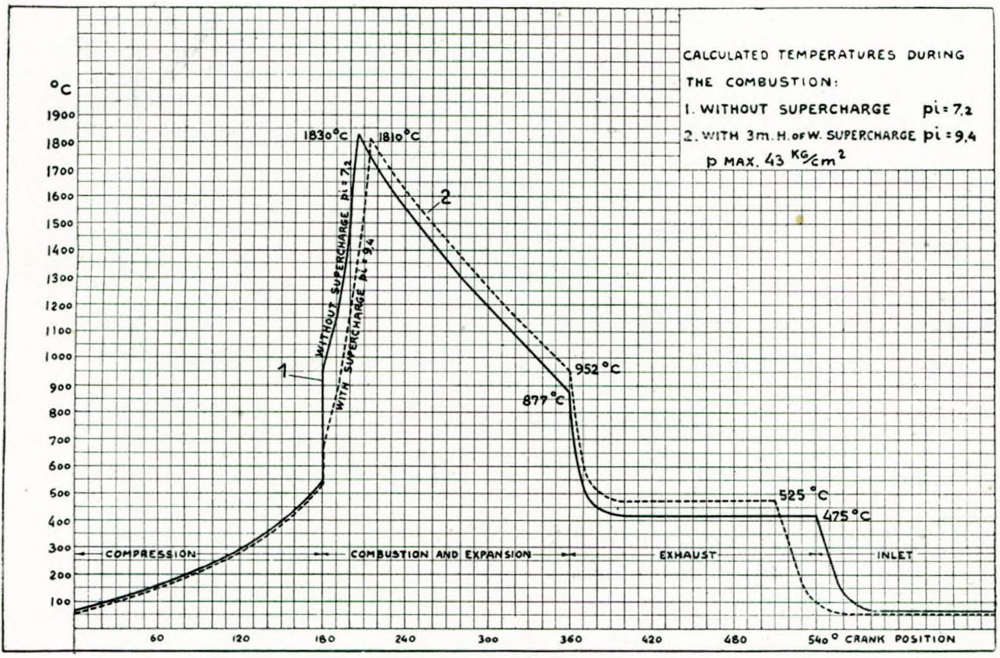


FIG. 1.—Temperatures of combustion in normal and super-charged engines.

rings and the cylinder liners are practically the only parts of a modern well-designed Diesel engine which are apt to wear. Their construction and the material employed are of vital importance to the power developed and the maintenance costs of the machinery.

The heat stresses in the main parts of a Diesel engine—cylinders, pistons and covers—are not proportionate with the quantity of fuel burnt, but with the relation between the quantity of fuel and the volume of clean air used for the combustion.

In the graph (Fig. 1), curve 1 shows approximately the temperature during the combustion in a Diesel engine, arranged for free air inlet, having an indicated pressure of 7·2kg. per cm.², and mechanical injection.

Curve 2 represents in a similar way the temperatures of a supercharged engine with a mean indicated pressure of 9·4kg. per cm.².

Of most importance is the condition during the combustion and the first part of the expansion, where the temperature is highest. By utilizing a large air volume the temperature in this period will be *lower* for the supercharged engine than for the one arranged with free air inlet.

The temperature of the exhaust gases may be higher for the supercharged engine than for the latter, but this is no measure for the heat stresses of the main parts of a Diesel engine, only for the exhaust valves.

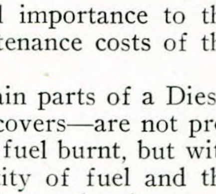


FIG. 2.—Indicating the pressure on piston rings.

The steel industry has during the time developed so that special steel suitable for exhaust valves now can be produced, able to withstand the highest exhaust temperatures.

High-pressure supercharge should always be adopted for four-stroke engines fitted with mechanical injection.

The high temperature of the exhaust gases is of importance to exhaust-fired steam boilers, and such should be fitted on shipboard as well as for stationary plants, if the steam can be utilized.

Besides producing steam the exhaust gases are cooled down in the boiler, whereby the volume is considerably reduced, decreasing the resistance in the exhaust piping, which for marine plants may be rather long, owing to the necessity of carrying the exhaust well clear of all deck erections.

The resistance to the exhaust from a Diesel engine is very injurious to the combustion, and affects the horse-power output. For this reason mechanically operated supercharge blowers are preferable to exhaust gas driven blowers. The latter naturally set up a counter pressure to the exhaust gases, in spite of the piping between the engine and the turbine being branched, and the diameter of the exhaust pipe from the turbine very large. It is well known from the law of physics that action and reaction are equal. The pressure driving the exhaust turbine must have a corresponding counter pressure, acting on the piston when the cylinder is exhausting, thereby reducing the horse-power of the Diesel engine equal to the power required by the mechanically driven blower.

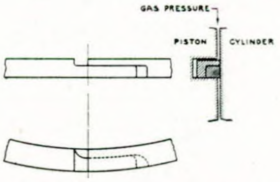


FIG. 3.—Piston ring design for a Diesel engine.

The cylinder liners, covers, pistons and piston rings in all first-class Diesel engines are of Perlit, which is very heat resisting.

Perlit is not, and should not be, particularly hard, the degree of hardness being between the numbers 180 and 220 Brinell; it can thus readily be machined.

The piston rings are also of Perlit, but of a more fine-grained quality. The hardness is practically the same as of the material used for the cylinder liners; it may be somewhat harder without being injurious.

As the area of the piston rings in touch with the cylinder is much smaller than the area of the latter, it is mainly the rings which will wear, although they are somewhat harder than the liner. It is particularly the upper ring which is likely to wear.

The clearance between the ring and the groove should be about 0·06mm. for new rings and liners, increasing later from wear. The rings are pressed down by the gas pressure against the bottom surface of the groove, and out towards the oil film on the cylinder liner, as indicated by the arrows (Fig. 2).

If the piston rings and the cylinder liner are of suitable material, the surface of the liner will attain a perfect polish, so hard that it can be manipulated only by means of carborundum. On the other hand, the piston ring surface will wear without hardening and be quite bright with smooth wearing edges.

However, should the piston ring material not be fine-grained, although the liner and the rings are of Perlit of suitable chemical composition, the liner will wear and the surface become dull. The piston ring will also wear and the edge attain a serrated form.

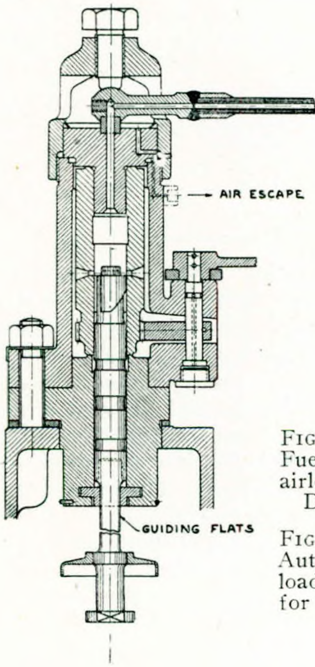


FIG. 4. — (Left) Fuel pump for an airless - injection Diesel engine.

