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Practical Refrigeration for Ships.

BY A. GREENFIELD.

READ

Tuesday, December 11, *at* 6.30 *p.m.*

CHAIRMAN: Mr. W. E. FARENDEN, (Chairman of Council).

The CHAIRMAN: I have much pleasure in announcing that we have with us this evening the Author of this Paper, Mr. Greenfield. I think Mr. Greenfield is known to many who are present; he is, as you know, associated with Messrs. J. & E. Hall, of Dartford, and I am sure we look forward to hearing an enjoyable lecture.

ALTHOUGH this paper is to deal primarily with the practical side of marine refrigeration, a few preliminary remarks as to the principles involved may be of use.

The artificial production of cold is not a modern industry there being every evidence that it was known at least four thousand years ago.

The earliest record we have of cold being produced by mechanical means is in the year 1849, when a machine was introduced by Doctor Gorrie which produced low temperatures by the compression and re-expansion of air—the forerunner of the well known but now superseded cold air machine.

The first marine application seems to have been in 1873 but this was unsuccessful. The first successful attempt to import meat was carried out in 1880 in the S.S. *Strathleven*, using a Bell-Colman cold air machine.

Practically all modern refrigerating machines—both marine and land, work on the compression system, the chief refrigerants used being CO_2 carbon dioxide, NH_3 ammonia and SO_2 sulphur dioxide.

Table 1 shows a comparison of the chief properties of these agents. It will be noticed that there is an enormous difference in the vapour pressures, *e.g.* at 68° F. the absolute pressure of NH_3 is $2\frac{1}{2}$ times the pressure of SO_2 and only about 1/7th the pressure of CO_2.

TABLE I.

PROPERTIES OF REFRIGERANTS.

Temperature °F.	Absolute Pressure in Pounds per Square Inch.				Volume of 1 Pound in Cubic Feet.			
	NH_3	CO_2	SO_2	H_2O	NH_3	CO_2	SO_2	H O
—4	27·59	283·8	9·30	0·0171	9·991	0·3131	8·08	15940
+14	42·18	382·5	14·84	0·0398	6·703	0·2285	5·164	7232
+32	62·29	504·1	22·71	0·0886	4·637	0·1668	3·437	3294
+50	89·19	650·0	33·45	0·1780	3·294	0·1204	2·348	1702
+68	124·3	827·0	47·78	0·3386	2·393	0·0838	1·652	928
+86	169·2	1039·0	66·45	0·613	1·772	0·0474	1·185	529·5
+104	225·4	—	90·38	1·066	1·334	—	0·865	313·3

Another important property is the specific volume of the gas. Again taking 68° F. the volume of one pound of NH_3 is nearly $1\frac{1}{2}$ times the volume of SO_2 and 30 times the volume of CO_2.

From this it will be readily understood that other thermo dynamical properties being equal the compressor volume required when using NH_3 would be greater than when using SO_2 and very considerably greater than when CO_2 is employed.

Another property having an important bearing on the subject is the critical point. This is the point at which the change from liquid to vapour or *vice versa* is carried out without expenditure of internal energy—it follows that at this point there is no latent heat.

The critical points are SO_2 312° F., NH_3 266° F., CO_2 87·8° F.

In cases where high condensing water temperatures are met with it may be assumed that SO_2 and NH_3 are the better media to use but that CO_2 is still efficient at temperatures above its critical point has been amply proved in practice. It is practical considerations which have determined the agents which have come to be exclusively used in the modern marine machine, under which heading we do not include the cold air machine.

At ordinary refrigerating temperatures SO_2 works at a pressure below atmospheric—hence the grave danger of damp air being drawn in, the formation of H_2SO_3 and the very rapid corrosion of working parts.

With NH_3 the pressures are considerably higher for equal temperatures but there are certain dangers attaching to serious leaks, whilst its action on certain metals precludes their use in the construction of the plant. The pressures with CO_2 are always above atmospheric and it has none of the other disadvantages, it can be inhaled safely in large proportions—has no odour and providing it is anhydrous has no deteriorating effect upon any of the metals usually employed in engineering practice.

These are the chief considerations which have given the CO_2 system first place in the marine refrigerating plants of the world.

The theory and principle underlying the use of either agent are however identical.

A compression refrigerating machine consists of three essential parts:—

(*a*) The compressor.

(*b*) The condenser.

(*c*) The evaporator.

Diagram 1 illustrates the arrangement of these units and shows the gas cycle.

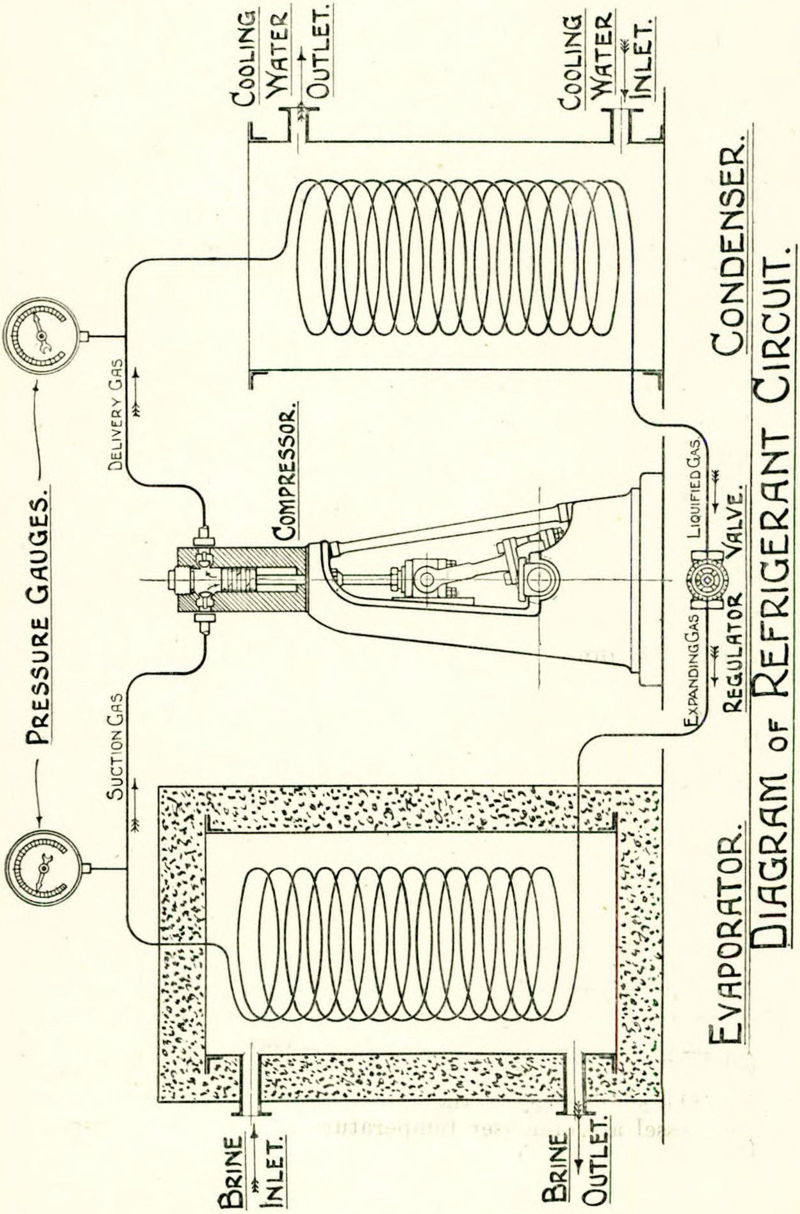


Diagram 1.

The refrigerant is drawn into the compressor on the left hand side at the pressure shown on the suction or evaporator gauge, is compressed to the pressure necessary to liquefy it, discharged at this pressure—shown on the delivery or condenser gauge, into the condenser where it is condensed into liquid form, passes the regulating or expansion valve, is evaporated in the evaporator and is drawn again into the compressor.

The refrigerant returning to the compressor in its original state—the operation is cyclic.

Evaporation is carried out at constant pressure—compression is theoretically adiabatic—condensation is at constant pressure.

The various changes of state may be enumerated thus:—

(*a*) In *Evaporator*. Heat is absorbed at constant pressure and at low temperature.

(*b*) In *Compressor*. Gas compressed.

(*c*) In *Condenser*. Superheat—latent heat and sensible heat rejected at constant pressure and high temperature.

(*d*) In expanding in the regulating valve no heat is expended or rejected.

The foregoing describes the ordinary cycle as applied to the vast majority of refrigerating machines but it may be appropriate to mention at this point another cycle which is sometimes employed, known as the liquid cooling or multiple effect cycle.

As its title denotes, the cycle aims at cooling the liquid refrigerant before it reaches the regulator.

Diagram 2 shows the components of such a plant and indicates how the various units are coupled up.

As will be seen the compressor delivers gas to the condenser in the ordinary way, it is liquefied but instead of passing direct to the evaporator through the regulator it passes into an intermediate vessel—the liquid cooler. This vessel has two outlets, the top one connects to the compressor suction and the bottom one is the cooled liquid outlet. Liquid enters the vessel at condenser temperature and at the corresponding pressure. When the vessel is opened to the compressor suction

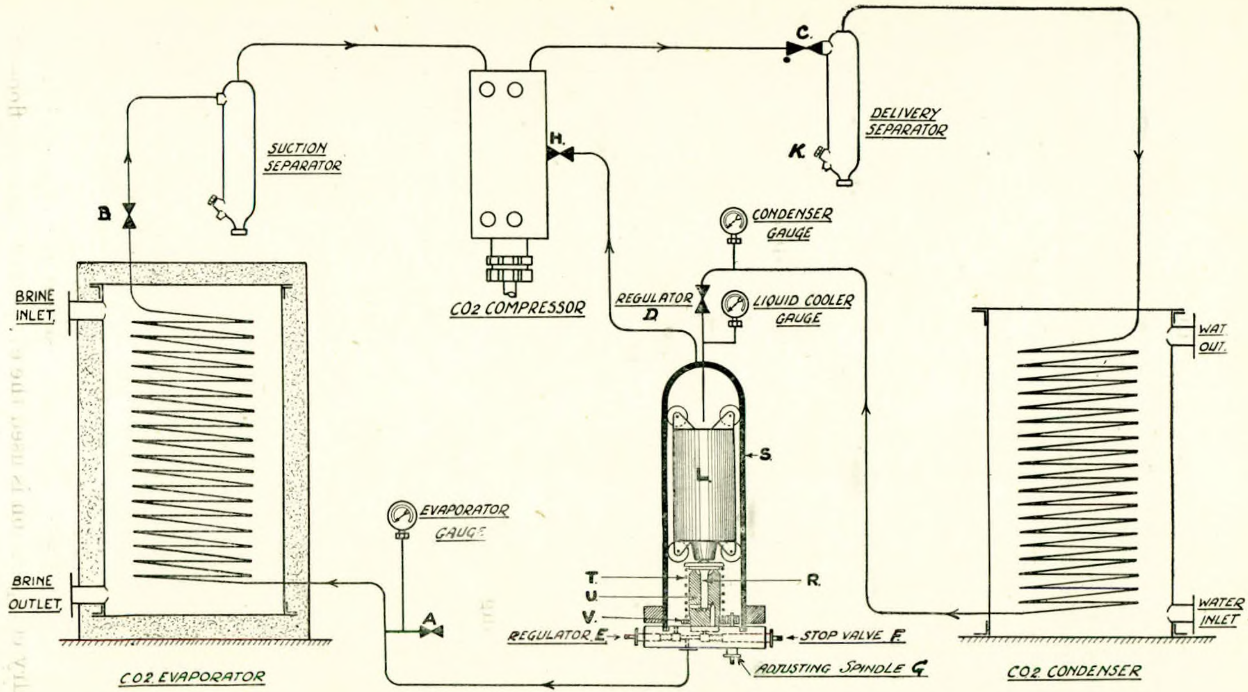


DIAGRAM OF CO_2 CIRCULATION IN MACHINE FITTED WITH LIQUID COOLER

Diagram 2

the pressure immediately falls, the liquid evaporates and the temperature of the vessel and of its contents falls also.

The gas given off by the evaporation of the liquid is drawn off into the compressor whilst the cooled liquid passes on to the evaporator either through a float or a hand-operated valve. The cycle is completed as in the ordinary machine.

The gas from the liquid cooler is admitted into the compressor through ports at the end of the stroke, the ports being opened and closed by the piston.

To take an actual example, we will assume that the condensing water is 80° F. and the liquid leaving the condenser and entering the cooler has a temperature of 85° F. The pressure in the vessel would then be 1,012 lbs./sq. inch—the piston reverses and draws gas from the evaporator at say 240 lbs./sq. inch. At the end of the stroke the piston uncovers the port connecting to the cooler and evaporation of the liquid takes place until the pressures equalise, which in the example taken, would be at about 407 lbs./sq. inch.

This then is the intermediate pressure shown on the gauge connected to the liquid cooler and it would indicate that the liquid in the vessel and that passing to the evaporator had been cooled to about 20° F. from its original temperature of 85° F.

In the arrangement shown the quantity of liquid passing from the condenser into the liquid cooler is hand controlled whilst the float operated valve allows the required amount to pass to the evaporator.

It is not proposed in this paper to discuss the merits or demerits of the cycle—suffice it to say that it has advantages when high temperature cooling water is met with but it introduces complications which are not found in the simple cycle.

Throughout the paper it is assumed that the " wet compression " cycle is used, as " dry compression " is used only with NH_3 and has not, we believe, been applied to marine work. Briefly, in a wet compression machine the gas returning from the evaporator to the compressor is wet, *i.e.*, it contains an amount of unevaporated liquid. On the suction stroke this liquid evaporates and cools the gas in the compressor so that the discharge gas is not excessively hot—about 120° to 140° F.

When dry compression is used the evaporator coils are flooded with liquid thus ensuring perfect heat transmission. Large quantities of liquid are carried over to the suction but before entering the compressor all the liquid is trapped out and pumped back into the system by a special liquid pump. The gas passing to the compressor is thus perfectly dry—there is no liquid left to be evaporated in the clearance spaces of the compressor and the compressor discharge temperature may be anything up to 250° F. The absence of liquid in the clearance spaces increases the compressor efficiency.

No matter what cycle is used the highest efficiency is obtained from a refrigerating machine when the difference between the temperatures of evaporation and condensation is least, that is, the evaporator gauge should be kept as high as possible and the condenser gauge as low as possible consistent with a full charge of gas.

This point regarding efficiency, is often lost sight of by engineers who struggle to obtain that usually unnecessary " extra degree " and then wonder why they have to run the plant an excessive number of hours.

To quote an actual example, assume a certain machine is capable of eliminating 1,000,000 B.T.U. per hour using condenser water at 70° F. and cooling brine to 20° F.

The same machine, at the same speed, using the same temperature water but cooling brine to $-5°$ F. would only eliminate 630,000 B.T.U. per hour or little more than half its previous performance.

Coming to more really practical considerations—it has been mentioned that a refrigerating plant consists of three units—compressor, condenser and evaporator.

The *compressor* may be properly regarded as the heart of the installation whilst at the same time it should be appreciated that it is only a special form of pump. The compressor piston may be driven by any convenient form of motive power—steam engine, oil engine, electric motor or belt. The speeds vary from about 80 r.p.m. for the large horizontal slow speed machine to as much as 500 r.p.m. for the modern high speed vertical multi-cylinder machine direct coupled to electric motor.

CO_2 compressors which may be single or double-acting, are now almost universally manufactured from high carbon steel ingots. In the smaller sizes the suction and delivery passages are incorporated in the main block whilst in the larger sizes they are in separate blocks bolted on. The valves are of steel and usually of the mushroom type although plate valves are sometimes used. In some types of single-acting machines the suction valve is housed in the piston head. The piston rods are made of nickel steel and modern practice is to have either a solid or built up piston head fitted with cast iron piston rings. Metallic packing is almost exclusively used for the glands of present day machines and a number of satisfactory types are available. There are of course still a very large number of compressors in use having both pistons and glands packed with hydraulic leathers. In double-acting compressors the gland is subjected to full condenser pressure and this may be in the vicinity of 1,400 lbs./sq. inch. Most glands are oil sealed, the seal being maintained by a differential pressure pump operated by the high pressure gas. Some compressors have oil injection for lubricating the bore but the majority rely on the oil which leaks past the gland packing. NH_3 compressors are similar in principle but are generally made of close grained cast iron sometimes fitted with renewable liners. For equal duties the NH_3 compressor is much larger than the CO_2 compressor owing to the greater volume of gas to be dealt with; whilst the working pressures are correspondingly lower. As for CO_2 the compressors may be single or double-acting, the valves are steel either of the mushroom or plate type. In large units four delivery and four suction valves are fitted to each compressor, in order to obtain the necessary area. Piston rods are of nickel steel—piston heads cast iron with cast iron rings. There is a wide choice of gland packings both of the metallic and soft types. Ammonia itself has lubricating properties and it is not usual to provide any special arrangement for lubricating the bore—the gland is fed by sight feed lubricator.

All refrigerating machines are fitted with safety valves, these being usually incorporated in the compressor or in the compressor pipes. A common form for CO_2 compressors is a copper disc backed by a spring loaded valve. The disc fractures at a pre-determined pressure—about 2,300 lbs./sq. inch and the escaping gas lifts the spring loaded valve. When a safe pressure has been reached the valve closes and saves the rest of the charge.

For NH_3 a tin disc is used, fracturing at about 400 lbs./sq. inch but owing to the properties of the gas, it is not convenient for the excess pressure to blow to atmosphere and the arrangement is such, that, when the disc fractures, the suction and delivery sides of the compressors are put into communication, thus balancing the pressures and preventing a further rise.

On leaving the compressor the gas passes through an oil separator to the condenser.

Condensers are made in many forms—submerged, double pipe, evaporative, multitubular, shell type, etc. For ships the submerged type is almost exclusively used although the double pipe form is sometimes fitted. The submerged condenser is, as its name suggests, a series of coils contained in a casing, the coils being kept submerged by sea water pumped through the casing. The condenser may be embodied in the machine base or it may be an entirely separate unit. For CO_2 machines the coils are of copper, for NH_3 they are made of steel.

The double pipe type is built up with a series of pipes contained inside outer tubes, the gas being confined to one set of pipes and the water to the other. In some designs the gas occupies the annular space between the tubes and the water passes through the inner tubes whilst in other arrangements they are reversed. This type of condenser gives an exceptionally good heat transfer.

Continuing the cycle, the gas now liquefied passes to the regulator or expansion valve—this is merely a throttle valve, and so to the evaporator.

Evaporators also take many forms but for marine installations the submerged brine cooling evaporator is in almost universal use. In form it resembles the submerged condenser but the coils in this case are always of steel. For smaller plants—provision room, cooling, etc., the direct expansion evaporator is sometimes employed. In this form the evaporator coils are arranged on the ceiling, walls and bulkheads of the space to be cooled, the expanding gas obtaining its heat of evaporation from the surrounding air which is correspondingly cooled.

The gas passing from the evaporator coils through some form of strainer or separator to the compressor completes the cycle.

Having briefly described the apparatus necessary for the production of low temperatures it may be of interest to record the various sources of heat against which these temperatures have to be maintained, or which have first to be eliminated. These are:—

(1) Heat from air in the space.

(2) Heat from goods to be stored including dunnage, packing cases, etc., when used.

(3) Latent heat if goods are to be frozen.

(4) Heat generated by some goods such as fruit and vegetables.

(5) Heat from any fresh air introduced by opening doors or air changing, from persons entering, lights left burning, etc.

(6) Heat passing from outside atmosphere or water, surrounding the cooled space.

Numbers 2, 3, and 6 are the chief of these, the loss from the latter is kept as small as possible by insulating the compartments in which low temperatures are required.

Too much attention cannot be paid to the efficient insulation of all compartments which are to be cooled, an inefficient or badly fitted insulating material will inevitably result in long hours of running, if in nothing worse. Cork, in one form or another, is practically the only insulating material now used for ships, silicate cotton and charcoal being very seldom seen. Probably the most common method is to employ granulated cork which is held in position against the ship's structure by T. and G. boarding, nailed or screwed to wooden grounds which in turn are bolted to the frames and beams of the ship. As granulated cork settles due to its own weight and to the working of the ship the top boards must always be screwed to allow for filling up. The cork can be filled either by hand or by compressed air and the amount used should be 7 to 8 lbs. of cork per cubic foot.

Granulated cork compressed into boards and known as "slab" cork is often used and is considered by many to be more efficient than the granulated form although there is really little difference as shown by the test figures given by the National Physical Laboratory and shown in Table 2.

TABLE II.

MATERIAL.	AVERAGE THERMAL CONDUCTIVITY. B.T.U.'S/SQ. FT./HOUR FOR 1" THICKNESS AND FOR 1° FAH. DIFF. IN TEMPERATURE.
SLAB CORK. SAMPLE 1.	0·333
SLAB CORK. SAMPLE 2.	0·304
GRANULATED CORK. PACKED 5·4 LBS. CUB. FT.	0·319
GRANULATED CORK. PACKED 7·3 LBS. CUB. FT.	0·345
SLAG WOOL. PACKED 13 LBS. CUB. FT.	0·302
SLAG WOOL. PACKED 21 LBS. CUB. FT.	0·290
CHARCOAL.	0·348
WOOD.	1·306
CONCRETE BLOCKS.	8·2

Slab cork is applied in two or more layers arranged to break joints. The slabs should be coated with bitumastic solution in order to ensure adhesion to the ship's plates and to make joints air tight. The slabs are wedged tightly between the beams and frames. Second and third layers are applied in a similar manner having wooden pegs or skewers driven through them for greater security. Over the face of the cork it is usual to fit wire netting or expanded metal, the whole is finally faced with cement trowelled to a smooth finish. Various kinds of cement are used such as Portland, Keene's, Atlas, etc. Cracking of the finished surface very often occurs, in fact it is almost impossible to ensure that no cracks will develop. Asbestos fibre is sometimes mixed with the cement to aid in the prevention of cracks. A timber finish can be used if desired.

Cork in slab form has one advantage over granulated cork, in that there is no settlement and no filling to be done. Present day practice is to insulate decks on the underside only, a ribband being fitted on the top side to prevent creep of cold to the ship's plating.

The chief points to be considered in deciding the thickness of insulation to be fitted are:—

(*a*) The temperature to be maintained in the space.

(*b*) The highest outside temperature which will be met with.

Whilst for any given set of conditions the most efficient thickness for the insulation can be calculated, in ships it is practical considerations such as depths of frames and beams which are usually the deciding factors.

All steelwork inside an insulated compartment such as stanchions, ventilators, ladders, etc., has to be insulated as do the hatch coamings. The latter need special treatment as they have to withstand the rough usage caused by chains, cargo, etc. Ordinary practice is to bolt taper pitch pine coamings to the steel work, covering the wood with galvanised sheet iron. Insulated taper plugs are made in convenient sizes to close and insulate the hatch opening when the space is loaded and cooled down.

Having described the methods for producing and conserving cold it is now necessary to consider how the low temperature is applied.

It is proposed to divide "ships" into classes as follows:—

(*a*) The vessel using refrigeration to preserve provisions for the crew and perhaps a small number of passengers.

(*b*) The large passenger boat.

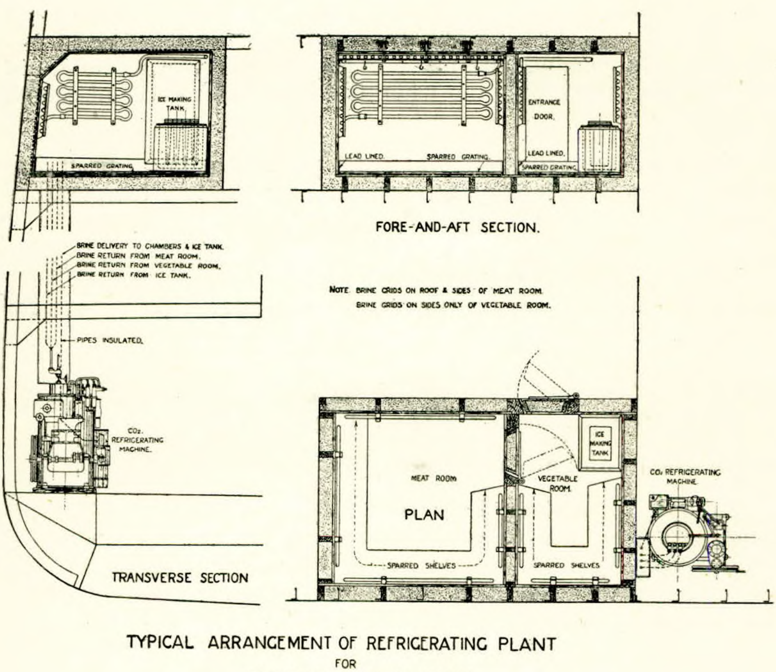
(*c*) The ship carrying large refrigerated cargoes.

(*d*) Naval and other special types.

Except in the case of air cooled spaces (which will be dealt with later) cooling of the chambers, holds or 'tween decks is exclusively by means of grids. These are lengths of pipe welded together and bent into grid form, the various grids being arranged on overhead, bulkheads and ship sides.

Through these grids the cooled medium is circulated—reduces the temperature of the surrounding air—is itself warmed up in the process and returns to the machine where the heat which it has removed is taken out and the again cooled medium is ready for re-circulation and more work. Except where direct expansion is employed the medium used is always brine.

This is a solution of calcium chloride and fresh water, having a low freezing point depending on the density used. For convenience Twaddle's Hydrometer is usually referred to and for ordinary refrigerating purposes a density of 45° to 48° Twaddle is recommended. This is equivalent to a specific gravity of 1·225 to 1·24 and at this density the freezing point is about −20° F. In considering whether the brine in a refrigerating plant is getting near to freezing point it must be borne in mind that the temperature to be regarded is not the temperature of the brine itself but the temperature of the compressor gas suction. If this falls below the freezing point of the solution being used the brine will freeze around the evaporator coils with disastrous effects to the machine's efficiency.



TYPICAL ARRANGEMENT OF REFRIGERATING PLANT
FOR
CREWS PROVISION CHAMBERS.

Diagram 3.

Diagram 3 illustrates *Class A*, which generally has a small machine cooling to the required temperature two insulated chambers, one for meat, fish, etc., the other for vegetables and fruit. A small ice making tank is sometimes added but it may be regarded in the light of a luxury in this class of ship. The vegetable room is piped on the sides only as its temperature being above freezing point, there would be drip from overhead grids.

A very simple installation only is required and it is practically only in this class that direct expansion cooling is applied in marine work.

Where brine is used the evaporator and condenser are often incorporated in the machine frame—a brine pump being driven off the crankshaft. This pump draws brine from the bottom of the evaporator, delivers it to the grids in the rooms, whence it returns to the evaporator.

When direct expansion cooling is used the evaporator is made up into grid form and the evaporation of the liquid refrigerant takes place inside pipes which are in direct contact with the air of the cold rooms. This method cuts out the heat exchange between gas and brine when the latter is used and, is therefore more efficient although the brine filled grids have a stabilising effect upon the room temperature during the periods when the machine is not running.

Class B.—The large passenger liner—presents a more difficult problem and calls for a larger and more elaborate plant. In the first place, there is a large batch of provision rooms to be cooled, accommodation having to be made for meat, fish, poultry, fruit, butter, cheese, eggs, vegetables, ice, ice cream, tinned goods, flowers, wines, beer, etc. Separate chambers are generally provided for each of the foregoing commodities whilst an ice-making tank is also incorporated in the system and is often housed in the handing room around which the chambers are grouped for convenience of service.

Each room is fitted with grids, the relation between cubic capacity and foot run of grid piping being varied to suit the shape of the room and respective temperatures required. For frozen goods the ratio is, of 1½in. piping (ft. run) to cubic capacity, usually 1·75 to 1 and for fruit, vegetable, etc., about 3 to 1. For special rooms such as those used for ice cream the ratio may be as much as 1 to 1.

In rooms keeping a temperature above 32° F. side grids only are employed with occasionally the addition of a small air cooler in the special rooms for things such as fruit or cheese.

The brine cooling evaporator is generally separate from the machine and is insulated as a unit or housed in an insulated room. Independent brine pumps deliver the brine through the evaporator to cast iron distribution boxes. On these boxes are mounted cocks—one for each brine circuit and from each cock a service pipe is led to the grid circuit which it feeds. The brine passes through the grids in the chambers and returns through a "return" pipe to the return tank which is usually housed in the insulated evaporator room. Each return pipe is fitted with a thermometer and control valve. The brine pumps obtain their suction from the return tank.

Freezing brine only is used—the varying room temperatures being obtained by the proportioning of the grid surface fitted—and by using the control valves to regulate the quantity of brine passed.

The ice-making tank is of steel with watertight cover. In some forms it is filled with stagnant brine which is cooled by a brine circulation pumped through an immersed brine coil. Other arrangements provide a constant circulation of the whole brine content by means of a weir, and return pipe to evaporator or return tank. The ice moulds are of varying sizes and are of course immersed in the brine for freezing. Unless distilled water is filled into the moulds, ice made by this method is always opaque. To make clear ice, some method of agitating the water to be frozen, must be introduced.

Provision room duty is always regarded by machinery manufacturers as a heavy one—as the insulated doors must of necessity be frequently opened, allowing the ingress of warm air. Another and very important duty has to be provided for in this class of installation, *i.e.*, the cooling of cold cupboards and larders and the provision of cooled drinking water.

There are refrigeration requirements spread practically throughout the ship, in such places as bars, smoke rooms, pantries, dairy, butcher's shop, bakery, cafes, etc. This is shown in *Diagram* 4.

As will be seen, the various cupboards and coolers are widely distributed, the demand made on them during the day time is continuous and obviously they cannot be directly controlled by

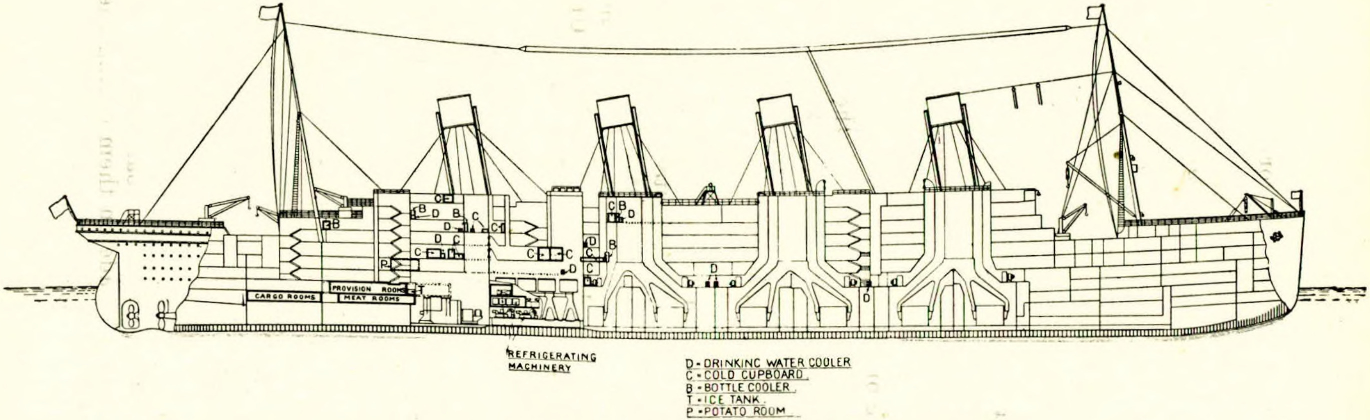


Diagram 4.—Profile of Passenger Liner,

the engineer. The result is, that, with the best designs the maintaining of them at required temperatures makes big inroads on the total output of the machines, they are frequently misused and often regarded as unsatisfactory. The usual method of cooling is by brine grids and it will be obvious that very long leads of service piping are inevitable. These are costly to instal, as costly to insulate and maintain and often form an ugly obstruction where they pass through passenger accommodation, as they must do, in order to reach the various points of application.

However well the pipes are insulated there is inevitably an appreciable loss of cold in such long leads.

There is now available the alternative method of having a small separate refrigerating machine for each cupboard or bar and this possibility is undoubtedly worthy of the serious consideration of owners, designers and superintendents.

A number of small machines driven by motors $\frac{1}{2}$, $\frac{3}{4}$ or 1 B.H.P. are now in the market and these are equipped with complete automatic control. By this is meant, that the machine will start itself when the chamber to which it is attached rises to a predetermined temperature, will stop when the temperature is as low as is needed, is automatically regulated, will turn on the water supply when it starts, turn it off when it stops and will cut out if the pressure rises too high, due to failure of water or any other cause.

The refrigerants used for this type of machine are usually CH_3Cl methyl chloride or SO_2. The advantages are obvious, and whilst the first cost may be rather higher than in the brine-cooled arrangement, there are no expensive insulated pipes to give trouble and to be maintained. Each separate cupboard can always be kept at the required temperature within very close limits (2 or 3° F.) regardless of whether the main plant and brine pumps are working or not and the work of the machine is automatically performed according to the demand, consequently there is no needless expenditure of refrigerating energy. Except to occasionally oil the driving motor, absolutely no attention is needed and the machines referred to will deal with insulated cupboards or cabinets having a capacity of 200 or 300 cubic feet.

As the supply of water required for these machines is only 20-30 galls./hour the automatic water valve can be dispensed with, if desired, leaving the water to run continuously. Should the machines intentionally be put out of action for long periods (by drawing out the main hand controlling switch) the water would of course be turned off at the control valve.

Class C.—Ships handling large refrigerated cargoes—is the most important of all and a large number of designs have been adopted to meet special requirements, cargoes and conditions. *Diagram* 5 shows the arrangement of a completely insulated ship. The machinery follows the lines employed for the previous class, but is of course of greater capacity and is always in duplicate, the rule being that one machine or one compressor shall be able to maintain the required temperatures throughout the ship in case of need.

Until recent years the duplex steam driven machine held the field and it is still very largely employed. The two compressors are driven from the tail rods of the two steam pistons. The engine is compound and is so arranged that one side can be completely disconnected from the other, thus giving the necessary duplication if one side is out of action.

A large number of vessels have had two separate steam driven machines—cylinders compounded and arranged tandem—compressors driven from tail rods as before. The advent of the motor driven ship has brought about the introduction of the large motor driven machine, the drive being either through gearing or by direct coupling.

Gearing has disadvantages and compressor design has tended for always increasing speed, thus making it possible to obtain a motor of reasonable size and cost for direct coupling. Some large horizontal units now run up to 150 r.p.m. and smaller vertical types up to 500 r.p.m. Control of the refrigerating duty is essential as the requirements vary according to the amount of cargo and whether cargo is being loaded, carried through the tropics, carried in cool climates or unloaded. This control can be obtained in a variety of ways, the best of these being by speed variation. On the steam driven machine a full range of speeds is to be had by manipulation of the steam stop valve but for the electric drive either negative boosters or variable speed starters have to be introduced.

The advantages of the electrical drive are too obvious to need comment, one of the greatest being the saving of space.

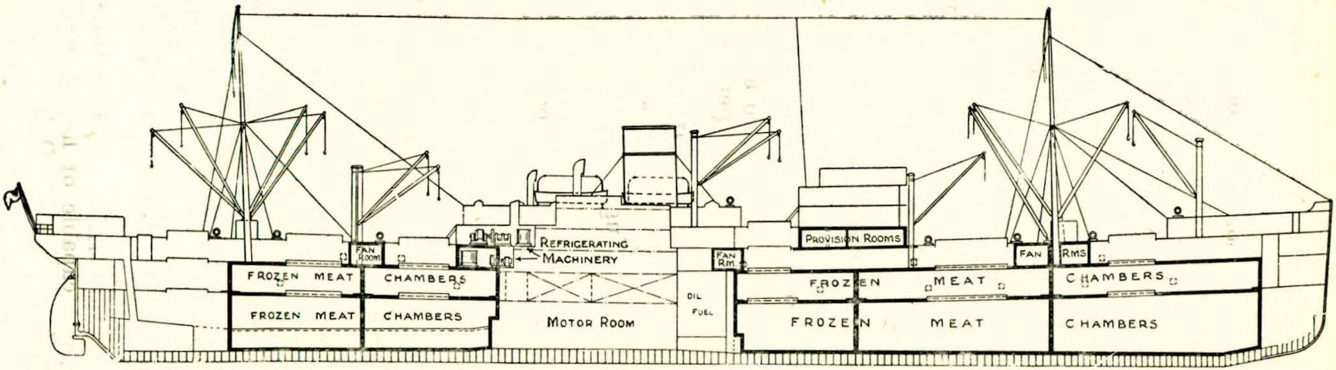


Diagram 5.—Completely Insulated Ship.

Usually each compressor works on an independent condenser and evaporator although where four or more compressors are fitted some designs provide for the compressors to be coupled in pairs—each pair operating on one condenser and one evaporator. This arrangement means that two compressors draw from a common suction pipe and deliver to a common delivery pipe—there is one regulator and obviously it is difficult to guarantee that each compressor will always get its fair share of gas and consequently give its maximum output. Where each compressor is coupled to a separate condenser and evaporator the control in each case is the same as for a complete and independent machine.

Whatever the number of the condensers, the coils may be housed in the main base or in separate casings as best suits the conditions.

The evaporator coils are arranged in W.I. or C.I. casings which are almost invariably put into an insulated room, thus leaving all joints and connections open for inspection without disturbing anything. As already explained, the function of the evaporators is simply to cool the brine, it is the methods of distributing and applying the brine to cool the insulated spaces that call for varying and sometimes complicated designs.

The remainder of the engine room equipment comprises brine and water pumps (either steam or electrically driven), a brine heater and in the case of a CO_2 plant, a drier for removing moisture from the gas before it is charged into the machine. The brine heater is a cast iron casing containing a steam coil and is used for warming the brine when thawing down is to be carried out. To meet the requirements of motor ships—where steam is not available or is scarce—electric brine heaters are being introduced.

It is well known that different commodities have to be carried at different temperatures, and it is for dealing with these varying temperatures on the same ship and at the same time that special provision is necessary. It is proposed to deal first with the ship which is arranged for one temperature only —usually referred to as the "frozen" temperature.

Diagram 6. In this arrangement at least two brine pumps are necessary—each capable of handling the entire circulation—thus providing a spare. Only the working pump is shown. The "open" brine system is usually used, *i.e.*, all the returning brine comes into an open tank which may be either the evaporator itself or if the evaporators are under pressure it is an independent return tank from which the brine

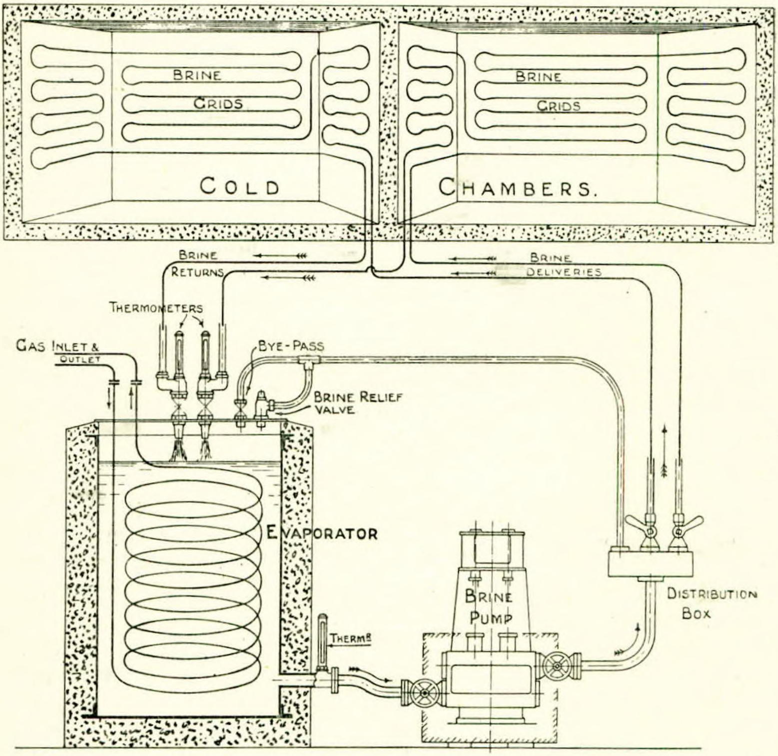


DIAGRAM OF BRINE CIRCULATION.

SINGLE TEMPERATURE.

Diagram 6.

pumps take their suction. As in the case of the provision room installation, the cooled brine is delivered to distributing headers fitted with control cocks—passes through the grid circuit, returns to the tank and then to the evaporator for re-cooling. A provision room is comparatively small and generally sufficient cooling can be obtained by one, or at most, two circuits. The amount of piping required to cool a hold or 'tween deck is considerable and may be as much as 15,000 feet.

To have this length connected in one long continuous circuit would give a very great temperature difference between the inlet and outlet brine and naturally the portion of the space at the outlet end would be at a much higher temperature than the portion in the vicinity of the ingoing cold brine. To obtain an even distribution of temperature in the hold and to give a small temperature rise to the brine (usually 2° or 3° F.) the total length of cooling piping is divided into a number of circuits of approximately equal length—in a large space as many as 12 or 13 circuits may be required. Good practice limits the length of any one circuit to about 1,400ft. Each circuit has an independent control cock on the distributing header and a separate valve and thermometer on the return tank. In arranging the circuits in the space, care has to be taken to ensure even distribution of the cold and warm (comparatively) brine, also the possibility of one or more circuits becoming choked, must not be overlooked. Side circuits should be kept separate from roof circuits and in all cases the various grids making up a circuit, have to be carefully interwoven with the grids of other circuits, so that as far as possible an even air temperature is obtained under the most adverse circumstances. Brine returning from all the circuits of a space should be at the same temperature, this being controlled by the valve and thermometer on the return tank. The service pipes which convey the brine to, and return it from, the grids are grouped together, they must be well insulated and provision must be made for ensuring water tightness where these groups of pipes pass through decks and bulkheads.

Joints should be accessible—arranged in groups and insulation in way of them made portable. The generally accepted method of jointing for service and grid piping, seems to be the well known socket and backnut one. This has proved quite reliable in the past, but with the coming of the motor ship, the possible increased vibration and movement of deck plating, one is forced to wonder whether we may not evenutally see a ship piped out with all joints welded. Whilst there are difficulties and disadvantages connected with this method there are also undeniably many advantages. Methods of securing grids to the ship's structures may be briefly referred to. Overhead grids are supported on angle or channel irons these in turn being carried by bolts fixed to the beams. As the bolts are practically in direct metallic contact with the cold brine pipes, methods of insulating the bolts from the ship's structure have to be employed. These usually take the form of insulating washers and insulating ferrules in the eye of the bolt. Side and bulkhead grids are carried in special supports or chairs—these being usually of wood but sometimes of metal. A facing strip of wood or metal holds the grid firmly into the support and the whole is secured either by bolts as in the case of the overhead grids, or by coachscrews screwed into the wooden studs of the insulation.

From the straightforward single temperature job, the next step is to provide for the modern ship which is required to deal with frozen and chill cargoes at the same time.

Diagram 7 shows a sectional profile of such a ship, a plan showing a typical machinery layout and a section of the brine return tank used. As illustrating the magnitude of such an installation the following figures may be of interest as they refer to the actual ship of which the diagram is a section.

Refrigerated Spaces ...	54 Independent Cargo spaces including 24 hatch trunks and 3 provision rooms.	
Capacity	560,900 cub. ft. including provision rooms.	
Brine Cooling Pipe ...	195.637 feet	37 Miles
Brine Service Pipe ...	46,250 feet	$8\frac{3}{4}$,,
Evaporator Coil	12,897 feet	2·7/16ths ,,
Condenser Coil	13,854 feet	$2\frac{5}{8}$,,
Tube Meat Rail	60,000 feet	$11\frac{1}{2}$,,
	TOTAL PIPE ...	62·5/16ths Miles
Bulb Angle Hatch Meat Rail ...	11,000 feet	2·08 Miles
TOTAL Meat Rail—11·5 plus 2·08		13·58 Miles
Brine Circuits	198, including water cooler and oil cooling coil circuits.	