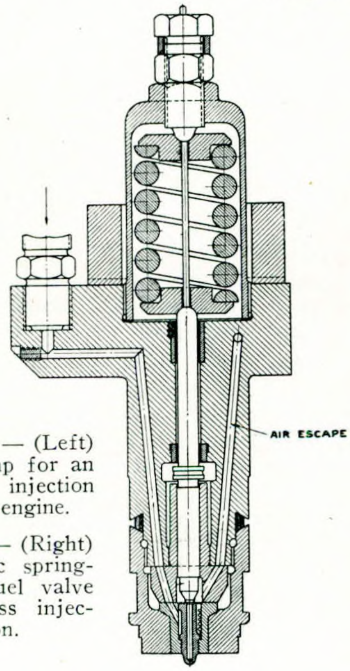


FIG. 5. — (Right) Automatic spring-loaded fuel valve for airless injection.

Numerous faults have during the time been made by the foundries, even such as specialize in Diesel castings. It is not the quality of the material used in production which solely determines the adaptability. The cooling operation is of great importance, therefore each thickness of cylinder liner and each thickness of piston ring should be cast of differently composed alloys, to obtain the right qualifications.

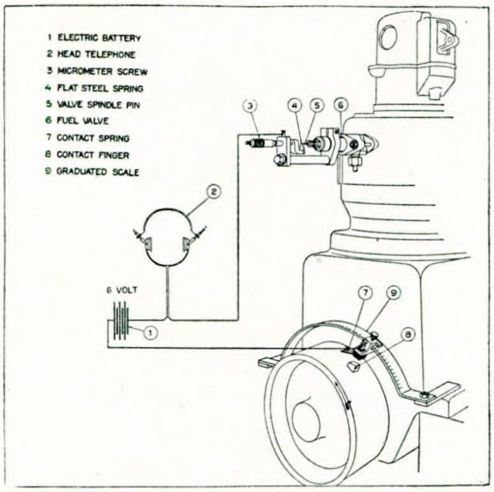


FIG. 6.—Sketch showing apparatus for adjusting fuel pumps.

The process of casting can best be carried out by use of a rotary furnace, wherein the allows can be thoroughly heated. Each charge must be analysed, subjected to a microscopical examination and tested for hardness, to ascertain that it is in every respect of the correct composition.

The wear between a piston ring and a cylinder liner may be compared to the grinding of a knife blade in oil on a fine stone. The material for the piston rings should be so fine-grained that particles worn off act on the cylinder liner in the same manner as the best polishing cream.

It is not necessary to employ magnifying means to ascertain if a ring is good or poor. The difference in the edges of the two rings can readily be distinguished by rubbing them.

The bottom surface in the piston groove will wear on account of the ring working to and fro, which takes place even in a new cylinder, owing to the greater expansion of the liner at the top than at the bottom, due to heat. The piston should therefore be of the same material as the cylinder liner, resistible to wear.

The piston ring lock should also be as tight as possible. The increase in pressure on the back of the ring is mainly due to leaking.

The ordinary obliquely cut piston rings are not adequate for Diesel engines. The ends of the rings should overlap each other on a flat surface.

The lock shown in Fig. 3 is very tight and various types of double or triple sealed piston rings are also suitable, if correctly manufactured.

It is very important that the rings when first fitted are in good and uniform touch with the cylinder liner. Should the gases blow past the oil film will be destroyed, and the formation of the polished surface on the liner prevented.

The wear on the cylinder liner and the piston ring does not solely depend on the material, but is greatly affected by the combustion. Poor combustion gives considerable after-combustion during the whole of the stroke, whereby the oil film is destroyed, causing the piston ring to stick in an asphalteous paste. Besides, carbon particles will further add to the wear on the rings and the cylinder liner.

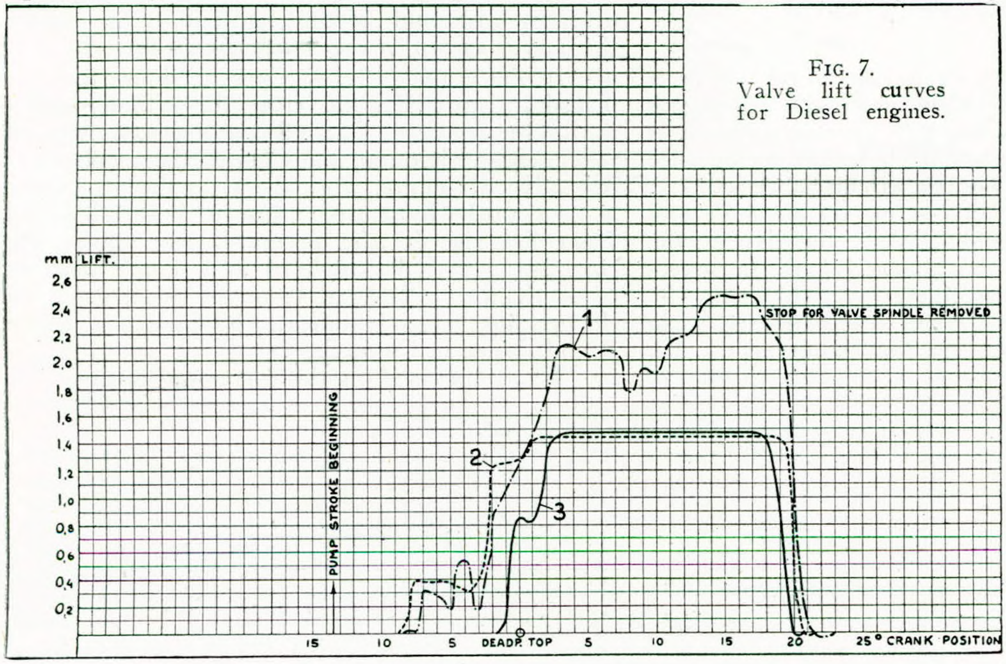


FIG. 7.
Valve lift curves for Diesel engines.

Mechanical injection takes place through atomizer holes of from 0·3mm. to 0·7mm. in diameter, and under a pressure on the fuel oil of from 300kg. to 400kg. per cm.^{2}. If the oil is very heavy the pressure will be from 500kg. to 600kg. per cm.^{2}.

The manufacture of fuel pumps and fuel valves demands the most minute care, on account of the high pressure. The fuel pump consists of a plunger and a bush or pump chamber, ground together very accurately and made of case-hardened steel.

Fig. 4 represents a sectional view of a pump chamber. The fuel oil is supplied to the pump under a pressure of from 2kg. to 3kg. per cm.^{2}, to avoid air from being drawn in on the way. Regulation takes place by turning the pump bush or plunger. The fuel supply is cut-off by means of screw-formed cutting edges, as soon as the quantity corresponding to the immediate load has been injected through the fuel valve.

The fuel valve shown in Fig. 5 is automatic, spring-loaded and fitted with a stop. This type of valve should always be used in sea-going motor ships, so that the engines can utilize the cheap qualities of fuel oil, which is often very asphalteous and supplied at the various bunkering depots all over the world.

The opening of the valve must be momentary to burn this quality of fuel oil. The closing should be instantaneous and effective. Open nozzles with the valve located in the fuel pump are, therefore, not suitable, owing to the pressure being transmitted too slowly through the piping, so that the oil freely can drip through the atomizer holes, before the high pressure corresponding to the atomizing is built up.

The piping leading from the fuel pump to the fuel valve should be as short as possible to avoid elasticity in the pipe itself, in the oil remaining in the pipe and particularly the action of the pressure wave motion in the oil at the beginning of the pump stroke.

In view of the above, an arrangement with fuel pumps built in groups for larger units is not adequate, although preferred by many, owing to the cheapness in the manufacture and the convenient position on the lower platform.