The oil cooling coil referred to is a special circuit arranged for cooling the oil in the machine gear cases.

For this service a "two temperature" system (freezing and chilling) is essential but as such installations usually incorporate a thawing temperature also, it becomes a "three temperature" system and as occasionally two distinct chilling temperatures have to be provided for, it may at times become "four temperatures." The two chilling temperatures may be called for, either because chilled meat and fruit are being carried or because chilling brine at a temperature lower than the main chill supply is needed for circulating through spaces high up in the ship and exposed to the sun's rays.

There are two distinct brine systems, the open and closed. *Diagram* 8 illustrates the former.

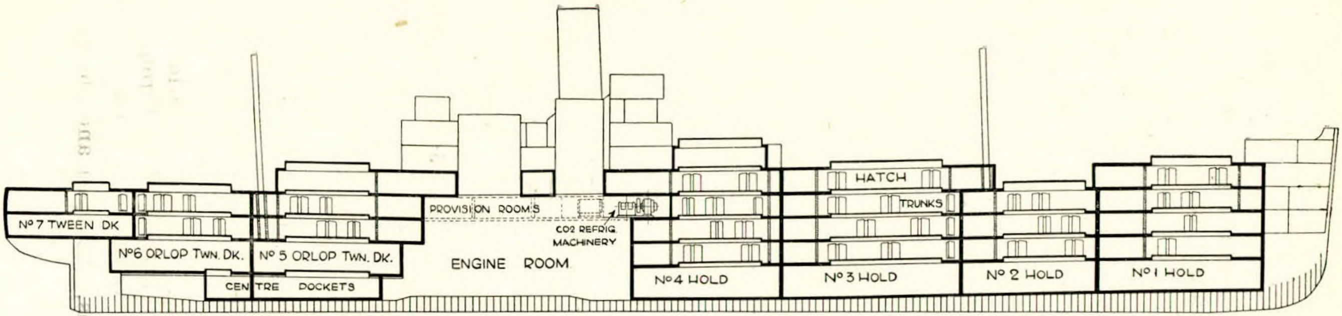


Diagram 7.—Profile of Insulated Ship,

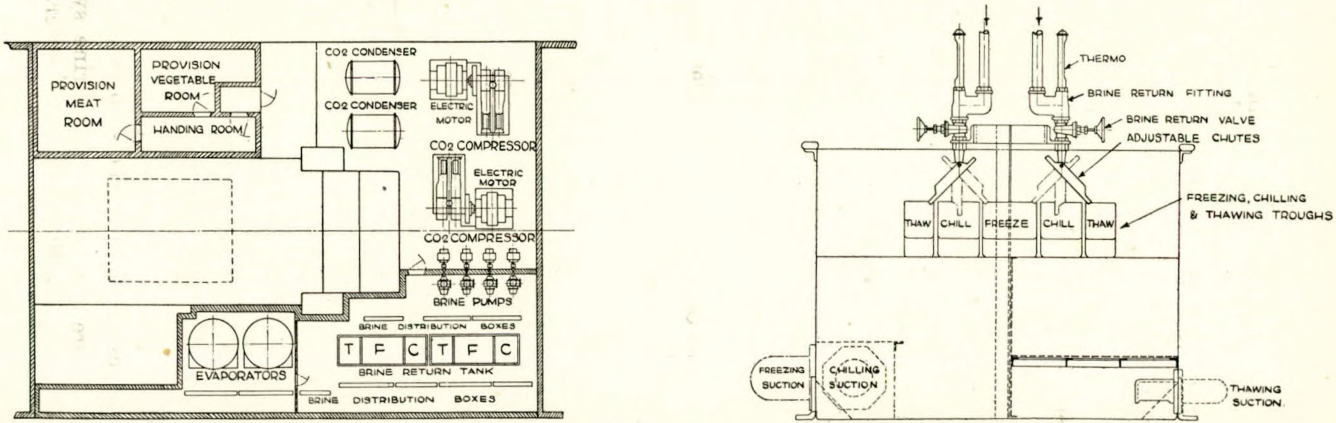
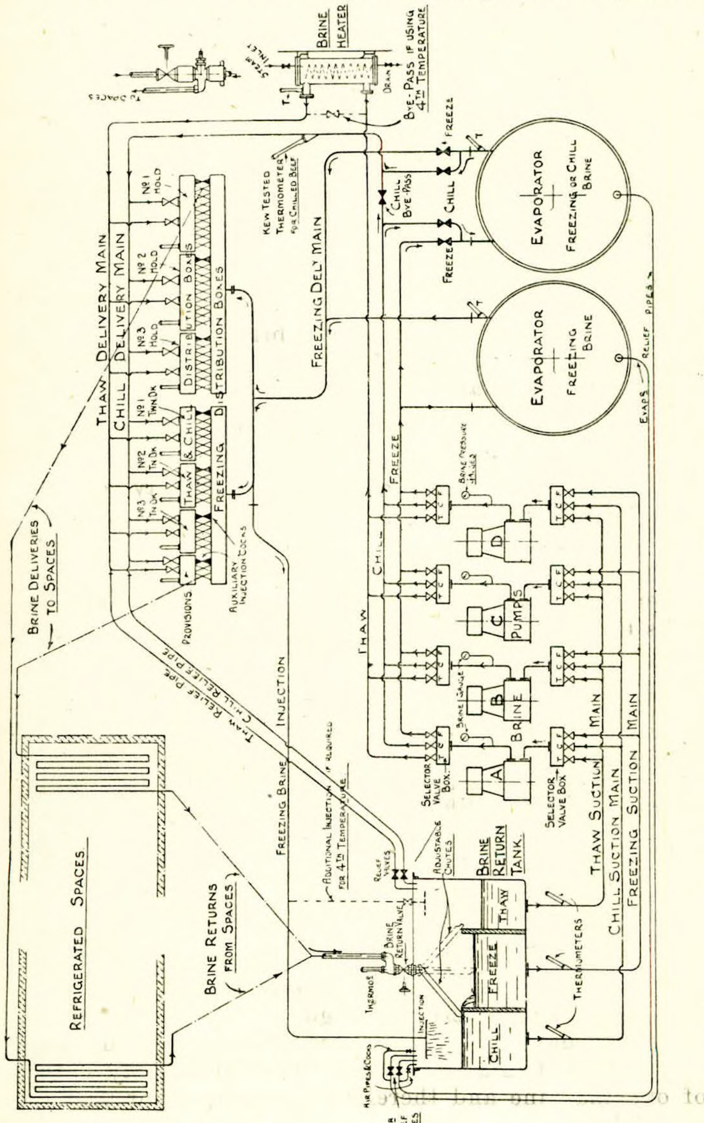


Diagram 7A.—Showing Engine Room Plan and Brine Return Tank.

The freezing brine is obtained as described earlier, *i.e.*, by direct cooling in the evaporator, but the chilling brine may be maintained at its required temperature by two methods.



TYPICAL DIAGRAM OF {THREE / FOUR} TEMPERATURE BRINE CIRCUIT.

OPEN SYSTEM.

Diagram 8.

(*a*) direct cooling in an evaporator (*b*) injection of freezing brine into the chilling brine, when the latter is circulating without passing through an evaporator.

Whenever cargo conditions warrant it, the direct cooling method should be employed and insisted upon because, as previously stated, the efficiency of the machine is much higher when the evaporator pressure is kept up. Obviously cooling brine to say 20° F. is much more economically done by working an evaporator at that temperature than by cooling the same quantity of brine to the same temperature by the injection of brine which is at say – 5° F. and has had to be cooled to that temperature with a correspondingly low evaporator pressure.

In the single temperature system the brine for the spaces is distributed from a single distribution header, but with varying temperatures to be dealt with, extra boxes are necessary, and a typical arrangement is shown.

Mounted above the ordinary freezing box is a series of similar but smaller boxes, each of which can supply all the brine circuits of one complete and particular insulated space. Between the two sets of boxes a cock is mounted and from this, the service pipe to the particular circuit is led. There are a number of highly ingenious special cocks provided by some makers but broadly it is a two-way cock, by the adjustment of which, brine can be taken from either the top or bottom box. The end elevation of the boxes will make this clear.

The brine passes through the grid circuit and returns to an open tank as before. This tank is of special design with compartments to receive the different temperature brines.

For deflecting the various returns to the correct compartment a number of devices have been employed but that shown has the advantage of simplicity and accessibility.

To assist in describing the cycle, let it be assumed that Nos. 1, 2 and 3 holds are filled with frozen meat, that Nos. 1, 2 and 3 'tween decks have chilled cargo and that the provision rooms are being thawed down; all this work being done simultaneously. Also it is assumed that the chilling duty is the output of one machine and therefore one evaporator will be on this work alone.

One machine will cool brine to say $-5°$ F. and the other to say 20° F. The thawing brine will be raised to say 60° F. or 70° F. by means of the brine heater.

Three brine pumps must be run—A. Freezing. B. Chilling. C. Thawing. D. is standby and can take either duty when needed. Pump A. sucks through the selector valve box from the centre portion of the return tank, delivers through the freezing evaporator via the freezing delivery main to the bottom distribution boxes. The left hand box is using no freezing brine, so the contents are stagnant, on the other box the distribution cocks for the three holds are set to take freezing brine which passes through the grids, returns to the centre of the tank and is recirculated.

Pump B. will circulate brine in an exactly similar manner from the chill compartment of the tank, through the chilling evaporator and by way of the chilling delivery main to the top boxes for Nos. 1, 2 and 3 'tween decks returning to chilled compartment of tank, after passing through the grid circuits.

Brine for Pump C. will be drawn from thawing compartment delivered through brine heater to top provision room box, thence through the grids in the rooms and back to the thawing section of the tank.

To follow out the injection system assume No. 1 hold and 'tween deck have chilled cargo—the other spaces all frozen and provision rooms thawing as before.

Both evaporators will now be cooling brine to say $-5°$ C.

Pump A. will circulate as before except both evaporators are in its circuit—the brine for the frozen spaces being taken from the bottom distribution boxes and returning to the freezing section of the tank. Pump B. will draw from chill section of the tank and deliver through the chill bye-pass direct to the chill delivery main and thence into No. 1 hold and No. 1 'tween deck top boxes the brine returning to tank and being deflected by shoots into the chill section.

In performing its work in the spaces this brine will be raised from say 20° to 22° F. and to reduce it to the lower temperature again before recirculating, freezing brine is injected by the injection pipe shown. This injection results in a surplus of brine in the chill sections and this surplus is allowed to overflow into the freezing section of the tank for re-cooling.

As chilling brine temperature has to be accurately controlled, a Kew tested thermometer is inserted in the delivery main.

Pump C. works exactly as before for thawing the provision rooms.

Should it be necessary to carry four temperatures simultaneously, it would be necessary to add another compartment to the tank, another brine pump and another set of mains.

Usually when freezing and two chilling temperatures are required, the thawing service is utilised for the second chill circuit. Pump C. then works exactly the same as Pump B. the brine heater being bye-passed as shown.

It will be noticed that the respective space distribution boxes have each an auxiliary injection cock from the frozen brine. This is provided for use, in case the temperature in any chill space may lag, and enables the brine being delivered to that space to be reduced in temperature below the common chill delivery temperature.

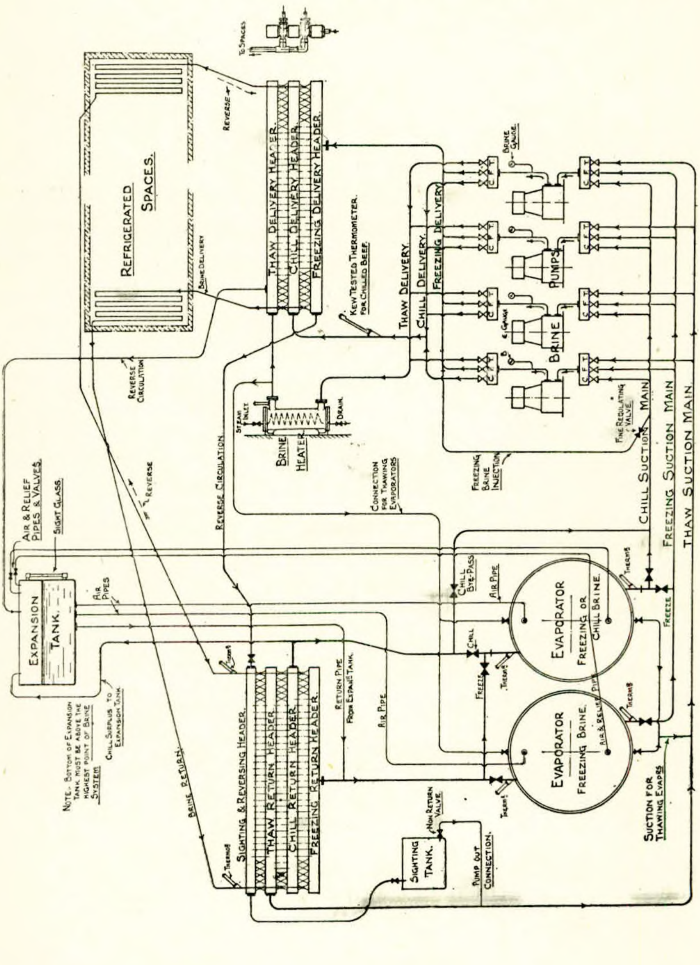
Diagram 9 shows the closed circuit which is perhaps rather more complicated than the one just described. The difference lies chiefly in the fact of the returning brine from the spaces being led into closed boxes instead of into an open tank. The return headers are exactly similar to the distribution boxes fitted on the delivery side with the addition of an extra one as shown on the diagram. In the arrangement shown, the individual holds and 'tween decks are not provided with separate boxes.

The arrangement of pumps, evaporators—valve boxes, heater, etc., is similar for both systems. The actual circulation varies however—the pumps draw from the evaporators instead of delivering through them and a constant head of brine is maintained by the expansion tank. For frozen temperatures the circuit is evaporator—pump—delivery box—grids—return box—evaporator.

For chill when running one evaporator at the higher temperature—the circuit is as above. Thawing is a similar circuit—the brine being heated in the heater instead of being cooled in the evaporator.

When chill temperatures have to be carried by the injection method, the chilling brine circulation follows the ordinary route—the evaporator being bye-passed. The injection of freezing brine has to be made into the chill brine main through a special valve, and the surplus in the chill circuits, caused by the brine injected—is returned to the freezing system by way of the expansion tank.

It will be noticed that the thawing service provides a connection to the evaporators. This enables them to be thawed down, also it affords a ready means of heating the brine when it is required to clean the oil from inside the coils. To do



TYPICAL DIAGRAM OF THREE TEMPERATURE BRINE CIRCUIT.

CLOSED SYSTEM.

Diagram 9.

this efficiently a brine temperature of at least 180° F. is necessary.

The extra header on the return side is called the sighting and reversing header. In the open system, a circuit, not running correctly, is located by observation at the return tank, but in the closed system the only indication is by the temperature recorded on the return thermometer.

Should a circuit be suspect the cocks controlling it and connected to the various headers can be so set that this circuit will deliver to the sighting header and thence to the sighting tank when the amount of flow can at once be seen. The brine delivered into the tank is drawn off by one of the pumps and delivered back into the circuit. Flowmeters are sometimes fitted in preference to the sighting tank.

It is well known that a choked circuit can usually be much more easily cleared by applying a pressure in the opposite direction to the usual flow, hence the reversing header. To clear a choke, the pipe connecting the freezing delivery header to the reversing header, will be opened up. The return control cocks for the choked circuit will be set so that the delivery brine from the reversing header will pass through the circuit in the opposite direction to the usual flow. The corresponding cocks on the delivery headers will be set to connect the circuit with the thawing header—thus any brine and dirt pumped through will pass via this header through the special pipe provided into the expansion tank, the brine returning to the circuit and the dirt being trapped.

The question of which system is the better is very largely a matter of opinion but a few points may be mentioned.

In the open system all brine returns can be examined at a glance whereas it takes time to locate a defective circulation by reading the thermometers.

The return tank of the open system takes more space than the return boxes of the closed, also the return brine falling into the tank is liable to become aerated, bringing on the attendant troubles of air-locks—frothing, etc.

Once the air is expelled from the closed system there is little chance of more getting in and further it is impossible for brine to overflow through the stoppage of pumps or any other cause.

The open system puts slightly more work on the pumps especially when starting because the static head is always balanced on the closed system and it is not quite balanced in the former case, even when the circulation is established.

Most things are improved by their being cleaned occasionally and a brine system is no exception. To clean out and recharge a brine system is costly, but after a number of years use, owners and superintendents should certainly consider whether the gain in efficiency would not outweigh the expenditure.

It may be advisable to mention a few details as to the arrangement of piping, etc., in a chill hold or 'tween deck. As chill meat has to be hung—meat rails and hooks form a very important part of the outfit. The rails are generally $1\frac{1}{4}$in. galvanised pipe running fore and aft and arranged exactly 12in. centres throughout the whole width of the space. Meat hooks vary in design and usually sliding hooks are included.

Meat chains are used for carrying the lower tiers of meat in holds and deep spaces.

As the meat rails run fore and aft and must not be crossed by brine pipes, the grids have to be arranged in a similar manner, and all connections between circuits, etc., are made on bulkheads. The same care in interlacing circuits is observed as for frozen spaces, the ratio of cubic capacity to piping being usually 3 to 1 for 'tween decks, and 3·5 or 4 to 1 for holds, the length of piping per circuit being usually about 1,200 feet. The stowage capacity usually allowed for chilled meat is 110-120 cubic feet per ton and for frozen meat about 90 cubic feet per ton.

Very secure fixing is necessary for supporting the meat rails in view of the weight to be carried. A common method is to fix bolts to every other beam and support both rails and grids in special clips. A clip carries two grid pipes and one rail, and has two supporting bolts.

The hatchway is usually enclosed in an insulated trunk thus forming an entirely separate compartment. This trunk is treated in every way as an insulated cargo room—is provided with independent brine circuit—meat rails, etc. This arrangement enables cargo at two different temperatures to be carried in a space and its hatch trunk; also it makes it possible to work cargo from say a hold whilst maintaining a low temperature in the 'tween decks above.

Underneath the insulated hatch plugs, overhead grids and meat rails have to be provided and these of course must be portable. They are carried on and fixed to channels which rest in shoes let into the hatch coamings—so that grid and support are lifted out together. To couple these portable grids to the brine service, is a difficult matter, particularly as to avoiding brine drip on to cargo when they are uncoupled for removal. The service pipes are generally led to special cocks housed in the coamings and these cocks couple to companion cocks on the grid terminals. The latter cocks are of course necessary for retaining the brine in the grids. A number of different cocks have been designed, some embodying very ingenious features for preventing the possibility of drip.

Meat rails in hatchways are generally bulb angles carried in coaming shoes.

So far, the methods employed for carrying fruit have not been considered. These methods sometimes vary greatly from those already described, and further, the question as to which is the best of them is at the present time, one of the most debated points in connection with the industry. The divergence of opinion centres chiefly around the questions of whether a forced air circulation is a necessity, an advantage, or neither.

When forced air circulation is used the air is cooled by passing over a battery of coils—either brine or direct expansion coils being used. The battery may be housed in an independent insulated casing or it may be formed by erecting shutters in front of the side and bulkhead grids which are fitted in the space. A fan forces the air over the battery and through the fruit, after which it returns to the battery for recooling.

Batteries, where housed in a separate casing, generally have their grids arranged in one of the following forms:—

(1) The most common, vertical grids in square pitch arranged parallel to the flow of air.

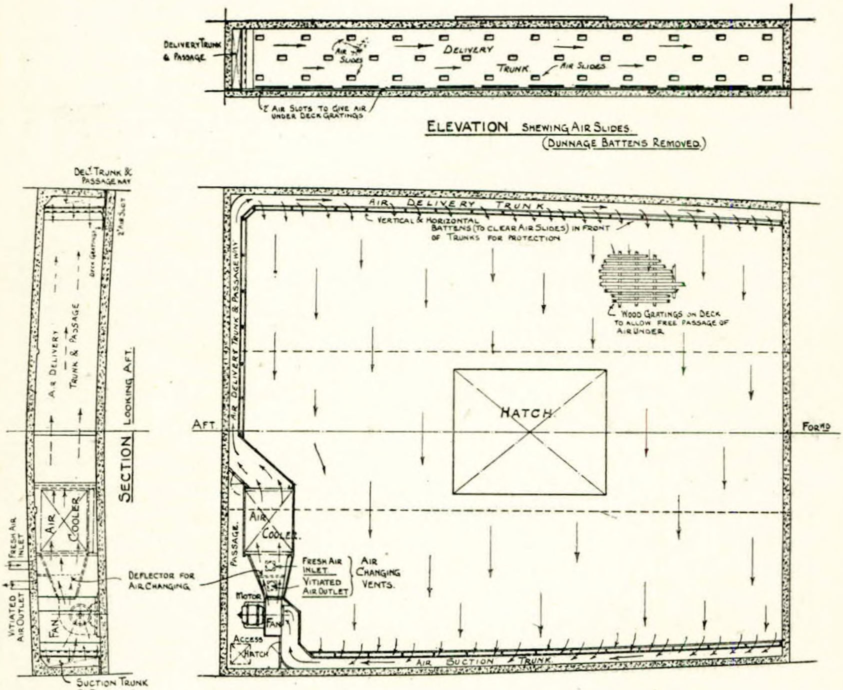
(1) Vertical grids in square pitch across the flow.

(3) Vertical grids in triangular pitch across the flow.

(4) Concentric coils with their axis at right angles to the flow.

It is quite impossible to describe in this paper all the air circulation arrangements which have been successfully used, but a few of them may be briefly mentioned.

Diagram 10 shows a common arrangement, the cooler and fan being housed inside the insulated space, the cooled air being delivered through a delivery trunk and the return air being drawn back through a similar suction trunk. The two trunks run fore and aft on opposite sides of the space with sometimes the addition of occasionl branch trunks to deal with pockets, hatches, etc.

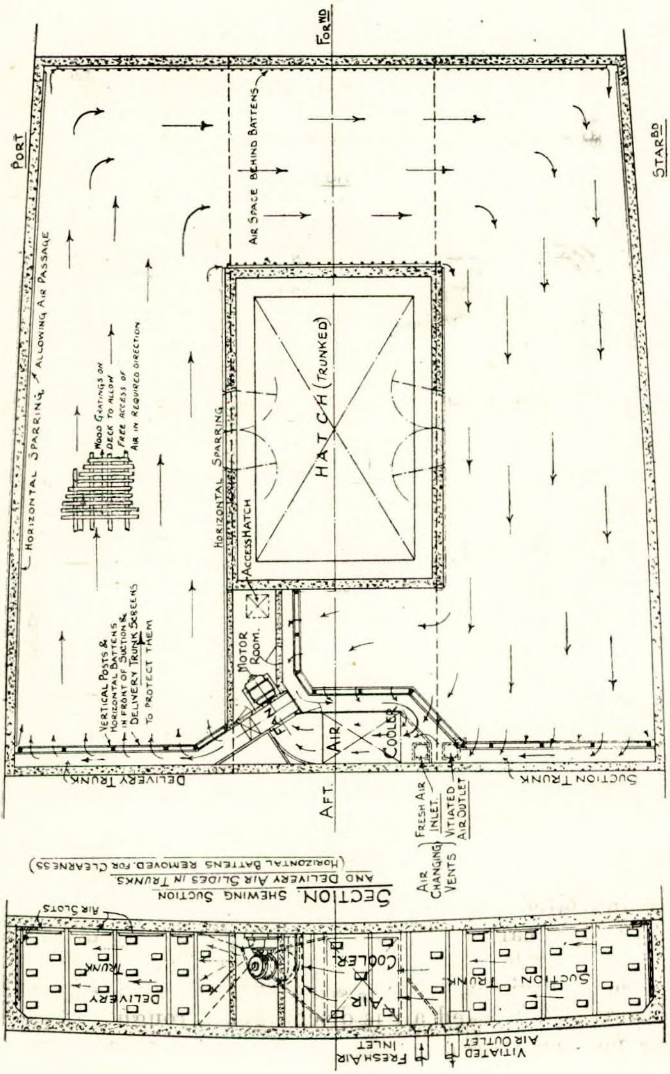


TYPICAL DIAGRAM OF AIR CIRCULATION.

ORDINARY TRUNK SYSTEM.

Diagram 10.

Where an insulated space is provided with a trunked hatch the Gyratory system can be employed, as shown in *Diagram* 11. Here the fan and cooler are fitted in the space and in such a way as to form a division between a bulkhead and the end of the hatch trunk. The cooled air is discharged through a trunk on, say the port side of the cooler bulkhead—passes completely round the space returning to the cooler by a trunk on the starboard side of the cooler bulkhead. In this arrangement there are no air trunks along the sides to break up stowage space.



TYPICAL DIAGRAM OF AIR CIRCULATION.

GYRATORY SYSTEM.

Diagram 11.

When the ordinary side and bulkhead grids form the battery, the shuttering along one side of the ship may form the delivery

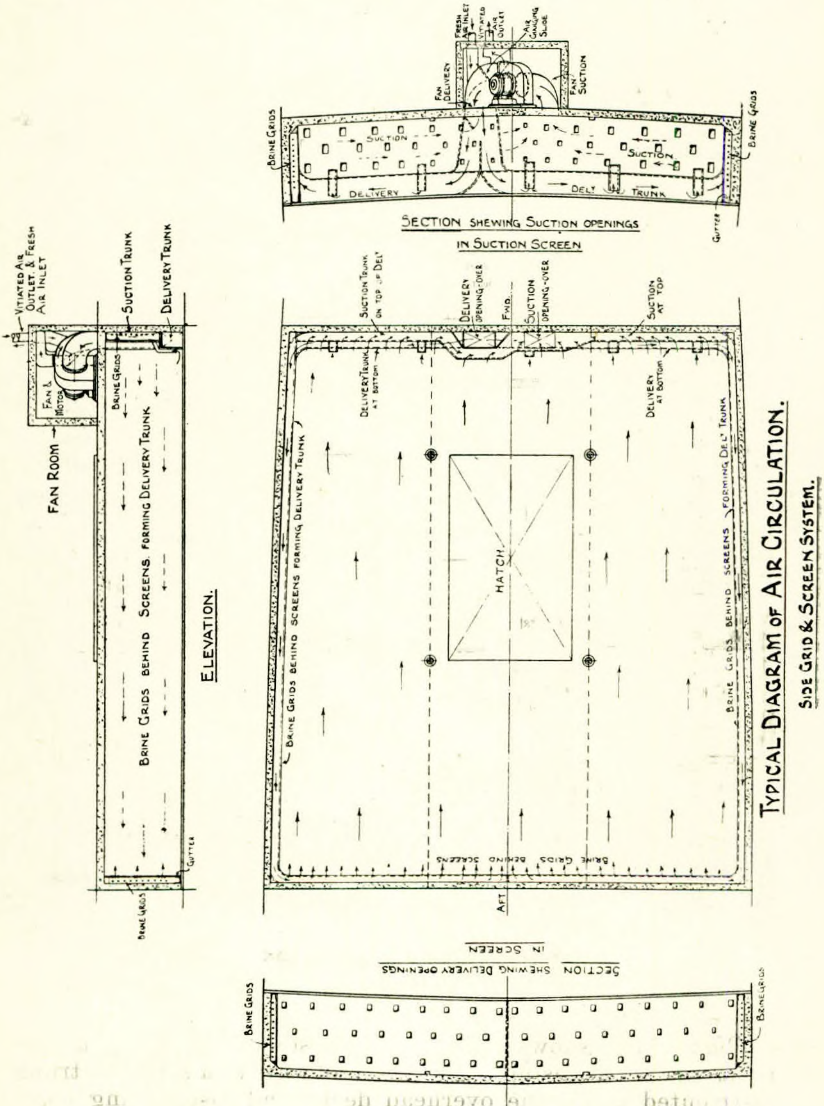
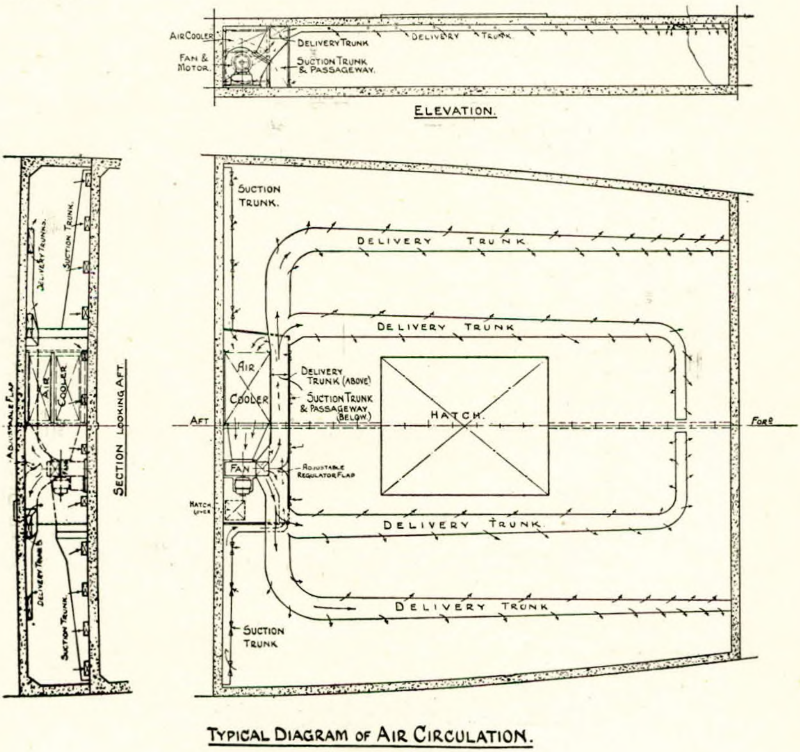


Diagram 12.

trunk, whilst the suction trunk is a similar arrangement on the other side. The air is cooled as it passes over the grids in the trunks, which have slides spaced throughout their length to provide the circulation across the ship.

Diagram 12 shows a variation having the side shuttering without outlet slides—carrying the full quantity of air the full length of the space, discharging from the opposite bulkhead and travelling back to the fan end for recirculating. The air flow is fore and aft, only the bulkhead trunks having air slides.

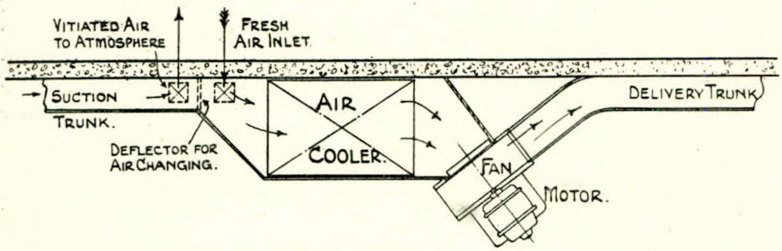


TYPICAL DIAGRAM OF AIR CIRCULATION.

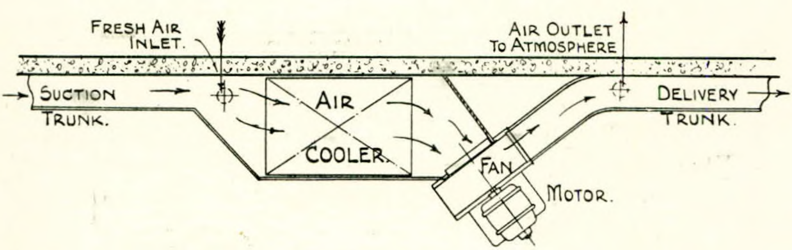
SPRAYING SYSTEM.

Diagram 13.

Diagram 13 shows still another system. This is a battery in an insulated casing, delivering cold air to a series of trunks distributed under the overhead decks and discharging downwards, the suction being taken back through a trunk on the cooler bulkhead. This method is employed chiefly for pre-cooled fruit and embodies to a great extent the "false ceiling" method of cooling which is very extensively used in Australia.



OLD METHOD OF AIR CHANGING.



NEW METHOD OF AIR CHANGING.

METHOD OF AIR CHANGING.—

Diagram 14.

Where forced air circulation is used arrangements are provided for changing the air, that is, the introduction of fresh air to replace the air which has been in circulation for some time. *Diagram* 14 illustrates both the old and the most recent method of carrying this out. In the old method the main suction trunk had connected into it two trunks leading to the atmosphere and between these two trunks a slide was arranged so as to completely divide off the main trunk. When air was being changed fresh air was drawn in on the cooler side and was delivered over the cooler back through the suction trunk, whence it was discharged to atmosphere through the air change outlet trunk. Experience has shown that with this method it is very easy to continue air changing too long (as the air change trunks dealt with a large quantity of air) and this, in some cases, resulted in dampness of cargo.

The later arrangement is to have the air changing trunks connected, one on the main suction trunk and the other on the main delivery trunk. The air changing trunks are comparatively small and when it is desired to use them, the air cooler and fan are operated as for ordinary running except that the air changing trunks are put into communication with the suction and delivery trunks respectively.

Assuming that the fresh air drawn into the suction side is 5% of the total air contained in the space, this small amount will be mixing with the air in circulation through the space and the amount rejected through the air changing discharge trunk will be 5% of the mixture, it follows that by this method the time taken to change the total volume of air in the space is much longer than in the older method and the risk of introducing dampness is correspondingly reduced.

Whichever system of forced circulation is used, there are certain fundamental points to be taken into consideration, the chief of which are:—

(1) The whole of the shaft H.P. taken to drive the fans is transmitted in the form of heat into the space and has to be removed by the refrigerating machine.

(2) Heat leakages through the insulation are great due to the air movement and pressure.

Whether forced air circulation is used or not, the following two points have a great bearing on the problem:—

(1) Fruit generates heat within itself by chemical action and the evolution of CO_2 gas.

(2) Heat is brought into the space by the necessity for introducing fresh air in order to keep down the percentage of CO_2.

The maximum amount of CO_2 permitted is 10%. Good running practice usually provides a content of not more than 8% CO_2.

Cambridge scientists have carried out extensive research work as to the rate of evolution of CO_2 gas by apples and from this has been calculated the heat generation which must accompany the action.

The amount varies with the temperature as shown in *Table* 3:—

TABLE III.

TEMP. OF APPLES. °F.	HEAT GENERATED BY CO_2 EVOLUTION.		
	B.T.U./TON/DAY.	B.T.U./HOUR/TON.	B.T.U/HOUR/ 100,000 FT³.
30	940	39·2	32,000
40	1510	63·0	52,000
50	2070	86·3	71,000
60	3720	155·0	128,000
70	5500	229·5	191,000
80	8250	344·0	285,000

These figures are for an average cargo and as far as at present known apply also to bananas.

For the carriage of fruit relatively high refrigerating power is required because the majority of fruit is not pre-cooled and is loaded at temperatures of 80° to 85° F. In the case of apples, pears, etc., the cargo has to be carried at about 35° F. and it is in the cooling down period that the maximum demand is made. Also shippers ask for this period to be as short as possible.

In order to ensure maximum output from the machine, the cooler must have sufficient surface to bring the brine temperature as close as possible to the air temperature.

As mentioned earlier, the work performed by the machine falls off rapidly as the brine temperature is lowered.

The quantity of air circulated, the shape of the space, the method of stowing are all matters affecting the relative temperatures of cargo, air and brine. Good practice gives an average cargo temperature of about 5° above the average air temperature.

Time does not permit further exploration of these questions but a few general facts illustrating modern practice may be stated.

Diagram 15 illustrates a ship arranged for the carriage of bananas, these are carried in bunches stored in bins, stowage space averages 150 to 160 cubic feet per ton and the usual carrying temperature 55° F. Forced air circulation is always employed. For a cooling range of 80° to 55° in a period of six to seven days about 30 air changes per hour are provided, for cooling through the same range in three to four days the changes are increased to approximately 40. For this trade a relatively high brine temperature can be carried and when the cooling down is completed it is possible to have the brine outlet temperature within 2° or 3° F. of the temperature of the air returning to the cooler.

Apples and similar fruits are usually carried in cases, stowage averaging 130 cubic feet per ton. For a cooling period of about six to seven days, between 30 and 40 air changes per hour are required to reduce the cargo to 35° F. For "maintaining" at this temperature, brine 10° to 12° F., below the air temperature will usually be required. Fans should always have variable speed devices in order to accommodate the changes to the varying demands—the smallest refrigerating demand being the "maintaining" after 35° has been reached.

As opposed to the forced air circulation, there are many who advocate the carriage of fruit by means of brine grids arranged as for meat carriage. One great advantage is that no air trunks are required and this results in saving of space whilst another advantage is derived from there being no fan to produce heat and consequent extra load on the machine. There is no doubt that some of the finest apple cargoes have been carried in grid cooled spaces.

As the carrying temperature of the cargo is in the region of 35° F. the possibility of drip from the grids has to be considered.

The whole of the side and bulkhead grids are utilised, but if all roof grids were in use either the temperature would be brought too low or alternatively the brine temperature would have to be raised so much as to result in drip and consequent cargo damage. Usual practice is to use all the side and bulkhead grids with the addition of one roof circuit. By this means and careful handling, drip is avoided but the brine in the roof circuit must be circulated continuously.

The cooling period with this system (assuming fruit loaded at atmospheric temperature) is much longer than with forced air circulation, and will sometimes be as much as two weeks.

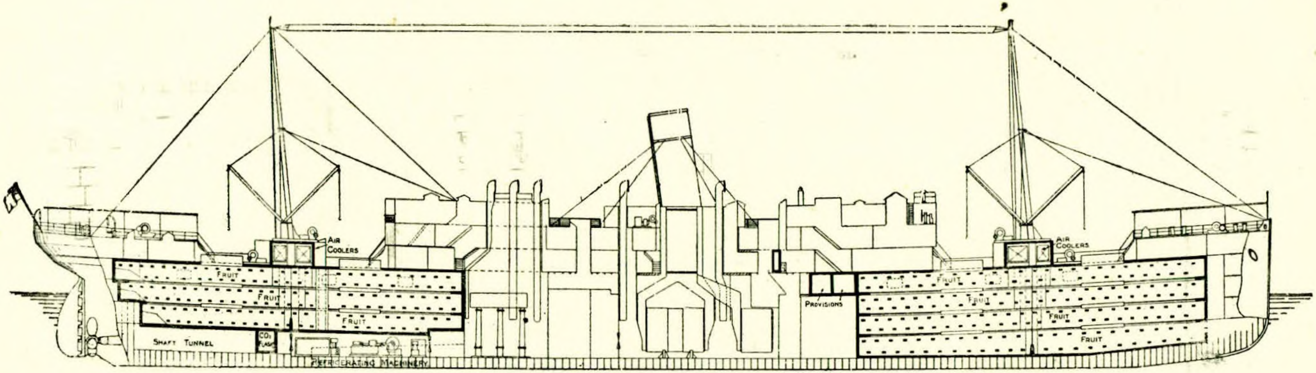


Diagram 15.—Banana Carrier.

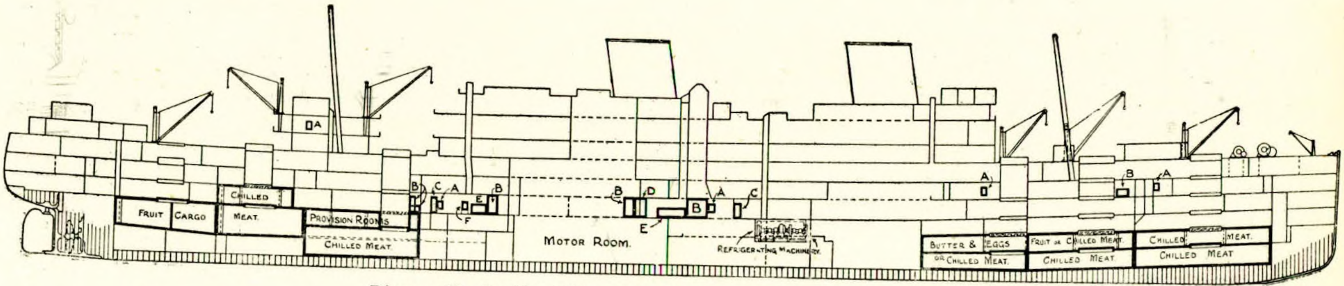


Diagram 16.—Profile of Ship arranged for Mixed Refrigerated Cargo

It must not be assumed from this paper that a ship can only carry one kind of refrigerated cargo at one time. A very large number of vessels carry mixed cargoes such as meat, butter, bacon, fruit, etc. A typical arrangement being shown on *Diagram* 16. Such cargoes are dealt with by a combination of the systems described, no special arrangements being necessary.

The final *Class* (*d*)—Naval and other special types—can only be very briefly referred to. Practically all surface naval ships are fitted with refrigerating plants both for cooling the magazines and for keeping the required temperatures in the small provision rooms.

On the larger vessels there are usually several complete refrigerating plants, each plant being housed in the vicinity of a set of magazines and all being cross-connected so that any one can take over the duty in another part of the ship should the necessity arise.

A simple form of the closed system is invariably used, the brine being cooled in an insulated submerged type evaporator and circulated through the various magazine air coolers and the grids in the provision chambers.

The magazines are always air cooled, a special type of cooler resembling the ordinary surface condenser being employed. The cold brine is circulated through a series of tubes carried in tube plates whilst the air is circulated outside these tubes through the cooler casing.

In the case of submarines the arrangement is somewhat different. No brine is used, all the cooling being carried out by means of direct expansion grids or air cooler coils. The condensers used are of the double pipe type, they are made of copper and are housed in the superstructure so that they are completely drowned when the boat is submerged.

When refrigeration is employed in connection with the battery rooms the cooled air is passed over the top of the batteries which are cemented in, the cooling being obtained through holes left in the tops of the various compartments. In other instances the batteries are contained in separate rooms through which the cold air is passed. The latter method is more effective as there is a much greater surface exposed for cooling. The air used for battery cooling is not recirculated owing to the hydrogen given off by the batteries being mixed with it. For ventilation purposes a drum type air cooler is used, and the air in this case can be recirculated.

Amongst the other uses for refrigeration on ships, the chief is probably the carriage of fish. Many methods of carrying and transporting fish have been tried, but for ordinary purposes nothing has been found better than using boxes which contain fish packed in ice, the boxes being stowed on a special arrangement of shelves inside an insulated hold, as shown on *Diagram* 17. This hold is cooled by brine circulation through grids in an exactly similar manner to that used for meat carriage.

The stowage space required for this method of transport is approximately 100 cubic feet ton.

In quite recent times ships have been fitted with plants which incorporate the quick freezing and glazing systems. When this method is used, two sets of evaporators and tanks are required, one set working with ordinary calcium brine, which is cooled and circulated through brine grids for cooling the spaces in which the fish is stored both for transport and for holding until such time as the market warrants its release. The other set of evaporators and tanks use sodium chloride brine, which is reduced to a temperature below 0° F. and into which the fish is plunged immediately after it has been caught and cleaned. After this process the fish is removed to the glazing tanks and from there to the ordinary frozen holds or 'tween decks.

The temperatures recommended for the carriage of the principal classes of provisions are given in *Table* 4.

TABLE IV.

TEMPERATURES RECOMMENDED FOR CARRIAGE OF PROVISIONS.

Fruits...	34° to 40°F.
Vegetables	33° ,, 38°F.
Chilled Meat	29° ,, 30°F.
Frozen Meat	16° ,, 24°F.
Frozen Poultry	18° ,, 24°F.
Frozen Fish	10° ,, 20°F.
Butter	10° ,, 20°F.
Cheese	36° ,, 40°F.
Eggs	32° ,, 35°F.
Tinned Goods (Meats and Fruits)	36° ,, 40°F.
Beers, Wines, etc.	40° ,, 45°F.
Milk may be frozen in cans	18° ,, 24°F.