The fuel pumps for double-acting engines should be arranged in pairs, midway on each cylinder, so that the high-pressure pipes for the top and bottom can be identical, as short and straight as possible. Single-acting types should have one pump for each cylinder, arranged on the side of the cover at the top.

The adjustment of the fuel valve is determined by the shape of the cam, the size and number of the atomizer holes and the compression of the spring.

In Fig. 6 is shown an apparatus utilized for the adjustment.

The apparatus is designed in view of obtaining a diagram of the valve lift, showing accurately the motion of the fuel-valve spindle in relation to the position of the crankshaft. This apparatus is preferred to the ordinary indicators, on which the accelerating forces act too violently, whilst the optic indicators are impractical and too sensitive.

The fuel-valve spindle is provided with a pin following the motion of the spindle, and capable of being brought into touch with a steel spring by the adjustment of a micrometer screw. This screw is insulated electrically, and connected by means of a head telephone to a battery with a pressure of from 4 volts to 6 volts. The other pole of the battery communicates with a flat steel spring, fitted to, but insulated from, a clamp screw which is movable on a graduated scale, attached to the engine column. On a pulley fitted to the engine shaft is a contact finger; by touching the steel spring once every revolution the electric circuit is closed.

FIG. 8.—Exhaust Temp. 460° C. Scav. Pressure. 3·5 m. of water. Pe= 7·55 kg. per sq. cm. P. max.=51 kg. per sq. cm. Comp Press.=37·5 kg. per sq. cm.

By moving the clamp screw on the scale and adjusting the micrometer screw, the lift of the valve for each crankshaft position can be ascertained. When the micrometer screw touches the spindle and the contact finger simultaneously is in touch with the spring on the clamp screw, the electric circuit is closed and indicated by a snap in the telephone.

As the position of the contact finger in relation to the crank is known, the lift of the fuel valve in relation to the crank position can thus easily be ascertained, and a diagram drawn. The position on the scale can be marked along an abscissa, and the lifts ascertained by the micrometer screw marked off as ordinates.

The injection period is found by means of the diagram, and from it can also be seen if the valve opens and closes quickly, which is of great importance to the combustion. Further, eventual fluctuations in the oil stream of the pressure pipe can be ascertained, for instance, should the valve thereby be reopened, resulting in poor combustion.

In the graph (Fig. 7) are shown three curves representing the valve lift, and drawn by means of the aforementioned apparatus. Curve 1 is from the valve without a stop, showing the complete pressure motion of the oil during the injection period, the compression of the spring being known.

Curve 2 is from the valve with a stop, but the atomizer hole, the spring compression and the cam height are incorrectly adjusted. It is apparent how the pressure waves in the piping cause the valve to jump, whereby the fuel is unevenly injected.

Curve 3 is the complete valve lift curve with a correct adjustment and even fuel injection.

In the graph (Fig. 8) is shown a displaced diagram with and without ignition, from which the curves shown in Fig. 9 are drawn up.

In the graph (Fig. 9) Curve 1 shows the displaced pressure diagram from the cylinder taken during the ignition. Curve 2 is a displaced diagram taken without ignition, and Curve 3 the corresponding valve lift curve, worked out in the same way as previously illustrated. Curve 4 is calculated from the rise in the pressure, and shows the combustion period completed at a crank position of 40 degrees, calculated from the relative rise in the pressure, which is indicated by the Curves 1 and 2, and shown in Curve 5.

These curves show the correct adjustment for

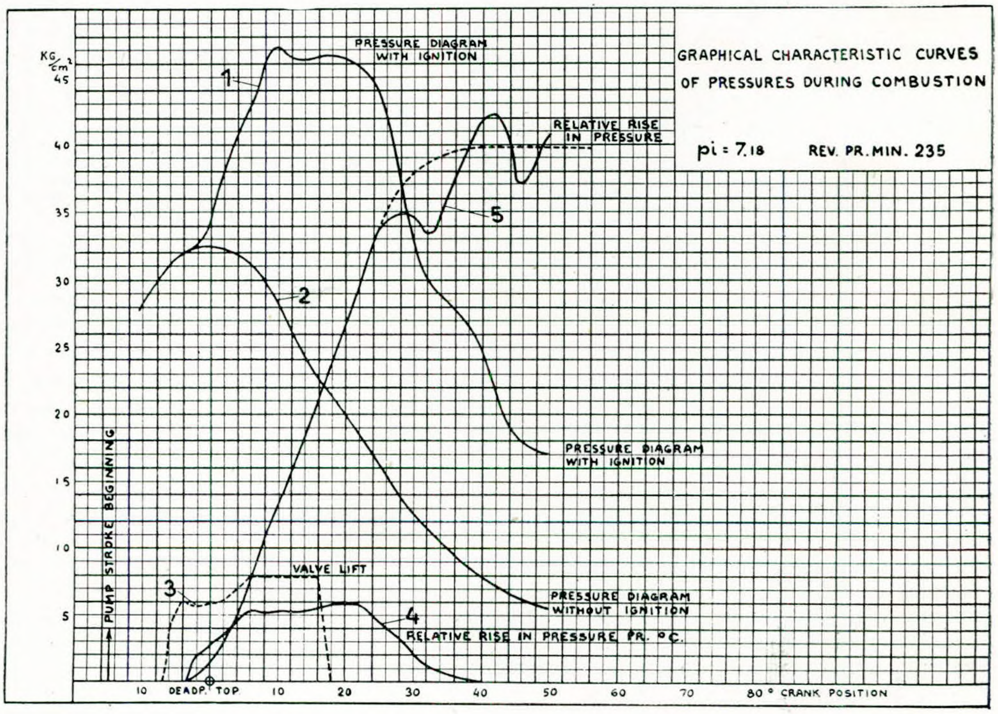


FIG. 9.

combustion, indicating the importance of carrying out thorough trials with marine engines after erection on the test bed. Such trials cannot very well be made on board, and readjustments must therefore be made based on the experience from the test-bed adjustments of similar types of engines.

The piston is, as previously mentioned, made of Perlit with a view to restrict the piston groove wear. This material has also for many years proved to be very resistible to heat stresses due to fuel oil jets.

However, in 1928-29 a quality of fuel oil was introduced, and supplied to almost every motor ship touching the port of San Pedro. This oil had been cracked in a particular way so that the properties were not the same as those of the oils previously supplied. It is well known that the cracking process consists of a decomposition of the molecules in the oil. Thus it is possible to get an oil consisting of unstable molecules, developing an intense heat whilst burning, similar to a hydro-oxygen cutting flame.

However, the aim in Diesel engine construction is to be able to manufacture an engine capable of burning all kinds of Diesel oil supplied throughout the world. The aforementioned cracked oil possessed good qualities and is still being used, but it is now possible to construct pistons which are able to withstand the action of the intense heat.

Such pistons are provided with a threaded plug of nickel-cast-iron as shown in Fig. 10. A feature of the nickel-cast-iron alloys is that they do not grow from heat, and are thus capable of resisting large heat stresses.

The plugs should be screwed in very tightly and the face scraped thoroughly. This work has, unfortunately, been carried out carelessly in some cases, resulting in leaky plugs, but with good workmanship this design will eliminate all the difficulties.

In Fig. 11 is shown an improved design employed for new engines of the four-stroke type. The piston rod flange and the opening in the piston at the bottom are amply dimensioned, allowing the plug, on the inside, to be fitted with a counter nut.