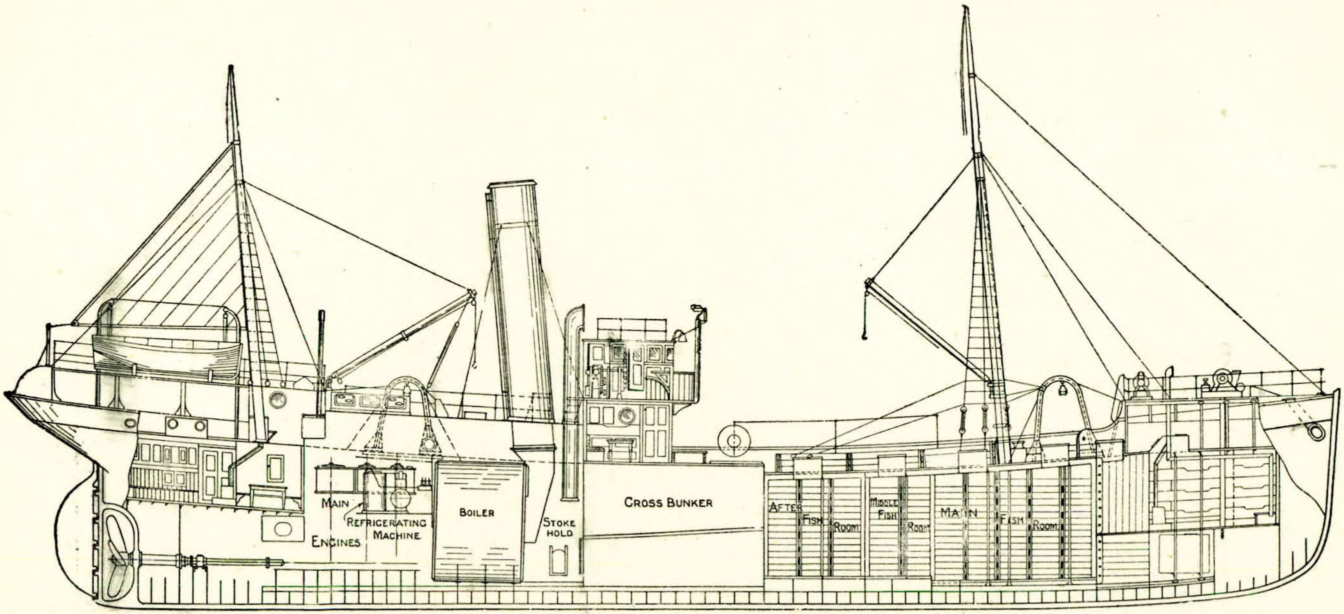


Diagram 17.—Profile of Refrigerated Trawler.

In conclusion I have to thank Messrs. Haslam, Messrs. Liverpool Refrigeration Company, Messrs. J. and E. Hall and Messrs. Seagers, for their kindness in lending me the slides which it is hoped have served to illustrate modern design and practice.

DISCUSSION.

The CHAIRMAN: The paper is now open for discussion. Before inviting other remarks, I should like to read a telegram which the Author has just received from Mr. George Adams, one of our Vice-Presidents who, I know, is keenly interested in this subject. His message is as follows: "Have just read advance copy of your paper, which is excellent and comprehensive. On galley page six you remark on possible vibration on motor ship and movement of deck plating. I fear you are on thin ice, and cannot be supported as to this. Sorry not able to be present."

I will now ask Mr. Gemmell to give us his views.

Mr. D. GEMMELL: Mr. Greenfield has told us that meat was first successfully imported by means of refrigeration in the year 1880. As a great part of his paper deals with systems suitable for the carriage of fruit, I think it may be of interest to mention that the first cargo of fruit was brought to this country from the West Indies under refrigeration in the S.S. *Nonpareil* in 1886. The S.S. *Oceana* brought apples from Australia in 1888, both cargoes being successful. Greater progress has been made in the carriage of meat than of fruit, but of course fruit carrying is a much more difficult problem, as fruit is a living organism which develops heat during the process of maturing, which process continues, although retarded, when cooled to a safe minimum temperature.

The Author states that the speeds of refrigerating machines vary from about 80 r.p.m. for the large horizontal machines to 500 r.p.m. in the case of the modern high-speed vertical multi-cylinder machine. I hope he does not mean that the slow-speed horizontal machine is not considered modern. Some of the recent installations with horizontal machines coupled direct to electric motors, and the latest arrangement of all, those coupled to oil engines, are in every sense modern. However, I am glad to see that a number of vessels at the present time are being equipped with comparatively high-speed, multi-cylinder machines. These machines have two or three single-acting compressors mounted on an enclosed crankcase with forced lubrication throughout, and are driven by electric motors coupled directly to them. These machines are being used for large installations, several units being employed, and the space occupied by them is small compared to the old steam-driven type. This I think is a great advance over the very long tandem steam-driven machines, which often give much trouble from mal-alignment, owing to the flexibility of the deck upon which they are situated.

Some seem to think that the high speed machines must necessarily cause troublesome vibration throughout the ship's structure, but, so far as I know, this has not been the case. I would like to have Mr. Greenfield's observations on this point.

The Author gives the various types of condensers used in general refrigeration, and he states that the double pipe type is sometimes fitted. Does he know of any vessels trading to the River Plate which have these condensers, and does he know if any special trouble has been encountered through the water tubes becoming choked with mud deposits?

I have seen condenser coils, after some years' service, one solid mass of hardened mud, which had to be punched out from between the coils, through which there could have been no circulation whatever. This is a serious matter for the shipowner, as it reduces the efficiency of the machine to a very great extent. Much more efficient means of sludging out condensers could be devised than those usually provided.

Referring to evaporators, it would be interesting if Mr. Greenfield could give us any results of tests taken from the individual coils of an evaporator to ascertain the comparative cooling effect of each. The only means of judging whether the coils are all doing work is by noting the frost on the terminals. This is a poor indication of what may be taking place in the evaporator, and I think, if thermometers were fitted in the suction terminals of each coil, and each coil could be regulated separately so as to give uniform results, much economy could be effected, and the shipowner would be repaid for the additional expenditure.

The Author states that silicate cotton is very seldom used on vessels now. That is so for general insulating purposes, but it is still used for bunker bulkheads adjoining insulated chambers.

Referring to insulation, cork in slab form is a better insulation than granulated cork, provided it is fitted and anchored to the ship's structure in a proper manner. If it is not anchored properly, the layers bulge and leave cavities between them, reducing the efficiency of the insulation and harbouring odours which may taint certain kinds of produce. It is, of course, a somewhat costly type of insulation to fit on a ship, but for cold store work on shore it is almost universally used.

The Author refers to the joints in brine leads which should be grouped.

The grouping of leads has, in some cases, led to very expensive repairs, where leads passing from the engine room to the forward and after holds are grouped, in some cases seven or eight pipes deep, from the ship's side. When leakage takes place in one or other of the leads nearest the ship's side, access to them can only be obtained by removing a large number of leads from the front of them.

Where this massed grouping is necessary, the leads should always be galvanized, and I think some arrangement might be devised whereby these lengths might be made more easily portable, and so reduce the time occupied in carrying out these repairs.

I agree that it would be ideal if all brine pipe joints could be welded, and so abolish the screwed socket joints, but I do not think this will be satisfactorily accomplished until a portable electric resistance welding machine can be devised for use on board ship. But, would it be advisable to weld all brine pipe joints? If part of a circuit became choked, it would be necessary to cut the pipe and rejoint by some other method.

The Author refers to the extensive scientific research from which the heat generated by fruit has been calculated, and he gives a table of values for various temperatures. Other figures quoted by scientists who have been engaged on this work over a long period are very widely different from those given in this table.

The estimation of the quantity of heat generated by fruit during the ripening process, which continues after the fruit is loaded, and is only gradually diminished as it is cooled down over a period of some days, is more or less a matter of guess work, and consequently refrigerating machinery of a very large capacity is installed to deal with this initial peak load. Owing to the lack of reliable information regarding the quantity of heat to be eliminated, the refrigerating machinery when designed for fruit carrying vessels is probably in many cases much larger than is necessary to meet the full demand.

However, I would mention, in this connection, that very valuable work is being done at the National Physical Laboratory, and I have no doubt that, in the near future, information will be available which will materially help in the solving of these problems.

Mr. H. BRIER: I wish to endorse Mr. Gemmell's remarks regarding the paper; Mr. Greenfield has given us a very complete description of what has taken place for refrigeration on board vessels, and must have put a great amount of work into preparing it.

I will only criticise one point and will deal with the remarks touching what is known as Liquid Cooling or Multiple Effect Cycle, as the information which the Author gives is, I consider, not complete or up-to-date.

It is not sufficient to say that Multiple Effect Compression has advantages when high temperature cooling water is met with, for it has also great advantages with cold circulating water.

The Author declares that it takes more power; this is only to a certain extent true, and is most misleading, as I will show later.

I would first explain that the full title of the cycle as we apply it would be "Pre-cooling by Primary Evaporation with Multiple Effect Compression and Automatic Regulation."

It was in 1890 Pre-cooling was first introduced by Linde and Lightfoot for ammonia for the cooling of the liquid refrigerant after leaving the condenser before entering the evaporator, and in 1901 Windhausen patented the same process for CO_2. Neither of these inventors dealt with Multiple Effect Compression; they endeavoured to handle the two evaporations in two compressor cylinders or in both ends of one cylinder, but were unsuccessful owing to inefficient regulation and lack of a suitable Primary Evaporator.

Professor Gardner T. Voorhees in 1905 introduced and patented Multiple Effect Compression. Briefly, this consisted of taking two or more charges at different pressures, one on top of the other, into the same end or both ends of the same cylinder. Voorhees made no claim for Pre-cooling, but his compressor was naturally suitable and proved to be the best for that purpose, and was able to do twice as much work as any of the others.

Another improvement in handling the two evaporations was the invention of an automatic regulator by Sir Wilfrid Stokes in 1912 of the sleeve valve type, and by the writer in 1918, when the float and safety valve type of regulator was introduced.

The following remarks will perhaps be appreciated by those who are not fully acquainted with this cycle.

The modern type of Voorhees compressor arranged for this cycle at first draws a charge from the main evaporator, is then at the end of its stroke super-charged by gas from the Primary Evaporator, and compresses the combined charge into the condenser. The CO_2 enters the Primary Evaporator through a spring control valve or regulator, which maintains constant pressure between the condenser and the Primary Evaporator. Partial evaporation cools the gas to liquefaction, and the liquid controls its own expansion into the evaporator, assisted by pressure variation. The gas evaporated in the Primary Evaporator returns to the compressor as a second charge.

This combination of regulations will maintain steady conditions even against speed variation, which will be found of great value, and is the only addition to which the Author can refer to as a complication.

By application of these automatic regulators, 18 to 20 per cent. may be added to the refrigerating output of ordinary compression machines, in addition to what can be gained by multiple effect compression.

It will perhaps be interesting to the Author to learn that the customer who reverted to ordinary compression, because he could not obtain a multiple effect compression machine from stock, lost no time in having automatic regulation fitted to the ordinary compression machine he was obliged to purchase, for he knew it saved a man's time.

To emphasize the fact that these machines are an advantage in this country for moderate temperatures, I would point out that we are building and altering machinery for cooling beer, and can guarantee to alter any ordinary compression machine of our own or any make to cool 50% more beer to 30 or 32°F., with an expenditure of only 38 to 39% more H.P., and very often for less, knowing perfectly well that under ordinary conditions, we would be able to cool 64 to 70% more beer with 37% more H.P. From this it would appear that the economy is on the side of the multiple effect compression machine.

From 1912 we have ceased making ordinary compression machinery and have confined ourselves entirely to multiple effect compression, and in every case we have proved the correctness of the figures which were given by the late Sir Wilfrid Stokes and Professor Gardner T. Voorhees in their papers about 1912, and I would give as well known examples the alteration of a refrigerating machine on S.S. *Telemon*, when the working hours, according to the owners' engineer's report, were reduced from 22½ hours to 9¾ hours per day. These figures are borne out again by the experiments we ourselves made in 1912, and a more recent trial of altered machinery on S.S. *Elizabethville*; a study of this four days' trial will show that one altered machine was able to do as much in 12 machine hours as the two unaltered machines in 30 machine hours per day, with a direct saving in H.P. of 37·79%, or a saving in H.P. hours of 48½%, the running hours being 126 for the ordinary compression machines, whilst the altered machine took only 52, temperatures of sea water ranging from 60 to 84 and 85°F., brine being kept about zero. These logs show exactly that although the machine itself, compared singly, took about 24½% more H.P., when compared with the two machines was economizing 48½%.

It cannot, therefore, be truly said that multiple effect compression takes more power when compared with the amount of work done.

I might say that application of an automatic regulator to any machine which had previously been fitted with a fixed regulator would more than pay for itself in a few months in actual work done, not counting the cost and the attention necessary to keep a machine with fixed regulator up to its work; anybody who has made these experiments would never again make use of a fixed regulator.

I can show the full log and report of the four days' trial of the machine which was altered on S.S. *Elizabethville*, and would add that since this trial was made, the second machine has been altered, and the two machines on the sister vessel, with equal results.

Mr. J. R. Douglas: To-night we have heard a most interesting paper to a modern engineer on a subject about which he is often expected to know as much as he does of the main machinery, and in this particular section of the merchant marine this branch is just as important as the propelling machinery, for no matter how economically and well he can run his main department, if his refrigerating section is not equally efficient, his owners are faced with a very serious liability, and those responsible are due for a rather rough time.

I am referring to those who are engaged in the carriage of refrigerated cargoes, whether it be chilled or frozen produce from China, Madagascar, New Zealand, Australia, South or North America, or the uttermost parts of the earth, and to a branch of engineering which I feel is not sufficiently recognised in view of its responsibility and immense value to the British Empire.

Mr. Greenfield has given us a most interesting outline of the plant required, but I am sure many of those present, and the writer, were hoping to hear from him a few secrets of how to detect various faults and their remedies in relation to NH_3 and CO_2.

Most of our young members, for whom papers of this class are especially written, would like to know " How can I tell when I have air in my system, whether this be NH_3 or CO_2, and how to get rid of it, and if water gets into the system, how can I get rid of it, and what method should I use. How to detect leaks, the cause of freezing back in compressors, the danger of carrying brine too weak in a piped system; how can I verify that the plant is charged, if the gauges give out; especially with CO_2 machines which are now installed in the majority of modern steamers. ? "

Then there are the interesting problems of multiple effect which Mr. Greenfield mentions, and which is now coming much to the fore in marine practice, namely, to increase the capacity of existing plant, it being the Büchi system of the refrigerating world; can he give us his opinion of the advantages of this thus ?

Another point the marine engineer is often asked: " What is the refrigerating capacity of your machine ? " Can you recommend a simple rule of thumb which can be memorised for future use ?

Now you probably wonder why a man of my age asks such simple questions, but there was a time when none of us knew these things, and I remember how difficult it was to get this knowledge when I made my first voyage in 1894, carrying chilled beef across the North Atlantic. There are many in the same position to-day.

With regard to insulation, I think the most important thing is to see that this is kept well packed and dry. After 34 years' experience, I still say that wood facing is the best, and preferably in the panel form. There are many cement faced types on the market, but they do not stand up as well as the timber. I think the younger members would like to know what ratio Mr. Greenfield considers the lineal length of piping should bear to the cubic capacity for chilled or frozen cargo. I would also warn the younger or inexperienced members against the careless handling of ammonia; for, if a very small amount of liquid be present in a valve or machine, there is a great danger of a bad accident, as when the pressure is removed, the liquid evaporates and I have seen a gland sent flying across the engine room with sufficient force to have killed anyone in the way.

Now, as regards the carriage of chilled cargoes, such as fruit, I do not agree with the Author; I consider overhead circuits better than side grids, because the circulation is better; further, there is less liability of getting damaged cargo, due to chilling through the cases coming into contact with brine pipes, also there is less stowage space lost, which is a big factor.

The most successful cargoes come home in battery air-cooled ships. This is the only satisfactory method for the carriage of bananas, although experiments have been tried with brine piped spaces and found reasonably successful, but when carrying fruit as well as other cargoes, it is unwise to dogmatise, as the unknown factors are too many and each case must be judged on its own merits.

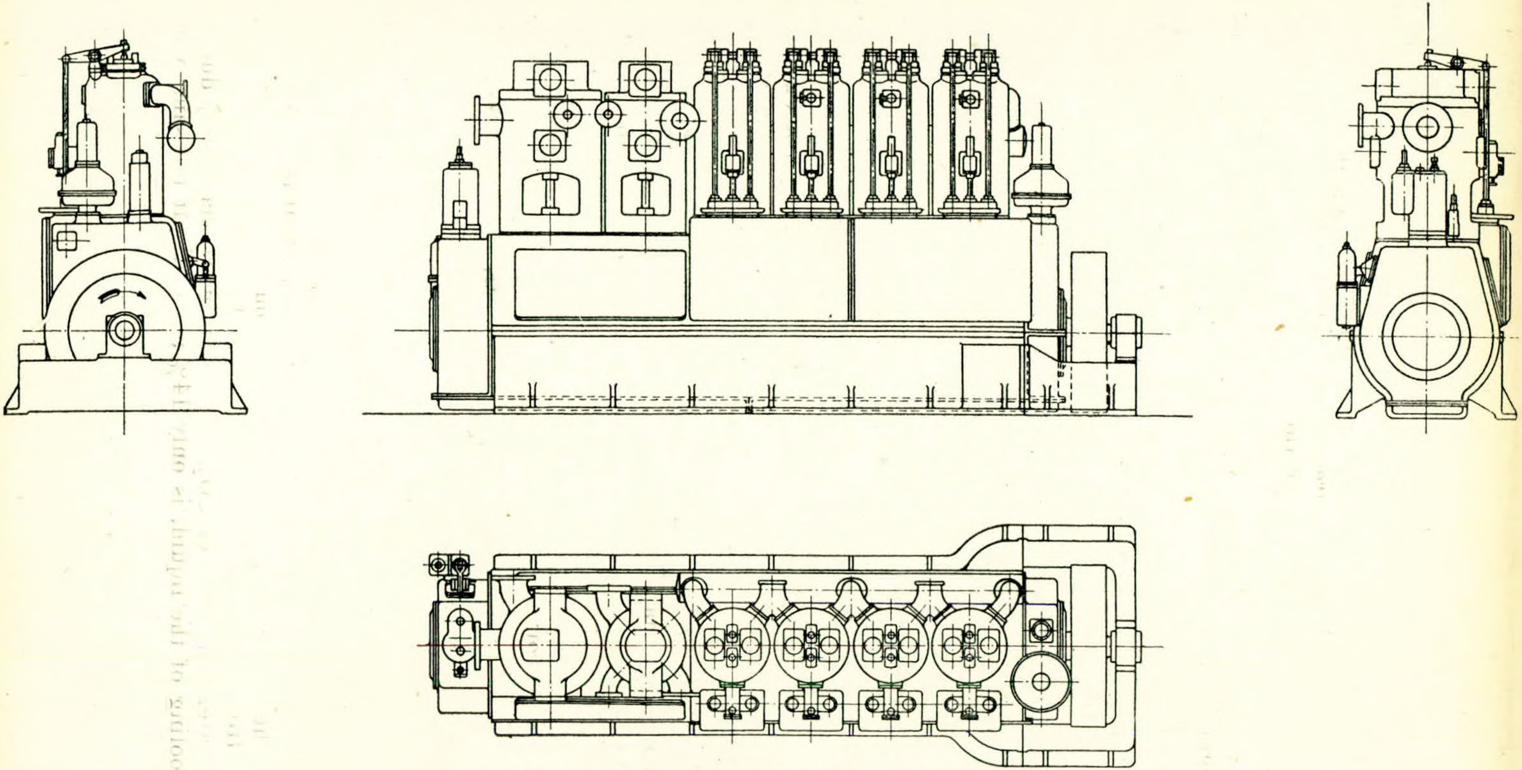
In 1900 we carried bananas home from the West Indies in the Imperial West India Mail Steamers, at a time when I happened to be Chief Refrigerating Engineer, with a certain amount of success. The temperature we then aimed at was 45°F.; since then, however, our successors have found it better to carry at a higher temperature.

There is one common point on which I think we all agree; that is the removal of the CO_2 gases, as these are found to hasten ripening. This gas can be removed by fitting small fans in the pipe system, which can either draw or deliver fresh air to the spaces being used, excess air being allowed to escape by means of trunks, or through the thermometer tube pipes to the atmosphere.

I trust that the lecturer will accept my thanks for his well-developed paper, in preparing which I feel sure he has spent much thought and possibly many sleepless nights.

Mr. J. Calderwood, M.Sc.: It seems to me that the Author has been rather unfair to the NH_3 machine, in that he has pointed out all its disadvantages, and has only mentioned the advantages of the CO_2 plant. If the pros and cons of the question are considered in detail, I think that there is a good deal to be said for the adoption of the NH_3 and this is shown by its increasing popularity in the marine field.

Marine refrigerator manufacturers have been very slow to adopt the direct Diesel driven compressor, although plant of that type has recently been put into operation. In view of the fact that almost every ship built recently for frozen or chilled cargo has been propelled by Diesel machinery, there seems to be plenty of scope for direct Diesel driven refrigerator plant. In such ships the adoption of electrically driven compressors has made it necessary to fit much larger generator sets than would otherwise be required, with a consequently high first cost. With the Diesel drive, you cut out something of the first cost and also the losses in transmission efficiency. Further, you have the advantage that the generators can be designed to carry the normal load, and have not to be running on a widely varying load on the outward and homeward voyages, The problem of direct Diesel engine drive is rather a question for a company having special experience of both Diesel engines and refrigerator plant. To illustrate my remarks I have a slide here, which, however, there is not time to show now, but I will send a copy of it for inclusion in the printed report of the discussion. This shows a Diesel engine and NH_3 compressor, designed as a single perfectly balanced unit. There is no doubt that Diesel driven machines will be much less liable to give rise to vibration than the ordinary electrically driven plant, as the engine and compressor can be designed to give absolutely perfect balance. That brings me to the chief criticism of the paper, which Mr. Adams' telegram raised. That is, the question of vibration with reference to the Diesel engine. I do not think there is any reason whatever why the Diesel-engined ship should suffer from more vibration than a steam ship. If it does, it is a matter of bad design on the part of shipbuilders or the engineers. I have never come across a case of bad ship vibration arising from the main Diesel machinery, with any of the types of engine of which I have had experience. I have come across instances of vibration from auxiliary Diesel machinery and from propellers, and these have occurred without reference to the type of propelling machinery, one of the worst I have known being a ship fitted with turbines.



Sulzer Diesel-driven Refrigerator Plant of unit construction.

Mr. W. McLaren: With regard to insulation, I am surprised to note the Author's figures for the insulating properties of slag wool. They suggest a question as to what should be the thickness of cork to be used, as compared with slag wool. That is a question for the designer rather than the shipowner. With regard to grids, should anything go wrong with these while under way, how would you get at them? And what allowance is provided for moving the cargo in such circumstances? Would it have to go overboard?

In the case of forced air circulation, and considering the space taken up by the ducts in the air chamber, what would be the difference in that space if you had to carry grids? I am known as an advocate of the CO_2 system, and having been associated on shore with NH_3 plants, I must say I would not like always to wear a helmet!

The small machines for retail provision work described in one of the Author's slides are proving a great success, as I can confirm from personal observation.

Mr. R. H. Mackillican: It is stated in the paper that Table 1 shows a comparison of the chief properties of these agents; i.e., CO_2 ; NH_3 ; SO_2. The table gives absolute pressures corresponding to various temperatures, for saturated state, and specific volumes. No mention is made of *latent heat* nor *specific heat of the liquid*, both of which are important factors, as is shown in what follows, and the statement "other thermodynamical properties being equal" is wrong in its implication.

Assuming the temperature of the liquid leaving the condenser to be 86°F., and an evaporator temperature of 14°F., the heat carried through as the liquid passes into evaporator is equal to (specific heat) × (86 – 14). This amounts to

54·5 B.T.U.'s in the case of CO_2
79·5 ,, ,, ,, NH_3
and 23·2 ,, ,, ,, SO_2

*See footnote.

The latent heat of CO_2 being 114 B.T.U.'s per lb. at the lower temperature, it is seen that the loss of cooling effect on the brine, due to this cause, is nearly 50%; that is, nearly 50% of the heat of evaporation is drawn from the liquid CO_2 instead of from the brine. The latent heat of ammonia is very much greater than that of CO_2, and the proportionate loss, due to cooling of the liquid, is only 14%; it is about the same with

* Figures quoted from W. Inchley's "Theory of Heat Engines."

SO_2. The action is similar to that which occurs when water is released from a boiler under pressure. Rapid evaporation takes place due to the surplus heat in the water, this heat being utilized in converting part of the water into steam.

The Author states that the compression is theoretically adiabatic. I suggest this might well be modified by pointing out that, in the case of high speed machines, adiabatic compression is more closely approached than in a slow speed compressor, adiabatic compression implying that no heat passes through cylinder walls or piston. To obtain adiabatic compression, high speed and efficient lagging would be necessary.

The usual explanation as to why a CO_2 machine continues to work effectively in the hottest climates—I have known one to work well when the sea temperature was 95°F.—is not very satisfying. Are we to assume that the critical temperature of CO_2 in bulk is more than 7° above that found in laboratory tests? Possibly Messrs. Hall or others have investigated this matter, and an explanation would, I think, be of interest to many members of the Institute.

If, under such conditions, the gas does not liquefy at all, the cycle of operation must be similar to that of the cold air system and one would not expect effective refrigeration.

I would like to relate an experience I had with an ammonia plant. The ship carried Linde compound compressors in the main engine room. On the occasion referred to, a serious leakage developed in the suction pipe, which pipe passed underneath the store-room deck. One of the men donned a helmet and, taking an oil lamp with him, climbed up to investigate and tighten flanges if necessary. He came down again very quickly, for the gas immediately ignited, burning with a yellowish flame. We started one of the machines working—they were idle at the time—and, keeping the regulator shut, drew the gas from the pipe.

I thank the Author for a most interesting and instructive paper, a valuable addition to the work of the Institute.

Mr. T. A. Bennett (By Correspondence): I should like to congratulate Mr. Greenfield on his excellent and exhaustive paper, but it is regrettable that any paper should be so long as to curtail useful discussion.

In reading through the paper, one thing I noticed was the large number of different scales engineers have to be conversant with to measure the same thing; I refer to the density of liquids. The density of the water in the boilers is measured in 30 seconds, the density of the sea water in ounces per cubic foot, the density of oils in Beaumé; then there is specific gravity, and the density of the brine is always measured in Twaddell degrees. I know that many engineers think that this latter scale gives ounces per gallon, but this is not correct; to obtain the ounces of calcium chloride per gallon of water we must multiply the Twaddell density by 0·8; e.g., 50° Twaddell equals 40 ozs. per gallon.

I am sorry the author did not say more about liquid cooling. Without going into details, he could have stated how the economy was to be effected. In cooling the liquid in a separate vessel by evaporation, the heat taken from the liquid must be absorbed by the gas and work must be done on this gas in the compressor. Without a liquid cooler this evaporation and cooling takes place in the evaporator coils, and the gas produced has still to be compressed, so we cannot lose anything by fitting a liquid cooler. It appears to me—and I should like the author to correct me if I am wrong—that the gain of economy by using a liquid cooler is that the cooling effect is produced with the coefficient of performance of the machine; that is, if the coefficient of performance is 5, and say 20 B.T.U. were taken from the liquid, then the work required to recompress the gas produced would be equivalent to only 4 B.T.U.

I do not agree with the author in first stating that if the temperature of the brine is lower than necessary the efficiency is reduced, and then giving an example that if 1,000,000 B.T.U. were extracted at 20°F., only 630,000 B.T.U. would be extracted at −50°F. He can only have it one way, because it is obvious that by increasing the speed of the machine he would extract more heat, and it may be necessary to lower the temperature quickly. It is still worthy of note that to run with a low brine temperature for long periods is very uneconomical.

Few engineers understand the cycle of a CO_2 machine when the sea temperature rises above the critical temperature of the carbon dioxide, and I think a few remarks on this would not be out of place. The pressure in the condenser would be over 1200 lbs. per square inch, and the CO_2, although not a liquid, would differ considerably from a perfect gas. In a perfect gas, throttling produces no change of temperature, but when this CO_2 is throttled through the regulating valve, the temperature falls as well as the pressure. When the critical temperature is reached, the carbon dioxide becomes a liquid without the evolution of heat, as the latent heat at the critical temperature is zero. Some of the liquid evaporates and cools the remainder of the liquid below the temperature of the brine. Evaporation and extraction of heat from the brine proceeds as in the ordinary cycle. A coefficient of performance of 3 may be obtained with this cycle.

Mr. E. F. SPANNER (By correspondence): I think the Institute of Marine Engineers is to be congratulated on having from Mr. Greenfield such an extremely comprehensive paper of particular interest to everyone concerned with the building and equipping of vessels to carry refrigerated cargo, or with the equipping of vessels in which large quantities of provisions for passengers and crew have to be carried in cold chambers.

Personally, I have not come across any other exposition of this particular subject which conveys so much information in so condensed and concise a form.

There is one point in which, as a naval architect, I am particularly interested, and that has to do with the formation of the chambers and the lining of the chambers required to be cooled. The problem is quite easy where large volumes require to be made available for refrigerated cargo, as, in general, these spaces are not subject to continuous traffic.

In connection, however, with meat and vegetable rooms for instance, in a passenger ship, some little difficulty has been experienced in the past with regard to the arrangements made for providing a non-conducting, watertight, and durable floor covering. Having been connected with the very early applications of asphalt as deck coverings on board ships, I have been particularly interested in watching the great extent to which this material has gained favour, and I think those concerned with the particular subject of the Author's paper may be interested to see the attached drawing, which illustrates what is now an approved (provisionally protected) system for utilising the well-known hard wearing and water-proof qualities of asphaltic compounds for the floorings of small refrigerated chambers, and also brine rooms.

One great difficulty with small chambers, of course, is the great amount of wear which takes place on the floor, and which results in lead lining being rapidly ruined. The simple application of asphaltic material to the floor, even when it is well filleted around the edges, does not fully meet the case of providing an intact watertight tray capable of "giving" to a certain extent with possible movements of the structure.

The particular arrangement shown in the drawing was worked in conjunction with a well known slab-cork insulation system, but the same principles hold good if wood matching or any other background is present. It has been developed by a marine

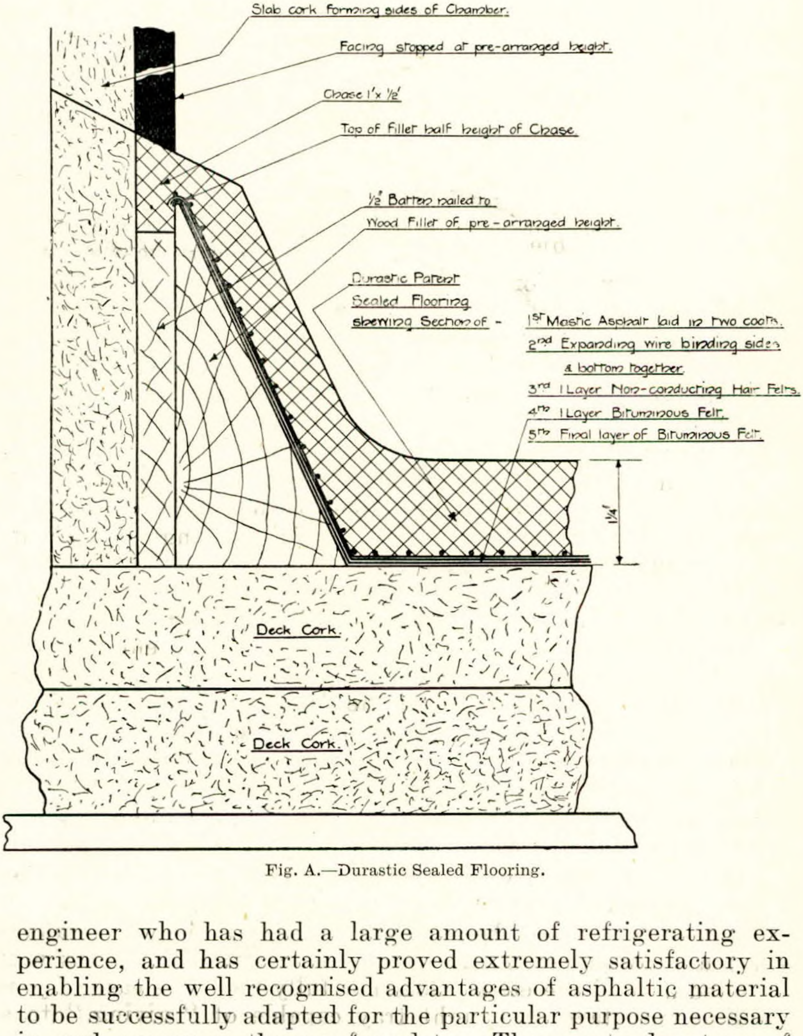


Fig. A.—Durastic Sealed Flooring.

engineer who has had a large amount of refrigerating experience, and has certainly proved extremely satisfactory in enabling the well recognised advantages of asphaltic material to be successfully adapted for the particular purpose necessary in such spaces as those referred to. The great advantage of the system illustrated, which is termed Durastic "Sealed" flooring, lies in the fact that the cornering provided is well-anchored and elastic.

A further advantage is that in the unlikely event of a crack developing in the asphalt, moisture is prevented from finding its way through to the valuable insulation underneath, owing to the provision made by the various felts which have been amalgamated by the action of the heat from the asphalt.

Mr. F. D. Moul, B.Sc., A.C.G.I., (By Correspondence): As mentioned by my colleague, Mr. Calderwood, the Author has been rather unfair to the ammonia machine, as he has mentioned nearly all its disadvantages, as compared with the CO_2 machine, without referring to any of its advantages.

The prejudice, for prejudice it is to a very large extent, against the NH_3 machine, seems to date from the early days, when direct expansion was used for cooling the cargo spaces. In those days, refrigerating machinery was not so highly developed as at present, and leaks were practically unavoidable. The result was that shippers found that their cargo was often tainted when carried in boats fitted with NH_3 plant, whereas where CO_2 plant was used, this tainting was not noticeable. The consequence was that shippers quite rightly gave their preference to boats fitted with CO_2 equipment. With modern plant, however, there is no longer any reason for this, as in the first place leaks are of comparatively rare occurrence in a well-designed plant, and secondly, such leaks are confined to the machinery space, as cargo spaces are now almost invariably cooled by brine circulation.

The Author mentions the time honoured argument that, owing to the lower specific volume of CO_2, the compressor is much smaller than an NH_3 machine of the same output. This is undoubtedly true of the actual cylinder, or rather of the piston displacement, but owing to the far higher pressures to be dealt with, and the increased power input required with a CO_2 machine, the actual unit is little, if any, smaller, and enables scarcely any floor space to be saved. And this brings me to two very important points to which the Author did not refer, namely, weight and power consumption.

In the CO_2 machine the working pressure, with cooling water at 85°F., is some 6½ times that encountered in NH_3 plant under the same conditions. The result is that the CO_2 machine must of necessity be of far heavier construction than the NH_3 plant.

The power input to an NH_3 compressor is little more than half that required for a CO_2 machine of the same capacity working under the same conditions. This represents a very considerable reduction in the fuel bill of boats operating in tropical regions. As an instance of this it is interesting to note that the Diesel compressor unit, of which an illustration is enclosed with Mr. Calderwood's remarks, has a rating of 78 tons refrigeration, and when working with an evaporation temperature of -13°F., and a condenser temperature of +100°F., absorbs about 127 H.P. This unit was developed by my firm, Messrs. Sulzer Bros., specially for use on large refrigerated cargo ships. The compressor end of this unit consists of two double-acting ammonia cylinders working on the special Sulzer compound cycle. This cycle is the outcome of considerable research, and has proved very successful in practice, as it enables considerable increases in efficiency to be effected, the saving in power consumption often being between 15 and 20% as compared with a single stage NH_3 compressor, running under the same conditions.

There is one other point. In his reply, the Author excused himself for neglecting the ammonia machine on the grounds that the percentage installed on board ship was so very small, amounting to about 2%. Reference to Lloyd's register will show that this figure is very far from correct, the percentage being more like 27%.

The Chairman (By correspondence): Mr. Greenfield refers to the advantages of CO_2 machines as compared with NH_3 machines for marine work. We know the inconvenience and danger of having an ammonia machine installed, say in the tunnel recess of the engine room, in the event of a serious leak of ammonia taking place. If it is decided to fit this type of machine it should be placed in a separate well ventilated compartment away from the main engine room.

The author has referred to the liquid cooling or multiple effect cycle having advantages when high temperature cooling water is met with. Some makers claim great things with this type of machine, giving considerably more refrigeration on less horse-power, the number of hours running per day are reduced, and further a saving in gas and oil. Does this type of machine require more attention and adjustment than the ordinary cycle machine, or would it not be better to instal the latter with a larger margin of power?

Reference has been made to the direct expansion evaporator where the coils are arranged on the ceiling, walls and bulkheads to be cooled. This system has the disadvantage that when the machine is stopped the cooling effect also stops, whereas the low temperature brine can be circulated through the chambers.

Mr. Greenfield refers to the very important duty to be provided for the cooling of the various cold cupboards and larders spread practically throughout the ship, this entailing a heavy demand on the machine which cannot be directly controlled by the engineer. These are frequently misused and often regarded as unsatisfactory. The alternative is to have an independent machine to do this work, or a small separate machine for each cupboard. In a large passenger liner it would mean eight or ten small machines to deal with this work.

I agree with the author that the evaporators should always be placed in a well insulated room, the evaporators not being insulated, leaving all joints and connections accessible and ready for inspection.

Reference has been made to the jointing used for the service and grid piping being the well known socket and backnut one, but in view of the large motor ships and increased vibration it may be necessary to dispense with this joint in these vessels and adopt welded joints. I should like to know if this has been done, and if so with what success? The screwed parts of all brine pipes passing through bunkers, etc., should have a coating of white lead, and the pipes well covered with bitumastic.

The question has been raised as to the various methods of air circulation. I am in favour of passing the air through a battery of coils by a fan, the battery being housed in a separate compartment, the air being circulated through air trunks in the holds large enough for the engineer to go through to adjust the air slides. The trunks should be made portable or hinged when not required for fruit cargoes.

In fitting wood shutters in front and sides of bulkhead grids for forming the air space, once the cargo is stowed the means of adjustment of the slides on the shutters is stopped and there is always a danger that when the grids are thawed off the water from them will overflow the gutterway and stain the fruit cases.

The new method of air changing shown on diagram 14 is quite good, the vents being small so that the risk of introducing dampness into the hold is reduced. Reference is made to the amount of CO_2 permitted in the hold as being 10 per cent., and when this is exceeded the necessity of changing the air, which should always be done with discretion. If fruit was all pre-cooled and shipped at a temperature of 40 to 45 degrees it would not be necessary to change the air as very little CO_2 gas would be given off the fruit. Fruit is often shipped at 75 to 80 degrees and to reduce it down to say 35 degrees takes many days.

THE AUTHOR'S REPLY: The Chairman has remarked that the paper is exhaustive, and I only hope, in view of the time it has occupied in reading, that it has not proved exhausting!

On the subject of vibration, which both Mr. Adams and Mr. Calderwood have raised, I am quite in agreement that there *need* not be more vibration in Diesel ships, but my experience has been that generally there *is* more, and one is faced with the problem until it no longer exists.

As regards Mr. Gemmell's remarks, I apologise for the wording I used in connection with the slow speed machine. I only mean to say that the high speed machine is of more recent introduction. Mr. Gemmell asked whether any trouble has occurred due to serious vibration with high speed machines. The answer is no, when the machines are running steadily; but if they are carelessly handled vibration may occur on starting. That is brought about by the machines cutting in very rapidly; they run up to full speed in under half a minute. With a steam-driven machine one turns on the stop valve and the machine gets away slowly, with only the necessary care in bringing up the speed to prevent liquid being carried over into the compressor.

A question was raised as to a possible means of telling what each individual evaporator coil is doing. It is quite common practice on land installations to fit each coil with a thermometer, but they are not found to be of much use to the man in charge; they frequently get broken. I do not think I have ever seen them fitted on board a ship. It is certainly not usual.

Regarding the suggestion that galvanised leads should always be fitted, unfortunately owners do not like to pay for them. With regard to welded pipes, whilst I had in my mind the absolutely continuously welded job, I have thought that a great improvement would be made if the flanges were welded on. There are many disadvantages, but I think that the oval flange welded on would be a considerable improvement on the present socket and back-nut joint.

Mr. Gemmell queries my heat figures. I can only say that they came from the Research Department of Cambridge University, but, as you know, research in such questions goes on from day to day, and figures correct to-day may not be correct to-morrow. It was only quite recently that we have had any figures at all.

Mr. Brier's remarks on the multiple effect cycle are interesting. I cannot now go into this matter in detail, but I think that, while one still gets extra output, one still requires extra power, and it does introduce complications. My own experience has shown that, whilst many engineers make use of it, others do not, and go back to the ordinary cycle.

Mr. Douglas asks a number of questions, which I will answer in my written reply.

I am sorry if Mr. Calderwood thinks I gave unfair preference to the CO_2 machine, but the proportion of NH_3 to CO_2 machines in use at sea is very small. The majority of my remarks would have been on NH_3 machines if I had been dealing with land installations. As regards Diesel-driven compressors, the time is coming when the oil engine drive will be common practice, and one illustration I showed to-night was of a horizontal NH_3 machine coupled to an oil engine.

As regards Mr. McLaren's remarks, the figures I quoted for slag wool insulation were obtained by tests at the National Physical Laboratory, and are considered to be standard practice.

In writing I may now give a joint reply to Mr. Moul and Mr. Calderwood. Taking Lloyd's Register 1928-9, percentages of ammonia machines are found to be as follows:—

Lloyd's Register, Part 1:

Vessels having an insulated capacity of 80,000 cubic ft. and over and including all vessels holding Lloyd's Refrigerating Certificate.

Percentage of ammonia machines: 9·5.

Lloyd's Register, Part 2:

Vessels having an insulated capacity of less than 80,000 cubic ft. and not holding Lloyd's Certificate.

Percentage of ammonia machines: 28.

In Mr. Bennett's remarks he deals with the question of liquid cooling, and says the "Cooling effect is produced with the co-efficient of performance of the machine." Presumably this should read "with increased co-efficient of performance," and, reading in this way, we quite agree with the remarks made.

In comparing the output of a machine cooling brine to 20° F. and a machine cooling brine to minus 5° F., we were careful to make it clear that the machine was assumed to be running at the same speed in both conditions.

Obviously, the increased speed will increase the output, but it will also increase the power, and it is indisputable that a machine running at the same speed gives much less output when cooling brine to minus 5° F. than it does when working with the higher brine temperature of 20° F.

The effect of the critical point on CO_2 machines is not usually worried about by practical engineers, as it is well known that there is no change in the direction of the "duty" curve as the critical point is approached or even after it is passed.

Mr. Bennett's explanation of the cycle, when the liquid is at or above the critical temperature, is the usually accepted one, and is quite clearly explained by him.

With reference to Mr. Brier's queries, there can be no possible question regarding the statement that liquid cooling or multiple effect takes more power than is the case with the simple cycle, but is has never been suggested that it takes more power for an equal amount of work.

It is difficult to see how the application of the automatic regulator can give the machine increased output, always assuming, of course, that the ordinary hand operated regulator has been properly and efficiently used.

The figures given as the results on *ss. Elizabethville* indicate that one machine, when altered, did $2\frac{1}{2}$ times the refrigerating work previously performed, and from this it can only be assumed that the compressors or pistons were in very bad order before the alterations were carried out.

Turbo Charging.

Paper on "Turbo Charging of Internal Combustion Engines, especially Diesel Engines," by Mr. Alf. Büchi. See November issue, p. 633, and December, p. 781.

The Author's Reply to Mr. E. G. Warne: The efficiency of my system is due to the following:—

1. Emptying the cylinders of the exhaust gases at the end of the expansion stroke to a very high degree, owing to the big pressure fall at this point.