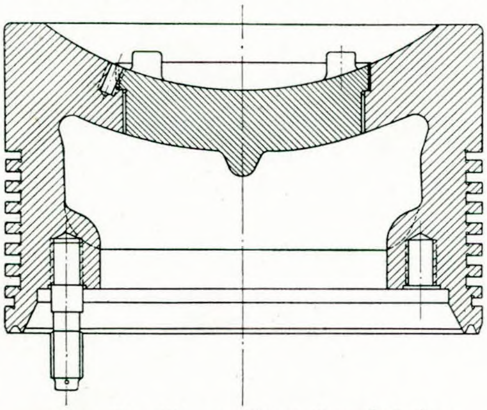


FIG. 10.—Piston with a threaded plug of nickel cast iron.

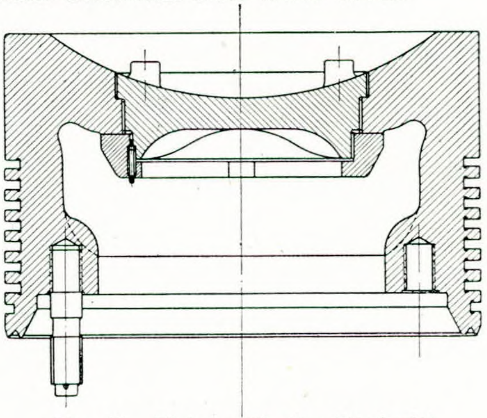


FIG. 11.—Piston with plug fitted with a counter nut on the inside.

In recent years the knowledge and production of suitable material for the main parts of Diesel engines have developed. In this way it is now possible to construct a two-stroke type, capable of working reliably with high mean pressures and equivalent horse-powers, taking up less space and being cheaper to manufacture than the four-stroke type.

The ordinary two-stroke type has transverse scavenging. The engine consists of a cylinder block with an inserted cylinder liner, and if double-acting, with two liners, one for the top and one for the bottom, secured by means of the covers.

The advantages of this system are that the branches for the scavenging air and the exhaust can be arranged on the cylinder block, allowing the top cover to be lifted right up and the bottom cover to be moved out horizontally from the engine after first removing the piston. But the water spaces are poorly de-ærated and badly cooled where the cylinder liner and the cover meet. Further, transverse scavenging embodies difficulties, and this type is therefore suitable only for working with a small mean pressure, and is not well adapted to mechanical injection.

The Burmeister and Wain type of double-acting two-stroke engine is constructed for uniflow scavenging.

In principle, the engine is built up similarly to the four-stroke B. and W. type. There is no cylinder block, and the upper cylinder liner is bolted to the cylinder cover by means of a heavy flange. The cover consists of an internal part of chromium steel to which the cylinder liner for the exhaust piston valve is attached, and an external square jacket of cast iron with bosses in the corners for the four stay bolts.

The lower cylinder liner is provided with scavenging ports, and is bolted to the internal chromium-steel cylinder cover, projecting into the cover jacket, which is square and secured to the columns by means of the above-mentioned four stay bolts.

The upper cylinder liner rests on top of the lower cylinder liner, and the whole system is held together by means of the four long elastic stay bolts. These offer the necessary elasticity for expansion. The exhaust piston valve liner is bolted to the internal chromium steel lower cover.

The scavenging air passage is arranged around the centre of the cylinder liner with a stuffing box at the top. Around the lower cylinder liner and flanged to the cover are cylindrical cooling jackets with the stuffing box free of the scavenging air passage.

Encircling the exhaust piston valve cylinder, top and bottom, are the double-walled and water-cooled exhaust passages.

The exhaust piston valve is oil cooled similar to the main piston, and operated by a system of eccentric rods from a layshaft, arranged in the crank casing parallel to the crankshaft. The layshaft is driven or, perhaps it is more correct to say, drives the crankshaft by means of a chain drive, as the exhaust piston valve transmits about 10 per cent. of useful work to the crankshaft.

One of the advantages of the uniflow scavenging two-stroke type is that it can be built with a long stroke in relation to the cylinder diameter. Burmeister and Wain construct four-stroke engines with a piston stroke of 1·9—2·0—2·75 times the cylinder diameter; for their two-stroke types the ratios are 1·8—2·35—2·65.

The propeller best suited to the ship determines the number of revolutions for a marine plant. By adopting a long stroke in relation to the cylinder diameter additional horse-power in the same relation is obtained.

Diesel engines of the transverse scavenging type cannot be constructed with a long stroke. It is very difficult to scavenge a cylinder clean, having a larger ratio between the stroke and cylinder diameter than from 1·5 to 1·7.

The exhaust piston valve for the uniflow scavenging type is but half the diameter of the cylinder, consequently the basis for leakage smaller. The thickness of the exhaust piston valve liner is about half that of the cylinder liner, and the walls of the valve less than half the thickness of the walls of the main piston. The exhaust valve and the valve cylinder are cooled similarly to the main piston and the cylinder liner. Therefore, the cooling of the valve and the valve cylinder is more effective than that of the main piston and the cylinder liner.

It is often emphasized, as of great advantage to engines fitted with cylinder blocks, that the bottom cover conveniently can be moved out horizontally.

The advantage is not obvious, as it is necessary first to take out the piston and the piston rod. The parts which should be examined are the packing rings in the piston rod stuffing box, which may be worn or sticking. It should be taken for granted that the engine is so well constructed that a regular renewal of the bottom cover itself is out of the question.

In the uniflow scavenging type the piston-rod stuffing box is arranged inside the exhaust piston valve. It is, therefore, the valve and not the cover which, for this type, should be taken out in overhauling. The exhaust piston valve is attached to a crosshead fitted with a bayonet lock, and can be taken out through the crank casing. The lower exhaust valve for even the largest unit, such as the 22,000 h.p. generator engine at Copenhagen, can be taken out on the working platform in the course of two hours.

The good combustion embodied in the uniflow scavenging system owing to the main piston controlling only the scavenging air, and separate piston valves the exhaust gases, is the reason why this type of engine is capable of running for from three times to four times as long working periods as the ordinary transverse scavenging type, before overhaul is required.

In the latter type water is utilized for piston cooling, and generally fresh water, which undoubtedly is the most adequate. The piston, piston rings and the lubricating oil around the piston rings, which, as previously mentioned, are so highly exposed to the heat from the exhaust gases, can thereby be kept cooler.

However, water cooling is dangerously straining the piston rods, which clearly is proved and described in a very interesting paper read by Dr. S. F. Dorey, chief engineer surveyor to Lloyd's, before the members of the Institution of Naval Architects.

Besides, it is risky to utilize water cooling for the pistons of the two-stroke type. The piston consists always of more than one part, and a leakage at the joints will instantaneously cause cylinder scoring.

The two-stroke uniflow scavenging type is simultaneously a supercharged engine, as the exhaust piston valve is displaced about 7 degrees in advance of the crank. In this way it opens fully to the exhaust before the piston opens to the scavenging ports, thus preventing the gases from gaining access to the scavenging space. The exhaust piston valve, on the other hand, closes prior to the scavenging ports, so that the cylinder is filled with clean scavenging air of a pressure of about 0·5m. head of water. On account of the above, the clean scavenging and the materials resistant to heat used, this type is well suited to work with a high mean pressure.