2. Filling up of the whole compression space with clean, relatively cold air.

3. Blowing through the cylinders when the piston is at its top position, and the combustion chamber a flat space, a large quantity of scavenging air amounting to two or more times the volume of the compression space. The inner wall of the cylinders and the valves are thus very effectively cooled by the cold scavenging air, all the exhaust gases are blown out of the cylinder, much more fresh charge and at a much lower temperature is taken into the cylinders than in the case of a normal Diesel engine. The overlap of the valve gear is somewhat different for different engines. But it is usually between 50 to 120 and more degrees.

4. The pressure fluctuation must be so chosen that the minimum pressure in the exhaust pipe takes place at a time when the piston is moving very slowly, and therefore the necessary time for introducing the scavenging air through the valves is at disposal.

5. The maximum exhaust gas pressure ought to be relatively high, so that in the turbine a high output is generated to increase as much as possible the quantity of the charging and scavenging air.

6. With engines of more than four cylinders, the exhaust of the different cylinders must be led to different independent exhaust pipes and inlet chambers of the turbine or to different turbines, so that no interference during the scavenging period takes place when another cylinder is exhausting.

Any neglect of this point would change conditions for the worse and diminish the reliability of the engine in question.

The matter is not quite so simple as suggested; there are many important factors to be taken into consideration. Reference should be made to the British Patent Specifications 157241, 256955, etc.

The figure in Table 1 should be $19\frac{7}{32}$ instead of $19\frac{7}{16}$. Therefore 488 mm. is correct. 420 lb. is the compression pressure when the suction air is aspired directly from the atmosphere, or no charging pressure exists. When the turbine-driven blower is in action, this pressure rises in function of the absolute charging air pressure up to the normal compression pressure as used in ordinary Diesel engines.

I thank Mr. E. G. Warne very much for his contribution and that he has given me the opportunity to answer his questions.

15.1.29.

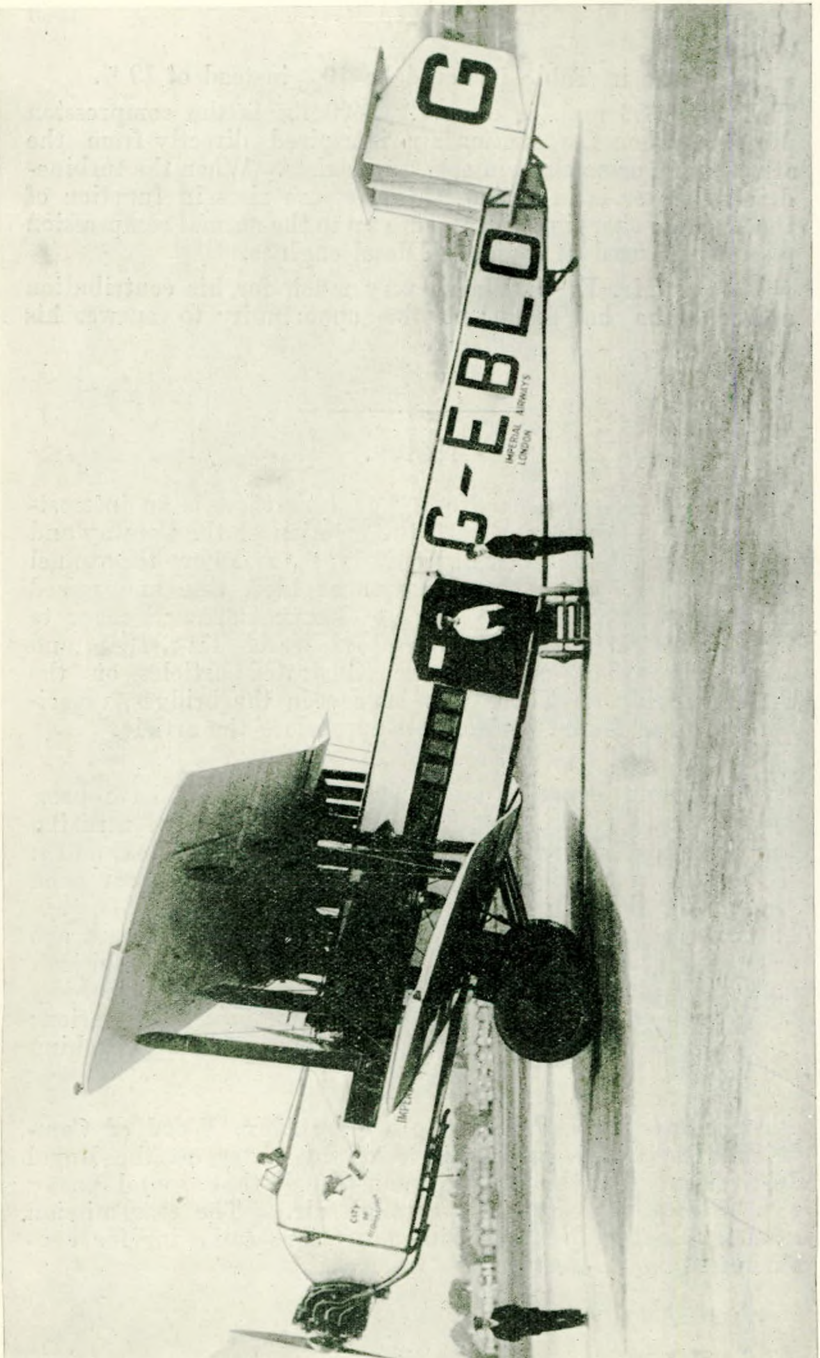
Notes.

In " The Edgar Allen News " of June there is an interesting article in connection with the erection of the Conway and Menai Strait Tubular Railway Bridges, and how the tunnel sections were brought into position at high tide and raised to the level of the railway line. References are also made to " The Illustrated London News " of March 11th, 1848, and June 30th, 1849, wherein are illustrated articles on the Tubular Bridges. Those who have seen the bridges, especially over the Menai Strait, will appreciate the article.

The Grand Junction and the Regent Canals have been united under one Company with the intention of utilising the waterways for traffic to an extent hitherto neglected, and it is hoped that the intention of the promoters will bear good fruit. The service which could be rendered by our waterways has been advocated for many years, and about 18 years ago articles appeared in the " Marine Engineer " on the subject, and were continued in following years; so also was the subject of the utilisation of our water supplies for power generation; the tunnel through Ben Nevis for this purpose is approaching completion.

An interesting lecture was given by Alex. Wood of Cambridge University, on sound travel by water, at the Royal Institution, in which he demonstrated that sound passes through water easier than through air. The transmission of sound for depth and diving operations came up for consideration in the lecture.

The following are two copies of additional photographs received from Major Mayo to further illustrate the subject of his lecture printed in the December issue.



E, The Armstrong-Whitworth *Argosy* Aircraft employed by Imperial Airways, on the London-Paris service.

F. The Armstrong-Whitworth *Argosy* Aircraft. Interior of cabin showing passengers' seats, buffet and steward.

The following is from "Gas and Oil Power," June, 1928 :—

THE INDEPENDENT INDUSTRIAL POWER UNIT. (Oil Engines Cheaper than Electricity for Ice Making).—One of Britain's industries that has seen great development since the War is that of ice making, which now mainly supplants the pre-war foreign import trade in this commodity.

Those responsible for the promotion of trustified electricity have been at some pains to canvass this thriving business for electrical power. In the absence of similar propagandist activity on the part of internal combustion engine manufacturers, some ice plants of considerable size have yielded to the argument of the electricity booster.

It is for the purpose of revealing to ice manufacturers up and down the country that the internal combustion engine is distinctly the cheapest power unit for this industry, that *Gas and Oil Power* has pleasure in publishing a paper from an Australian expert giving irrefutable data as to comparative costs in ice making power plants. The same evidence could be adduced from English practice, but it so happens that the comparisons given by Mr. R. C. Wallace in his paper before the Conference of the Victorian Institute of Refrigeration, in Melbourne, are so lucid and decisive that they may well serve on the present occasion. The fact that labour costs differ as between Australia and England does not, of course, affect the comparisons. In the course of his paper, Mr. Wallace said :— It is the object of this paper to show that for many applications a plant is now available which will generate power with the simplicity and reliability comparable with an electric motor. That plant is an oil engine.

Steam engines and gas engines which have had such a long and satisfactory run of life as prime movers have a very prominent disadvantage in that the steam or gas has to be generated before it is available for passing into an engine to develop power. This means that additional space and equipment and a staff of firemen have to be used before the power medium is available. Without this form of power for certain industries and under certain conditions it has its very definite uses.

For instance, before the present methods of ice manufacture were introduced, it was necessary to use distilled water to produce clear ice. What was more logical, then, than to use a steam engine to operate an ice making plant, and to use the condensed steam as distilled water in the ice cans, since it was found that approximately one pound of steam was necessary as power in the engine to produce one pound of ice.

Steam engine economy is generally proportional to the size of the unit, a large unit being considerably more economical than a small unit. This, however, is not so for an oil engine, for the fuel consumption per b.h.p. is almost as low in a small as in a large unit.

We will now examine the operating cost of an electric motor, a steam engine, and an oil engine, assuming the following data:—

Cost of electric current	1d. per unit
Overall efficiency of motor and wiring ...	85%
Cost of coal per ton	£2
Coal consumption per h.p. hour	2 lb.
Cost of fuel oil per pint	4·75 pence
Fuel oil consumption per b.h.p. hour ...	·42 lb.

When the cost of fuel per h.b.p. for 300 days, operating 24 hours per day, would be:—

	£	s.	d.
Electric Motor	26	6	9
Steam Engine	12	17	2
Oil Engine	6	13	0

As an illustration of comparative costs, we may consider an ice making plant having an output capacity of 50 tons of ice per day, and compare the costs for electric, steam, and oil engine drive. Without going into details of the capital cost of the plants, we will assume that the electrically operated plant costs £16,000, the steam operated plant £20,000, and the oil engine operated plant £18,000. In each case these plants are directly connected to their prime mover, and the sum stated includes machinery, erection, buildings, insulation, etc.

The following table would be a fair representation of costs:—

Electric Plant.

Electric Drive (including two synchronous motor-driven units).

Total investment, exclusive of land, £16,000.

Operating cost for one year, assuming 11,000 tons of ice made.

Labour.

	£	£
1 chief engineer at £500 per annum	500	
3 watch engineers at £5 10s. per week for 12 months	858	
3 ice pullers at £4 10s. per week for eight months' average	432	
		1,790

Power.

	£	£
Yearly average 2·9 h.p. per ton ice for 11,000 tons at 1d. per unit and 90 per cent. efficiency of motor and wiring	2,692	
Oil, waste, ammonia, calcium, etc., at 4d. ton ...	186	
Water for ice making and condenser make-up and thawing, 300 galls. per ton at 1s. per gall. ...	168	
Maintenance on machinery at £11,000 at 2 per cent	220	
		3,266

Fixed Charges.

	£	£
Interest, 6 per cent. on £16,000	960	
Depreciation on buildings at 4 per cent. on £5,000	200	
Depreciation on machinery at 6 per cent. on £11,000	660	
Insurance, taxes, and miscellaneous, 3 per cent. on £16,000	480	
		2,300
Total operating cost		£7,356
Cost per ton of ice		13/1½

Steam Drive.

(including 2 piston valve automatic cut-off steam-driven sets, and electric generator for auxiliaries).

Total investment, exclusive of land, £20,000.

Operating cost for one year, assuming 11,000 tons of ice made.

Labour.

	£	£
1 chief engineer at £500 per annum	500	
3 watch engineers as above	858	
3 ice pullers as above	432	
3 firemen at £5 per week for 8 months	480	
		2,270

Power.

Average 3·14 i.h.p. per ton ice, including storage at 14·5 lb. steam per i.h.p. hour, 9 lb. steam per lb. coal, coal £2 per ton	1,331	
Lubricating oil	80	
Oil, waste, ammonia, calcium, etc., at 6d. per ton	280	
Water for ice-making, boiler, condenser make-up and thawing, 370 galls. per ton at 1s. per 1,000	207	
Maintenance 3 per cent. on £15,000 machinery...	450	
	——	2,348

Fixed Charges.

Interest, 6 per cent. on £20,000	1,200	
Depreciation on buildings, etc., 4 per cent on £5,000	200	
Depreciation on machinery at 7 per cent. on £15,000	1,050	
Insurance, taxes, and miscellaneous, 3 per cent. on £20,000	600	
	——	3,050
		——
Total operating cost		£7,668
Cost per ton of ice		13/8

Oil Engine Drive

(including two direct connected oil engine driven compressors and generating set for auxiliaries).

Total investment, exclusive of land, £18,000.

Operating cost for one year, assuming 11,000 tons of ice made.

Labour.

	£	£
1 chief engineer at £500 per annum	500	
3 watch engineers as above	858	
3 ice pullers as above	432	
	——	1,790

Power.

Average 2·9 b.h.p. per ton ice at 3·4 galls. fuel oil per ton ice at $4\frac{3}{4}$d. per gall.	753	
Engine lubricating oil at 1 gall. per 2,500 h.p. hours at 6s. per gall.	80	
Compressor oil, waste, ammonia, calcium, etc., at 4d. per ton	186	
Water for ice making, etc....	168	
Maintenance, 3 per cent. on £18,000	390	
	——	1,577

Fixed Charges.

Interest, 6 per cent. on £1,800	1,080	
Depreciation on buildings 4 per cent. on £5,000...	200	
Depreciation on machinery at 6 per cent. on £1,300	780	
Insurance, etc., 3 per cent. on £18,000	540	
	——	2,600
Total operating cost		£5,967
Cost per ton of ice		10/8

Thus the costs per ton of ice making are as follows:—

By Electricity	13/1½
By Steam	13/8
By Oil Engine	10/8

The power costs in the three cases, including fuel, lubricating oil, and water, are:—

	£
By Electricity	2,692
By Steam	1,569
By Oil Engine	833

From this it is apparent that to compete with an oil engine on a basis of fuel, lubricating oil, and water costs, electricity must be available at a cost of ·31 pence per unit.

Thus we see that oil engine power at the price for fuel used in the calculations without doubt has a handsome lead over the other forms of power.

What the writer believes to be fair and reasonable allowance for maintenance and depreciation has been given in the above calculations involved in the ice factory operation, and in these calculations allowance has been made for variations in simplicity of operation in the various types of plant, by stating the number of men required to be employed, but it will be interesting briefly to consider here the amount of work required to keep the various plants in operation.

With the steam plant the boiler requires constant stoking and ash removal, a careful check has to be made of feed water and water level in the boiler, draught has to be varied, and analyses made of the flue gases; the lubrication has to be watched (although this is a small item, for it will probably be force-fed), and occasionally the engine has to be indicated.

With the electric motor, we may safely say that no attention is required beyond intelligent observation.

With the oil engine, an occasional glance has to be made to the lubrication pressure gauge, and cooling water flow meter, and periodical indications made.

Starting a solid injection oil engine consists in opening an air starting valve and closing it when the engine fires, after about two revolutions. So this is actually simpler than starting up an electric motor.

Those unused to the operation of solid injection oil engines may say, "But there must be more to do than that." It is not so. The writer has seen these people standing by when an oil engine is first started up, and the operator has then walked away as if he has no further interest in the engine, and those watching have become nervous and looked at one another, imagining it not right that the operator should be so casual. Surely the engine wants as much attention as a steam engine. No. In fact, in an oil engine-driven plant the operator is always everywhere but near the engine.

It would be of interest and of service to receive the views of members on the foregoing, based upon experience.

In "The Marine Engineering and Shipping Age," New York, July, the American Scantie Line, Messrs. Moore and McCormack, Bonus System is described in detail. The bonuses are divided into three main classes: Length of service, fuel saving, saving in repairs—calculated on a basis of estimated cost—saving of stores, profit on a year's running.

In "The Marine Journal," New York, September 15th, there is reproduced a good photo of the lifeboat crew of eight and the coxswain of the *Mauretania*, which won the International lifeboat race, held near Battery Point on Labour Day. The starting point was off the Statute of Liberty and there were seven entries and the time taken by each was given as follows:— *Mauretania*, Cunard Line, 9 min. 39 sec.; *Sparreholm*, Swedish-American-Mexican Line, 9 min. 50 sec.; *President Harding*, United States Line, 9 min. 54 sec.; *Port Victoria*, Furness-Bermuda Line, 10 min. 20 sec.; *Corvard*, Kloster Line, 10 min. 40 sec.; *Troubadour*, Wilhelmsen Line; *Robert E. Lee*, Eastern S.S. Lines, not timed, being in the rear.

They were started with an equal weight of 6,000 lbs., ballast being added when necessary to make up the amount. Each member of the winning crew was presented with a gold medal to commemorate the event.

In the "Shipbuilding and Shipping Record," January 3rd, there are two illustrations showing the French steamer *Paul Lecat* on fire in dry dock, Marseilles, and the damage done. The fire raged very fiercely, and it is stated the cause was unknown. It, however, is a lesson to all to exercise care and attention.

The following interesting special article is from "The Metal Industry" of October 12th, quoted by permission of the Editor:—

The Story of Early Metallurgy.*—The Dawn of the Copper Age.—By R. T. Rolfe, F.I.C.—In the Near East we see, invariably, a Copper Age preceding that of Bronze, this being inevitable, because of the absence of tin ore that has already been referred to, a deficiency that was ultimately remedied by the development of commerce with other and stanniferous regions. In the meantime copper had to serve, and the source of copper working in the Near East is somewhere in the rough ellipse that can be drawn through Anau, in South Turkestan, Susa in Persia, Egypt, Crete, and Hissarlik, back to Anau again. Cyprus, the copper island, and Syria, both of which has some claims to priority in this art, are included. So also in Babylonia. Within this area we may look for that primitive camp fire, which became by accident the first smelting furnace.

Among the discoveries that we may justly describe as "epoch-making" this was, perhaps, the greatest, for without metals man was poor indeed, and, although the spread of metal-working was necessarily slow, the line of demarcation between late stone and early copper age cultures is clearer than any that we can trace either before or since. It was not only a question of the superior weapons, implements, and general

* Mr. Rolfe, in his previous articles on this fascinating subject, on which he is an acknowledged authority, has dealt with two important sections of "The Story of Early Metallurgy." In the first section he discussed the subject of the use of the precious metals, gold and silver, in ancient Egypt. The articles relating thereto appeared in "The Metal Industry" of November 11th and November 25th, 1927. Section II. dealt with the use, by early man, of native metals, and appeared in the issues for March 30th and April 13th, respectively. In this third instalment of his series, Mr. Rolfe describes the dawn of the copper age. All rights of translation or reproduction of this or previous instalments of "The Story of Early Metallurgy" are reserved.

equipment which the discovery of metals provided, but also that, in metals, one had an exchangeable commodity of much greater value and far smaller bulk than those of anything in common use before. Rough bars of copper, as in early Egypt, constituted the first currency, and the organisation of Egypt and Babylonia, those first great empires of the East, only became possible when sufficient supplies of copper were available.

THE HOME OF METAL-WORKING.—Of the exact source of copper-working we cannot yet be sure. It appears at much the same period, some 6,000 or so years B.C., at several different places in the area in question, and since much excavation is being carried on, and some further discovery is made, almost before the stir from the last has subsided, the matter will in time become clearer. But already there are many links between the cultures whose remains are being so freely brought to light, and our conclusions can be something more than reasonable probabilities. Thus there is little doubt that a civilisation which saw the dawn of the copper age was common over a considerable part of western Asia, Asia Minor, and Egypt, long before the first appearance of the Sumerians in Babylonia or the coming of the first Egyptian dynasty. There are various links which connect the cultures existing at a number of widely-scattered sites at much the same time—including the transition period just before the metal age, and the first few centuries of it, the period sometimes termed "chalcolithic." Of these links, perhaps the most important is the painted ware, whose earliest types are found at Susa, in Persia, but which occurs also at many other places. Thus, at Abu Shahrein (the ancient Eridu); at Tell el 'Obeid, near Ur of the Chaldees; at Bandir Bushir, on the Persian coast; at Musyan, thirty miles west of Susa, and elsewhere, precisely similar ware has been found, ware which is related, on the one hand, with the early pot fabrics of Syria and Asia Minor, and, on the other, with those of Anau in South Turkestan, at the northern edge of the Persian plateau, between Merv and the Caspian. We have no space here to trace more fully the relationships between these early pot fabrics, fascinating though the subject may be; nor can we show the links between the associated implements and other relics, which connect, for example, the first culture at Anau with that of pre-dynastic Egypt, and even with the earliest culture of the Swiss lake-dwellings. There is, however, no doubt as to the widespread character of the neolithic civilisation of these regions at the time when copper first appears.

The Cultures of Anau and Susa.—The sites, both of Anau and Susa, were occupied for a long period with temporary abandonments; at Anau, by reason of periodic drought. Small objects of copper, and also of lead occur, associated with the painted ware, towards the end of the first culture at Anau at a time when the arts of agriculture, spinning and weaving were well established, and such animals as the horse, ox, pig, and two different kinds of sheep, were already domesticated. In the second period appear copper daggers, together with a smooth red or grey ware, without pattern, except for a dark smoke-mottling on the red ware, while the dog, camel, goat, and a species of hornless sheep have been added to the list of animals previously domesticated. Since the red-ware culture of the Near East finds a focus in the countries of Asia Minor and Syria, and considering also the character of the new animals which had become domesticated during the second culture at Anau, one can only assume the establishment of new relations between these two regions. Such relations would be facilitated by the drought, gradually increasing throughout the first period at Anau, and so gradually thinning the heavy forest growth on the highlands stretching between Mesopotamia and the Caspian, which had previously hindered communication between Anau and the West.