The largest Diesel engine constructed by Burmeister and Wain, and at present the largest in the world, is of the double-acting two-stroke type, and in service at the H. C. Orsted Central Electricity Works.

The cylinder diameter is 840mm. by 1,500mm. length of stroke. The indicated mean pressure is 8·35 per kg./cm.^{2}, the effective mean pressure 7·00 per kg./cm.^{2}, and the weight 55kg. per b.h.p.

Burmeister and Wain's intention, by introducing the two-stroke uniflow scavenging type, was to supply an engine which at the very least had the same power per stroke as their four-stroke type per every second stroke. The engine is capable of burning all qualities of fuel oil on the market.

It is, in this way, possible to construct Diesel machinery suitable for all existing types of ships in the various trades, and, in the same engine-room, with the same weight, and the same solid and rigid structure, to develop double the power, compared with the plants previously built, thus increasing the superiority of the motor ship, enabling the owners to cater for faster and more efficient tonnage.

The Economiser Protector.

"Engineering", 4th May, 1934.

Though, generally speaking, economisers give rise to little trouble in operation, there have been cases where more or less serious explosions have occurred with consequent damage to both the equipment and to the personnel. The cause of these mishaps appears to be due less to faults in the material or in the method of installation than to interruption of the flue gas flow and, even more frequently, to a temporary loss of water resulting in overheating and the generation of more or less large quantities of steam when the feed is re-established. The consequence is that the water is driven back into the feed range, while the sudden cooling of the heating surface which occurs may give rise to water hammer, overstress and explosion. These conditions may be prevented from arising by arranging that the pressures in the boiler and in the economiser are always maintained at the same value at all loads, even when the feed is interrupted and by ensuring that any steam generated in the economiser is led straight to the boiler, and that any water lost owing to its evaporation or to leakage is immediately replaced. It is claimed that all these objects can be effected by the economiser protector, which is manufactured by the Elektrizitäts Aktien-Gesselschaft, Frankfurt-am-Main.

A view of one of the patterns of this equipment is given in Fig. 1, while its construction and method of operation will be clear from Figs. 2 and 3. As will be seen, it consists essentially of a two-part vessel, which is connected in the feed range, between the economiser and the boiler, as shown in Fig. 4. In this diagram G is the protector, H the boiler and

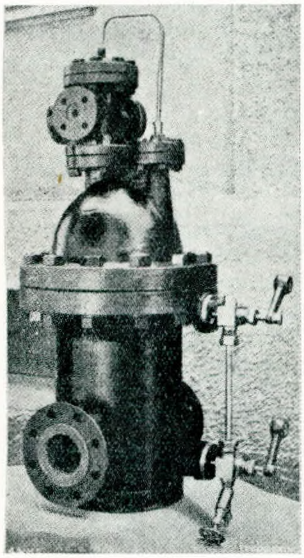


FIG. 1.

Fig. 2.

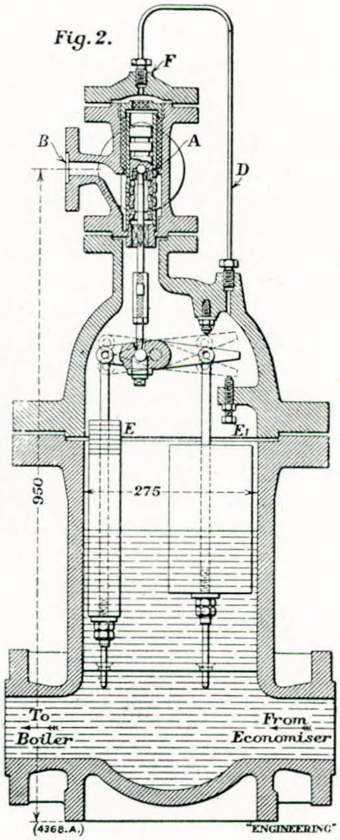


Fig. 3.

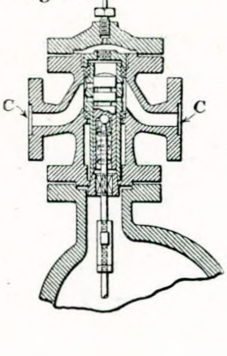
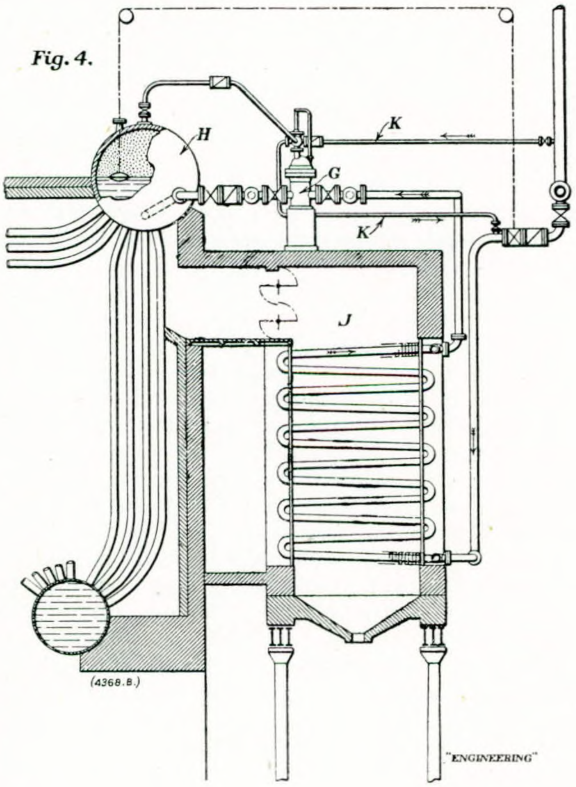


Fig. 4.



J the economiser. The upper portion of the protector contains a two-way regulator A and a flange B to which a pipe leading to the boiler is connected as indicated in Fig. 4. It is also provided with two other flanges C, in Fig. 3, for the connection of a replenishing pipe the ends of which are connected to two points in the feed range, one a short distance before the economiser inlet, and one on the other side of the feed-water regulator, as shown at K in Fig. 4. Finally, there is balance pipe D, which connects the top of the regulating valve to the space above the floats E and E_1, through the non-return valve F. This valve allows steam to be admitted from the boiler to the protector to equalise the pressure, but prevents water flowing in the opposite direction. The movement of the float E alters the regulator so that the passage B to the boiler is opened and the pressure equalised, while similarly the movement of the float E_1 opens the replenishing pipe, so that any loss of water is made up.

As regards operation, any steam which is generated in the economiser, causes the floats E and E_1 to rise when it enters the protector, and these being of different specific weights the regulator A is moved so that the outlet B to the boiler is opened first and the steam allowed to escape. The subsequent action of the second float causes water to flow in from the replenishing pipe and through the regulator into the economiser. When the water level in the protector has returned to normal the supply of make-up water is cut off and the steam connection closed in that order. It is claimed that the use of this protector prevents any dangerous formation of steam in the economiser owing to interruption in the feed or in the demand for steam, and that thereby an increased heating of the water, theoretically up to the saturation temperature of the boiler content, is obtained. This gives not only a better utilisation of the waste gases and reduced gas loss, but consequently a higher economiser efficiency. The withdrawal of the steam from the economiser is unrestricted and is replaced by water practically simultaneously, while there is no formation of steam cushions or generation of water hammer. As the pressure between the boiler and economiser is equalised there is no partial evaporation and steam formation in the latter when leakage occurs. It is claimed that the protector is suitable for all working pressures.

Oil from Coal.

The Present Situation in Great Britain.

By David Brownlie, B.Sc. (Hons.) Lond., etc.

"Internal Combustion Engineer", December, 1933.

In view of the fact that apparently the whole of the British Empire produces about 2½ per cent. of the liquid fuel of the world, and controls not much more than 5 per cent., it is hardly necessary to emphasise the vital importance of the production of petrol and oil for internal combustion engines from our own coal. Further, it will be remembered that Great Britain imports about 1,000 million gallons of petrol per annum, while the British Navy has been almost entirely converted to oil firing, with the sources of supply thousands of miles away, and the shortage of oil fuel in the world-war very nearly led to an unparalleled disaster.

In view of the vague reports that have appeared in the daily Press on this subject, it will be interesting to give the elementary facts. There are four chief methods of manufacturing liquid fuel from coal and similar products, that is, high temperature carbonisation such as used in gasworks and by-product coke oven plants; low temperature carbonisation; the "Bergius" or hydrogenation process for bituminous coal as well as lignite, and the "Synthol" or equivalent process for the catalytic reduction of carbon monoxide, which can be made from any convenient solid fuel, but chiefly coal or lignite.

As regards low-temperature carbonisation, there are hundreds of processes, and over 50 of these have been studied in Great Britain alone, in many cases with actual commercial plants. Some examples, to mention a few only of more recent origin, are the "Aicher", "Babcock" (Merz & McLellan), "Bussey", "Crozier", "Dvorkovitz", "Freeman", "Fusion Retort", "Hird", "Illingworth", "K.S.G." (Kohlenscheidungs Gesellschaft), "L. & N." (Nielsen), "Maclaurin", "McEwen-Runge", "Midland Coal Products", "Pehrson-Wheeler", "Plassmann", "Power Gas Corporation", "Pure Coal Briquette", "Richards-Pringle", "Salerni" (Piero), "Salermo" (E. Salerni), "Struban", "Tozer", and "Turner".

Many of these, and other, processes, however, both from the technical and profit-making point of view have been ignominous failures. At the present time, only one low-temperature carbonisation process, that is "Coalite", is operating upon the commercial scale, with three plants at Barugh (near Barnsley), Askern, and Greenwich, respectively, while numerous "Coalite" processes have, of course, been evolved and scrapped during the past 20 years or so, representing a chequered career also from the financial point of view.

Largely the trouble has always been the vast production of petroleum, and it will be remembered that not very long after the commercial discovery of petroleum in 1857, hundreds of low-temperature carbonisation plants throughout the world engaged in the manufacture of what was generally known as "coal oil" were ruined because of the low price of petroleum.

The whole position with regard to low-temperature carbonisation is also somewhat difficult because of the relatively low yield of liquid products. Thus one ton of average bituminous coal gives, approximately, two gallons of crude light oil scrubbed from the gas, 18 gallons of low-temperature tar, of which over 50 per cent. is available for

Diesel engines, and 14cwt. (70 per cent.) of smokeless low-temperature fuel. One ideal method, of course, in Great Britain is to develop upon a vast scale the use of the smokeless fuel for domestic use in place of raw coal, as well as towns' gas, especially as about 40 million tons of coal per annum are used in the domestic and similar field, with about 17 million tons in towns' gasworks.

With regard to hydrogenation, the method consists in heating pulverised solid coal or other material suspended in heavy oil at a temperature of 840° F. (450° C.) and under a pressure of 3,500lb. per sq. in. (1,250 atmospheres) with a large amount of hydrogen gas in the presence of a catalyst, such as oxide of iron. A considerable proportion of the solid is converted into a crude oil of complicated composition, which is fractionated to petrol, middle oil, and heavy oil. The latter is used for mixing for the next processing, and the middle oil is hydrogenated a second time at a slightly higher temperature, about 930° F. (500° C.) and the same pressure, being largely converted into petrol.

It is stated that about 100 tons of ash-free, and presumably also moisture-free, coal requires about 11 tons of hydrogen gas and gives a yield of approximately 62 tons of petrol, 28 tons of gas, 14 tons of liquor, and 12 tons solid residue. Also every one ton of coal hydrogenated requires a further 1½ ton for processing, so that the plant to be put down by Imperial Chemical Industries, Ltd., using 1,000 tons per day, will actually hydrogenate 400 tons and produce 248 tons of petrol, the other 600 tons of coal being required to operate the process.

Essentially, therefore, hydrogenation consists of four main operations, manufacture of the hydrogen, hydrogenation of the coal in the liquid phase, hydrogenation of the oil in the vapour phase, and refining of the petrol. The residual gas is used in the manufacture of hydrogen, the carbon monoxide content being converted to carbon monoxide, which is removed by scrubbing with water.

It is as well to remember, also, that the total consumption of coal by this £2,500,000 hydrogenation plant will be at the outside about 365,000 tons per annum, that is less than 0·25 per cent. of the coal production of the country, and equivalent to the work of, approximately, 1,400 miners out of a present total of 800,000, or 1,000,000 normally employed. Further, the consumption of petrol in Great Britain is slightly over 3,000,000 tons per annum, so that the total production of the plant, say, 85,000 tons of petrol per annum, corresponds to roughly 2¾ per cent. of the total, while in addition, of course, so far as can be made out, there is likely to be a loss in the revenue from petrol duties of £1,000,000 per annum.

One would like to know also, in connection with all the vast outpourings of information and comment in the Press concerning hydrogenation, why no mention is made of the highly important method, operating on a large scale in Germany, for the manufacture of low boiling-point motor fuels by the catalytic reduction of carbon monoxide.

Steam Propulsion without an Engine!

"The Marine Engineer", May, 1934.

M. Sauvageot has invented an ingenious system for steamship propulsion which dispenses entirely with the steam engine, or turbine and condensing plant. From the diagram given the tail shaft is hollow to permit the passage of steam from the boilers to the propeller. The blades of the latter are drilled radially so that steam, after coming through the tail shaft, passes to the tips of the blades, where nozzles are arranged so that the reaction of the steam escaping from them turns the propeller. The pressure drop through the nozzle amounts to the difference between the boiler pressure (less the frictional losses in the steam pipes, glands and passages), and the water pressure at the depth of the propeller. The inventor is stated to have made some preliminary trials which have proved that such an arrangement will work, and hopes from further experiments to determine its efficiency. The principal advantages are said to be reduction of weight and cost consequent upon the dispensing with an engine-room. The only adverse criticism cited is the difficulty of finding sufficient water for boiler feed purposes on a long passage.—*Navegacion, Puertos, Industrias del Mar, April.*

Universal Supercharging.

"The Motor Ship", May, 1934.

Among the many interesting comments which Dr. H. H. Blache (director Burmeister and Wain) made in a recent lecture was that "high-pressure supercharge should always be adopted for four-stroke engines with mechanical injection".

It has, indeed, been noted in these columns that at least 75 per cent. of the four-stroke engines now under construction are arranged for pressure-charging in one form or another. It is therefore interesting to have a definitely expressed opinion on this subject from an engineer who has so prolonged an experience with the manufacture of four-stroke engines for marine work as Dr. Blache.

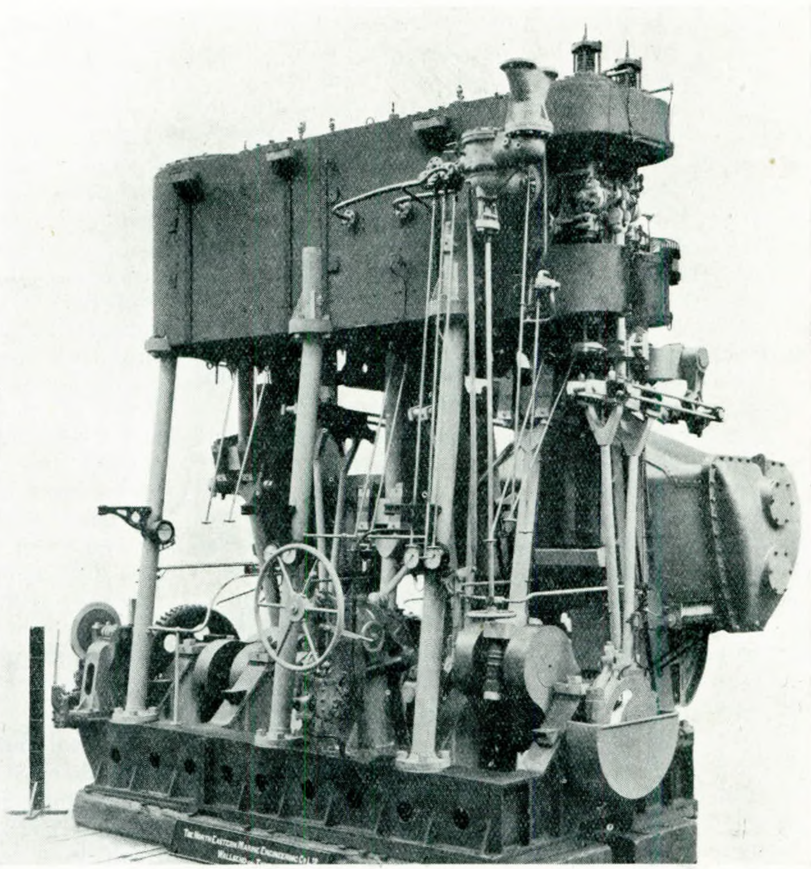
Sufficient time has now elapsed to show that there are no detrimental effects from the employment of the higher mean pressures involved in supercharging, over a number of years, and it was practically the only objection raised against the system that it might be found unsatisfactory in prolonged operation.

It may now be asserted that the modern four-stroke engine using airless injection and with pressure charging, can be rated at least 30 per cent. more, in brake power, than corresponding air-injection non-pressure-charged engines.

Propelling Machinery of S.s. "Arcwear" and "Arctees".

"Engineering", 18th May, 1934.

The propelling machinery, while conforming generally to modern steam practice, also has certain novel features tending to economy in running and giving it unusual interest. A brief account of it is, therefore, here given. The vessels are propelled by a single screw driven by a set of triple-expansion engines. These, as shown in the illustration, are of the open-fronted type, that is, the crossheads have slides on the back columns only, and, with the boilers, were supplied by Messrs. The North Eastern Marine Engineering Company, Limited. The high-pressure cylinder is 21½in. in diameter, the intermediate pressure cylinder 37in. in diameter and the low-pressure cylinder 62in. in diameter, the stroke being 42in. The working pressure is 220lb. per square inch, the steam being superheated to a temperature of 630 deg. F. The engines developed 1,750 i.h.p. on the trials.



The most unusual feature apparent in the illustration is the valve arrangement of the high-pressure cylinder. The valve gear is the usual Stephenson type with double-bar links and a "linking-up" slide on the wiper arm. Instead of the conventional valve spindle, however, a spindle attached to the valve crosshead at one end and, by a short connecting rod, to a crank on a transverse shaft at the other, actuates four cams. The actual valve spindles are operated by these cams, there being separate double-beat poppet valves for the top and bottom steam inlets and top and bottom exhaust respectively. This arrangement naturally reduces cylinder clearance by shortening the cylinder ports and enables the points of compression and release to be determined independently of the point of cut-off, both these features, as is well known, conducing to economy in working. The cams are so shaped that they open and close the valves quickly; but allow these to come to rest on their seats gently. Wear on the seats is therefore practically negligible, while a much greater degree of steam-tightness is obtained than would be possible with a slide or piston valve under the same conditions of pressure and temperature. The valve spindles work in long cast-iron bushes without packing so that they can run for long periods without attention. The intermediate pressure valve is of the Martin and Andrews' balance type and the low-pressure valve is of the ordinary flat double-ported type.

The condenser occupies the usual position at the rear of the back columns. It is of pear-shaped cross-section and is constructed of steel plates. The circulating water is supplied by an independent centrifugal pump driven by an enclosed forced-lubrication type steam engine. The discharge pipe is 10in. in diameter and the pump has a capacity of 1,600 gallons per minute. The flow through the condenser is arranged so that the incoming steam meets the hottest water first. The designed vacuum is 26in. with a sea-water temperature of 80 deg. F. The air pump and two bilge pumps are driven by a lever from the low-pressure crosshead. The main regulating valve is of balanced type and is made of "Lanz Perlit" iron, with special metal fittings. The reversing gear is of the "all-round" type, with locking gear. The high-pressure cylinder liner, and certain other parts are of Lanz Perlit iron, roller finished to ensure a smooth-working finish. The piston rods are of a special hard-wearing steel, selected in order to ensure long life before regrinding becomes necessary. The turning gear can be operated either by hand or by a reversible steam engine. In view of the high temperatures involved, both lagging and lubrication have received detailed attention. Oil is conveyed direct to the internal working surfaces, and the cylinder-oil consumption is thus stated to be reduced to one half that necessary with the more conventional arrangement, the reduced amount easing considerably the work of the feed-water filter. The thrust block is of the single-collar Michell type. The propeller is of solid bronze with a stream-lined boss and a cone fitted over the shaft nut. A model was tested, in conjunction with the hull, at the National Physical Laboratory, and the propulsive efficiency is high.

Steam is supplied to the main engines from two single-ended, three-furnace cylindrical boilers, each 13ft. 6in. in diameter by 11ft. 6in. long. Between them is a two-furnace auxiliary boiler 12ft. in diameter by 10ft. 6in. long. The main boilers are fitted with Howden's forced-draught apparatus. The air heaters are of the turbulent flow type, and the inlet trunk to the forced draught fan is kept well out of the way of dust, etc., to enable clean air to be supplied. The auxiliary boiler is arranged for natural draught. All three boilers have the same working pressure, *viz.*, 220lb. per square inch, so that the auxiliary boiler can be connected, if desired, up to the main engines. The main boilers have smoke-tube superheaters. A soot blower is fitted at the back of each combustion chamber, and soot blowers are also fitted in the smoke boxes for the air heaters. All the blowers use superheated steam. A somewhat unusual pipe arrangement is adopted, the regulating valves being grouped together on the engine-room side of the cross bulkhead, so that proper temperature control, etc., may be effected from the engine room. Separators are provided on the main steam outlets. Superheated steam is used for driving the forced-draught fan engine, the centrifugal pump, the generating set and the steering engine. The remaining auxiliaries take saturated steam.

The auxiliary machinery consists of the following: Two Weir feed pumps 6in. by 8½in. by 18in., each capable of providing all the feed water at maximum power. One ballast pump, 10in. by 9in. by 24in., capable of dealing with 170 tons of water per hour. One auxiliary feed and general service pump, 4in. by 6in. by 12in. One evaporator of 15 tons capacity, one primary exhaust-steam feed heater and one secondary live, or bled, steam heater connected in series. One "North Eastern" gravitation feed-water filter with automatic float gear for controlling the output of the independent feed pumps. One oil interceptor on the auxiliary steam range. One steam ash hoist with a 4in. by 4½in. engine. One winch condenser of 500 sq. ft. heating surface. The whole installation is an excellent example of modern marine steam engineering practice.

The Most Efficient Cargo Ship.

"The Motor Ship", April, 1934.

Although some of the statements in the paper which was read recently, entitled "Some Influences on a Shipowner's Choice of a New Cargo Ship", were very much open to criticism, as we stated in the March issue of "The Motor Ship", the discussion on this paper elucidated some very interesting points.

Mr. McNee referred to the authors' remark :—

> "There are many who feel that the owners of Diesel ships are men who bear their griefs in silence, and carry on making the best of a bad job".

He gave particulars of a vessel which has run 340,000 miles since she left the builders' yard about six years ago. In that time, the most expensive spares ordered by the owners were three piston heads and one gross of piston rings. A similar vessel has run over 320,000 miles, and an order for three cylinder liners has just been received. Previously, this vessel had been supplied with spares amounting to one piston head and 11 dozen piston rings.

Mr. A. Storrar made the following cogent comment on the paper :—

> "The Diesel engine nowadays does not require any apologetics, having been tried and proved, and it must be remembered that in the past, and even at the present time, most of the ships built for that most precarious of trades, the carrying of frozen meat, are Diesel-engined, not only for propulsion, but also for refrigeration. Further, can the authors explain why it is so difficult at present to get coal cargoes to South Africa? May it not be due to the fact that more ships than before are burning oil in the cylinders, and that the Diesel engine, far from being a spent force, is really coming into its own?"

Mr. W. L. Runciman also could not agree that the time for the Diesel engine is not yet, as has been suggested by the authors, who appear to have forgotten that the first ocean-going motor ship is 22 years old. He remarked :—

> "Its particular advantage, which seems at present conclusive, is the great power of mobility, conferred by being able to carry about large supplies of fuel, bought in the best market, without seriously impairing the deadweight capacity of the ship".

Constant Efficiency over Wide Speed Range.

"The Motor Ship", April, 1934.

In the paper to which reference has been made above, the authors, speaking from the shipowners' point of view, said that "what is required is an engine that will run at or near its highest efficiency over a wide range of speeds".

We stated that this demand had already been met by the oil engine, and during the course of the discussion on the paper Mr. McNee gave some very interesting particulars which proved the point conclusively. He produced the following figures for the fuel per i.h.p.-hour for a motor vessel, and the corresponding details averaged for a number of reciprocating-engined steamers. The motor ship in question is the "Buesten", equipped with a Barclay, Curle-Doxford engine of 2,000 b.h.p., and having three cylinders 580mm. in diameter, the combined stroke being 2,320mm. The consumptions in each case are for the main engine only.

FUEL PER I.H.P.-HOUR.

Percentage of power	50	75	100
Triple expansion ...	1·85	1·5	1·32lb. coal
Diesel	·25	·275	·31lb. oil
Per b.h.p.-hour ...	·335	·35	·37lb. oil

We have added, in the last line, the corresponding fuel consumption per b.h.p.-hour based upon the mechanical efficiency obtained with a similar engine on the test bed. As the mechanical efficiency will rise after a period of service, these figures per b.h.p. are probably somewhat on the high side.

Another engine of which we recently obtained particulars, developing 1,200 b.h.p. and of the single-piston two-stroke type, gave the following results :—

FUEL PER B.H.P.-HOUR.

Percentage of power	50	75	100
	·405	·395	·385

The figures are sufficient to show that within the possible working range of any motor ship (for power variation is not likely to be needed beyond 50 per cent.) the specific fuel consumption remains, to all extent, practically unaltered. There is no falling off of efficiency at low speeds as there is in the case of a reciprocating engine, which shows an increase of 40 per cent. in fuel consumption between half and full power.

It would be interesting to compare corresponding figures for turbines. In a previous article it was shown that the fuel consumption per b.h.p.-hour of a big geared turbine passenger liner in service was 20 per cent. higher than the trial trip figure when the maximum power was being developed.

There is a curiosity about some of the figures given previously. In the case of the Doxford engine, the fuel consumption at half power is lower than at full power, even on the basis of brake horsepower. It is a little difficult to understand why this should be, and with other classes of engines this does not appear to be the case, the consumption at half load being higher than at full load, although the maximum efficiency is generally obtained at somewhere between 75 per cent. and 100 per cent. of normal load. Possibly there are special reasons for this peculiarity in the Doxford engine, for the figures have been confirmed with other units apart from those to which reference has been made.

The Improvements in Hull Efficiency.

"The Motor Ship", April, 1934.

It is very illuminating to discuss with shipowners or their superintendents at the present time the possibilities of increasing speed or decreasing the necessary power for a given speed by the various expedients which are now available—Oertz and other streamlined rudders, Contra propellers, the adoption of the Maier form and other devices, whilst, in March, Dr. F. H. Todd, of the William Froude Laboratory, demonstrated by experiment that by substituting the deepest cruiser stern for an ordinary raised counter in a 200ft. ship having a speed of 9 knots, the power necessary to drive the vessel is some 7 per cent. less than it was previously.

All of the various means adopted apparently improve efficiency. Facts can be brought forward to prove this point by those who are responsible for the development in the respective instances. But shipowners are not always convinced that other conditions than those involved by the particular modification are wholly unaltered, nor that some other disadvantage may not creep in which is only recognized after prolonged service. The question of capital cost enters, for a gain in efficiency may be purchased at too high a price if the interest and depreciation charges on the capital are excessive.

We think those who are responsible for these various developments would do well to put forward information prepared by owners showing the improved efficiency in actual service compared with similar ships on the same trades, including operation in bad weather, light and loaded, and so on. It seems simple to claim that some modification represents an increase in efficiency, but in shipping there are so many conditions and so many factors that enter into consideration that conclusive proof is difficult to obtain.

The Subsidy Problem.

"The Motor Ship", April, 1934.

Most of those who have British shipping at heart will be very glad indeed at the greatly modified proposals which have been put forward by the Chamber of Shipping in the matter of Government assistance to the industry. Instead of continuing to urge that tramp shipowners should be paid money for laying up their ships or running them at will, the Chamber of Shipping merely suggests that "when any section of the British mercantile marine can show that a temporary subsidy is necessary and will ensure its preservation for the time, the Government should favourably consider the granting of such a subsidy, taking care not to prejudice any section of British shipping thereby".

There are so many "ifs" in this recommendation that the idea of a subsidy—at any rate, for the maintenance of inefficient ships—is no doubt definitely shelved. It is wholly satisfactory. British shipping, no matter how serious its temporary plight, cannot afford to lose any of that high prestige it has gained through centuries of agreeing to receive payment from the Government for keeping ships idle, or even for maintaining inefficient ships in service.

The greatest hope for shipping lies in increased home trade, and particularly growing international trade. The industry must concentrate on these matters, and it is in this direction that the Government can really be helpful.