Painted Ware of Susa.—The first painted ware of Susa, although clearly belonging to the same culture, is finer than that of Anau, and shows already in the lowest deposits the existence of the potter's wheel. In these, also, copper objects are much more plentiful than at Anau, suggesting that, whatever the source, Susa was nearer to it than was Anau. That, as with Anau, copper was introduced into Susa from the west, probably from Asia Minor or Syria, is more strongly suggested, however, by other evidence. Thus, in the second culture at Susa, which replaced the first after a sterile period, during which the site was temporarily unoccupied, we find the same intrusion of plain red and grey ware as characterised the corresponding culture at Anau. This period at Susa is contemporary with the earliest occupation, by the Sumerians of the Babylonian river valleys, probably before 4000 B.C., when—simultaneously in Egypt, Babylonia and Elam—hieroglyphic writing, and the use of cylinder seals, are first seen, and on the earliest river sites of Lower Mesopotamia—as at Lagash, Ur, Eridu, and Nippur—one finds the same undecorated red and grey ware, associated with implements of flint, knives, scrapers, arrowheads, and so forth, and also with rough objects of copper. The marked relations—which have already been discussed*—existing between the early copper industries of Egypt, on the one hand, and of Asia Minor and Syria, with Cyprus, on the other, have caused some to regard Egypt as the home of copper-working, but since this country was poorly provided with metal, whose chief deposits were located in the other three regions, the claims of Egypt must, to some extent, be discounted.

THE ORIGIN OF SOME EARLY METAL-WORKERS.—The Sumerians who occupied South Babylonia early in the metal age, a little before the Semites appeared in the North, had Mongolian affinities, and were closely related with the Kassites, the people of Elam, for the civilisations and religions were the same, while the two languages, although not identical, resembled each other closely. These two peoples had apparently some common origin in the region which begins with the foothills on the east side of the Tigris, and thence extends far to the east. If, as is probable, early Sumerian civilisation was due to Elamitic settlement, we have an explanation for its advanced state in the earliest times of which we have records. Although there was no copper in Babylonia, and the Sumerians had to depend entirely upon imported metal, the development of copper working in this country did not lag behind that of its neighbours, while the great amount of exploration in Babylonia in recent years, and the wealth of relics and inscriptions found, give us a clearer picture than can be found in other regious more favoured in their mineral wealth, and inhabited in the same early times. Egypt is, of course, a strong exception to this statement, and for long the development of metal-working in this country and in Babylonia proceeded on parallel lines.

THE SUMERIANS AND THE SEMITES.—At the beginning of the metal age, we see, then, already existing in South Baylonia, this old and prosperous civilisation, not ancient in having long occupied those river sites, but in its much earlier origin elsewhere. The river sites were partly in the north, Akkad, where the country, by reason of the coarser silt deposited in the upper portion of the alluvial plain, was less fertile, but more particularly in the richer South, Sumer, where among the chief towns were Sirgulla, the modern Zerghul; Girsu, later the site of Lagash; Erech (Warka), Eridu, Ur, Larsa (the Biblical Ellasar, now Senkereh), and Umma (now Yokha). In Akkad

* The Metal Industry, July 8th, 1927.

were Sippar, Barsip (Borsippa), Gish-Galla (later Babylon), and Kish. Midway were Nippur and Isin. Sumer and Akkad were for long geographical expressions rather than states, the separate towns being governed either by a priest-prince (patesi) or a petty king (lugal). These rulers quarrelled with and held temporary sway over each other, and endeavoured to withstand, as well as they could, the early and ever-growing Semitic menace in the north, where the names of Semitic town-kings appear on some of the first monuments.

Before 4000 B.C. there were Semitic rulers at Kish, who were contemporary with a Sumerian dynasty at Erech, and, later on, with a Sumerian dynasty at Ur. About 3200 B.C. we find a northern Semitic dynasty of Akshak, which was apparently at first predominant over the south, but seems later to have become weaker, for a Sumerian, Ur-Nina of Lagash (*c.* 3100 B.C.), assumed the title of king, and held sway in Sumer, where a number of city kings of Lagash succeeded each other, of whom the reigns, both of Ur-Nina and one of his successors, Entemena, saw the production of some notable examples of metal work. Of these kings of Lagash, the eighth successor of Ur-Nina, Uru-duggina, was defeated in 2897 B.C. by Lugal-zaggisi, patesi of Umma—the rival city to Lagash—who made Erech his capital. Since the king is described as ruler from the Upper (Mediterranean) to the Lower Sea (Persian Gulf), he may even have had dominion over Akkad also. Shortly afterwards the great Semitic empire of Sargon of Akkad, founded in 2872 B.C. at Sippar, temporarily united Sumer and Akkad under one rule.

There are later Sumerian kings or patesis of Sirgulla and Lagash, notably Gudea, and then, between 2474 and 2357 B.C. a Sumerian dynasty of five kings at Ur—Ur-Engur, Dungi, Bur-Sin, Gimil-Sin and Ibi-Sin—under whom copper working flourished. The downfall of this dynasty left the Semitic States of Isin and Larsa temporarily supreme, at first at peace with each other (2357-2263 B.C.), and then in opposition (2263-2214), the second period naturally affording the Sumerians a chance of making headway again in the south. A Sumerian revival is evident from the fact that, while the rulers of Isin between 2214 and 2167 are Semitic, this state was conquered in 2125 by Rim-Sin, and remained in Sumerian hands for several decades, until the time of Hammurabi. In the north, the first Babylonian dynasty (*c.* 2200 B.C.) had now come into being, and Hammurabi (2123-2080), who was its sixth king, by overcoming the last king of Larsa, achieved the final victory of Semitic over Sumerian power. Sumerian culture, which had always profoundly influenced that of the Semites, continued to flourish, however, in Elam. Amid these vicissitudes of kings and peoples, and whether Sumerians or Semites were temporarily in the ascendancy, copper played its all-important part, a part unfortunately disregarded by most historians, but which we shall not neglect here.

Copper in Early Babylonia.—In the early Sumerian period, weapons and ornaments were invariably of copper, and a remarkably fine example of the art of the ancient coppersmith is the lance-head found in Lagash, dating from the time of the Third Dynasty of Kish (*c.* 3638-3488 B.C.), for it bears the name of Lugal-?-aga, of this dynasty, who, if he was not, as his name implies, "king of universal dominion," certainly appears to have included Lagash in his realms, and to have had some excellent craftsmen, for the figure of a lion, which has been wrought upon the neck of the lance, is a realistic design, which would not discredit the artist of to-day. Interesting, too, although not particularly noteworthy from the artistic standpoint, are the little cast and wrought copper figurines of goddesses, found in the remains of the earliest Sumerian cities, in the foundations of the more important buildings. These had evidently some religious significance—possibly as guardians of the buildings—for their hands are usually folded as if in prayer; while the body ends in a long peg driven into the unbaked bricks of the foundations. At Lagash, where a central mound marks the site of the prehistoric Girsu, De Sarzec discovered, in recesses of the walls, two circular groups of these figures, which were used for the same purpose over a period of probably more than 2,000 years.

With Ur-Ninas, king of Lagash, about 3100 B.C., by which time the remains of Girsu had been long buried under a deep deposit of sand, a new use was found for these votive figures, each of which now supports, raised above its head, a small stone tablet with inscriptions. The details relate to the temples built by the king, and some of his other activities, and often throw a flood of light upon the history of these times. The period of this king saw the production of some remarkable examples of copper work in the life-size figures of lions found in 1919 by Hall at Tell-el-Obeid, near Tell Mu-kayyar ("Ur of the Chaldees"). These have cast heads—a difficult matter with straight copper, as here—and the results were naturally not always successful, and some of the heads are rather distorted. The bodies, of which only the fore-parts remain, were made of plates, hammered and wrought, fastened with nails over a wooden block—the same method of manufacture as was used in the VIth dynasty Egyptian statues of Pepi I. and his son, which were made, however, some centuries later†. The heads of the figures from El Obeid were filled with bitumen and clay‡, to give additional support in working on them afterwards, and a strikingly realistic effect was obtained by inlaying the eyes with red jasper, white shell, and blue schist, these materials being fastened, by copper wires, to the bitumen core. This inlay work, used for stone as well as metal figures, was also common among the Egyptians, and the resemblances in technique are, of course, no accidental ones, but indicate a natural relationship between the craftsmen of these neighbouring countries, a relationship which seemed to become weaker, however, in later years. There is further evidence from El Obeid of the skill of these metal workers of some 5,000 years ago, in the shape of a very fine relief, unfortunately now rather in pieces, but originally some eight feet long by three feet six inches high, in copper, representing Imgig, the cognisance of Lagash, a lion-headed eagle, holding two stags. The splendid silver vase of Entemena of Lagash (*c.* 300 B.C.) now in the Louvre, is of the same period. This is a silver tripod, round the neck of which runs a frieze of lions devouring ibexes and deer, while the body bears the eagle crest of Lagash, and is fixed on a copper stand, the whole wrought with great artistic skill, comparable with that of the Egyptian workers of the same early times.

A new type of the copper votive figures was found by De Sarzec at Urukug, near to the site of Girsu, where a few centuries later than Ur-Ninas, Ur-Bau of Lagash (*c.* 2700 B.C.) built a temple to the goddess of healing. Attached to a pillar of this temple was the figure of a god, in a kneeling position, with his hands placed on top of the post, as if he were driving it firmly into the ground. The figure is described as of bronze, which is certainly possible, for the alloy was known in Egypt as early as 3100 B.C., although remaining scarce for several centuries afterwards. On the other hand, it must be remember

† There is some little doubt as to whether the Pepi statues, which are generally described, probably correctly, as of copper, may not actually be of bronze, when good castings can much more readily be obtained; but the bulk of evidence favcurs the first alternative.

‡ Compare the materials of the image in "Bel and the Dragon." of "clay within and brass without."

that objects have often been described as of "copper" or "bronze", in an entirely arbitrary manner, without any chemical examination of the material, and many doubtful matters could be cleared up by analysis, to which, however, obvious objections arise.

THE COPPER AGE A LENGTHY ONE.—There are abundant data to show that copper was the metal in general use in Babylonia long after 2700 B.C. A statuette of Gudea of Lagash (*c.* 2700) and a vase of Ur-Engur (2474 B.C.) are both of copper, while the copper nails with gold heads found at Abu Shahrein are probably of about the same period. It is interesting to note that in Babylonia at this time, as with ourselves to-day, special industries tended to concentrate in particular towns, and in the time of Dungi (2456 B.C.) and Bur-Sin (2398 B.C.) we read that both Umma and Dur-gurgurri, near Larsa, were noted for their coppersmiths. Some good work was being done in these days, and there is a record of a presentation to Ur by Zariku, patesi of Susa, in the time of Bur-Sin, or possibly of Rimil-Sin (2387 B.C.) of the splendid image of a cow, in copper, inlaid with silver. A votive figure of the second type, with the inscribed tablet, dating from the time of Arad-Sin, King of Larsa (*c.* 2167 B.C.), and now in the British Museum, is also of copper.

THE DOMESTIC COPPER POT.—A letter surviving from the time of Hammurabi (2123-2081 B.C.) refers to the domestic copper pot, still used to-day both for carrying water and for cooking. The translation is somewhat as follows: "To Baba from Munawirum. May Shamash and Marduk keep thee in good health for ever. I am sending to thee Lumar-sha-Marduk. Please give him a copper pot. I will send thee the money. I have not been well. As thou lovest me truly, send the copper pot." And since the good lady, or gentleman, was evidently in some difficulty, the situation being indeed not without parallel, even in our own times, let us hope that she (or he) obtained the copper pot, and that Baba has no reason to regret his kind accommodation in the matter. The writer may have lived in a village, and would have to send to the bazaar in the nearest town to get one. In addition to their domestic uses, copper vessels of a more elaborate character were used in the service of the temples, and in the fourth year of the reign of Hammurabi there is a record of the restoration of such a vessel for the temple of Shamash, the cost of the repair being two-thirds of a mana††.

†† A mana was 60 shekels, or 1-60th of a talent and weighed 7,750 grains, or very nearly 17¾ oz. avoirdupois; in this instance, of silver.

THE DISCOVERY OF COPPER.—Although various other suggestions have been put forward, there appears little doubt that the first smelting of copper was brought about by the accidental use of a cupriferous ore for one or more of the ring of stones with which neolithic man enclosed his domestic hearth, the ore being reduced by contact with the fuel, presumably wood, and the charcoal produced from it. Copper oxides and carbonates are surface ores which would readily be reduced in this manner. The appearance of the bright red metal which had run down into the interstices of the hearth would inevitably attract attention, and the fact that this new and extraordinary material had taken the shape of the cavities into which it had run, together with its malleability, would suggest sooner or later that it could similarly be made to take the shape of any other mould, and that implements and weapons could be made from it. On attempting to repeat the experiment, it would be found that the phenomenon only resulted when a particular kind of stone was used, and the art of chemical metallurgy had begun.

It has been noted recently that there is a prospect underway of opening up a copper mine in Anglesea, which has been out of service for some years. Visitors who have been in the region and seen the appearance of the land around will probably agree that the prospect is likely to result favourably to the enterprisers and wish them well.

The following is from "The Shipping World" of October 17th:—

MERCURY VAPOUR BOILERS. TURBO-ELECTRIC PROPULSION.—Those who have followed at all closely the progress which has been made by Dr. W. L. R. Emmet, of the General Electric Co. of America, in the development of his binary fluid system, in which both mercury vapour and steam are utilised for turbine operation, will not express surprise that an attempt is to be made to apply that system to meet the requirements of more efficient marine propulsion. Speaking recently at the Propeller Club, Brooklyn, Dr. Emmet stated that after making many experiments with mercury vapour boilers in its own refineries, the Sun Oil Company of America had decided to have constructed an oil tanker, equipped with mercury vapour boilers, which could have a machinery output of between 3,000 and 4,000 shaft horse-power. The only further information Dr. Emmet gave with regard to the proposed ship was that the fuel consumption will be about the same as that of a vessel propelled by Diesel oil engines.

When, in 1914, Dr. Emmet first gave an account of his new invention in a paper read before the American Institute of Electrical Engineers, the plant with which he was then working had only the small output of 100 h.p. Since that time a 1,200 kw. turbine plant with a mercury vapour and steam boiler has been built and put into successful operation at Dutch Point, Hartford. Particulars of that plant are to be found in a paper read by Mr. W. J. Kearton, of Liverpool University, before the Institution of Mechanical Engineers in London, in November, 1923. On January 18th, 1924, some further details concerning the construction of the mercury boiler and turbine were published in "The Engineer," and in the issue of that journal of November 18th, 1927, there was an illustrated description of the latest and the largest mercury vapour turbine installation so far constructed.

The plant referred to is that which is being built by the General Electric Company, of Schenectady, for the South Meadow Power Station at Hartford. It will be designed to give an output of 10,000 kw. in a mercury vapour turbine, while a further 10,000 kw. will be developed in a steam turbine which will be supplied with 125,000 lb. of steam per hour from the mercury vapour condensers at a pressure of 350 lb. per sq. in. and a total steam temperature of 700 deg. F. The great advantage of using mercury which boils at a temperature of 677 F. at atmosphere pressure, compared with water at 212 deg. F., is that the temperature range of working is greatly increased, with a corresponding gain in thermal efficiency.

Pulverised Fuel.

The mercury boiler is of special interest. It will be arranged for pulverised fuel firing, and consists of seven vapour generating units. Each of these comprises a circular drum, furnished on its lower side with a series of thimble tubes, the ends of which project into the combustion chamber. Within each thimble tube there is a second close-fitting tube which is open at the top and nearly closed at the bottom. To this small aperture at the bottom of the inner tube there is welded a central tube of small diameter down which the mercury passes. It ascends between the walls of the two outer tubes, and, picking up heat, is delivered to the drum in vapour form at a temperature of over 880 deg. F. Neither the metal nor the vapour of mercury affects the tubes in any deleterious way, but to enable them to withstand better the heat of 800 to 900 deg. F. the thimble tubes are to be calorised with aluminium on the outside surfaces.

Various other ingenious devices have been introduced by Dr. Emmet with a view to reducing as far as possible the space in the boilers which it is necessary to fill with mercury, thereby economising in the amount of that rare metal which is required. Thus, in one form of boiler a large metal block is fixed within the boiler drum, and in another design two boiler drums are shown placed eccentrically one to the other, the narrow intervening space between the shells being employed as the mercury space. Both forms of boiler referred to differ in design from the earlier Hartford plant. In that plant a series of vertical hexagonal boiler tubes were employed, with circular upper ends welded into the tube plate.

In the new Hartford plant, 1,150,000 lb. of mercury will be vaporised per hour, a closed system being, of course, employed, so that practically no loss can take place and very little make-up will be required.

50 *per cent. Saving Claimed.*

The temperature of the mercury vapour will be about 884 deg. F., with a gauge pressure at the turbine of about 70 lb. per sq. in. It will be exhausted from the turbine at a temperature of 458 deg. F., and by giving up its heat to water in specially designed coolers it will be made to raise steam for the steam turbine and will be finally converted again into metallic mercury, falling back to the boiler under its own weight.

An interesting feature of the special mercury turbine is the adoption of an overhanging rotor with the idea of avoiding a turbine bearing, with its necessary sealing arrangements, on the pressure side of the machine through which a leak might possibly take place. Throughout the whole plant the greatest care is to be taken to prevent leakage of the very poisonous mercury vapour, and for this reason all ventilating ducts are to be arranged to discharge into a chimney, so that any vapour would be converted to mercury before it could emerge.

Dr. Emmet has calculated that with a mercury vapour boiler and turbine the saving in B.Th.U.'s per kilowatt of current generated would show a gain of 50 per cent. compared with the up-to-date 350 lb. steam turbine installation practice, and that this gain would be even more if compared with less economical steam installations. Presumably, it is from such figures that Dr. Emmet has worked out the results he quoted for a machinery installation for a liner of the size of the Cunarder *Mauretania*, with a designed output of 70,000 s.h.p. per hour. For such an installation it is claimed by Dr. Emmet that the application of the mercury vapour principle would mean a fuel saving of close upon £70,000 per year. Further, this cost of machinery equipment would be decreased by about £400,000, and there would be a saving of machinery weight of about 8,000 tons. Whether such figures are to be attained in actual practice remains to be seen. It is clear, however, from what has been said that while some working experience has been obtained with the mercury vapour boiler and turbine, more has still to be learned.

No real difficulties have yet been encountered, but, even if the savings referred to by Dr. Emmet are made, the question of compactness of plant and the additional complication introduced by the use of two working fluids would have to be carefully considered. As regards thermal efficiency, the recent figure given for the 1,200 kw. Hartford plant was about 32 per cent., which is surpassed by both the Scott-Still and the Doxford type of oil engine. An important economical factor is the probable effect of any serious increase in the number of mercury vapour plants, on the world's mercury markets. The output of the metal is at present strictly limited; there seems little possibility of its being greatly enlarged. It is for that reason that American engineers are working on the possibility of utilising other fluids in place of mercury vapour. The proposed installation referred to by Dr. Emmet in one of the tankers of the Sun Oil Company is of interest to engineers, and it may be looked upon as the logical outcome of the slow but steady development of an ingenious invention.

High Pressure Boiler Feed. Application to Merchant Ships. By Engr.-Capt. W. Onyon, R.N.—Mr. John Johnson's system of high pressure "boiler feed," as applied to ordinary merchant ships, merits further consideration. In continuation of the article in "The Shipping World" of June 27th, it would be well that the shipowner and superintendent engineer should be quite clear in their minds as to the advantages gained, and to be gained, by adopting the system installed in the cargo and passenger vessels recently completed and tested so satisfactorily by the Canadian Pacific Steamship Company, if it be realised at once that without that system the introduction of watertube boilers would be impossible.

In the first place, it is hardly necessary to remind superintendent engineers of the enormous gain there is, and always will be, if they use perfectly pure water for boiler feed purposes on every possible occasion, and it is remarkable that it is only quite recently that three large vessels of the Cunard Company have had fitted in their engine rooms, for use in cylindrical boilers, a water softener supplied by the Patterson Engineering Company, Ltd., of Windsor House, Kingsway, London, which has specialised in the purification of water for many years. The *Mauretania* is one of these three vessels with Scotch boilers so fitted, and her recent splendid voyages and record speeds, may, to some considerable extent, be attributed to the fact that her boiler efficiency has been increased by the treatment the feed water has received, owing to the installation of what is known as the "Basex" water softener. The steamers *Caronia* and *Carmania* have also had this system installed recently.

Impure Water Supplies.

There are, as is well known, two distinct types of impure water supplies; both objectionable from the boiler point of view. Suspended impurities are present in most river-waters and in supplies from wells and springs, and dissolved impurities are found in all water supplies—the most important being—carbonates and sulphates, chlorides and nitrates.

It has been the custom on occasion for many years past when working Scotch boilers on board ship, to make use of sea water as make-up feed, although most vessels are supplied with evaporators. I regret to say without the slightest hesitation that in many ships these evaporators have been seldom used in the past. It has been often stated that a small amount of sea water is good for sealing up leaky joints; and the chief engineer has not hesitated to use a certain amount of this source of make-up supply when his supply tanks have run short.

The enormous advantages gained by the use of pure water in the case of Scotch boilers, are evidently only now becoming appreciated: and in the case of watertube boilers, we are simply bound to use only distilled water if we wish to avoid serious trouble, or in fact, if we wish to succeed at all. It is now well known that two tubes of the high pressure watertube boilers of the *King George V.* running on the Clyde, burst at the end of last season, owing to the fact that shore water *untreated* had been used for make-up feed purposes, instead of distilled water, and the interior of the tubes had become coated and consequently overheated.

It is felt now that it will not be long before the fitting of watertube boilers in passenger liners, etc., will become general, as the excellent results obtained by the CanadianPacific Steamship Company's vessels have proved that it is quite safe to adopt this type of boiler if precautions are taken to keep the feed water pure, and to take advantage of the new designs evolved by Messrs. Yarrow and Co., Ltd., and other experts, both in boilers and in superheaters.

In this connection, it is hoped that high pressure boiler drum forgings will be obtained in future from makers in this country, and that it will not be necessary to import these forgings from Germany or Austria.

Decision of the C.P.R.

The *Duchess of Bedford* has now completed four round voyages and has left Liverpool on the fifth, and it can be safely said that she has proved herself a great success. The same remark also applies to the sister ship *Duchess of Atholl.* The fuel economy in both these vessels has exceeded expectations and the speed has been easily maintained. The two new vessels under construction on the Clyde, are to be slightly faster, and will be found to be improvements on the first two.

Invitations have recently been issued by the Canadian Pacific Steamship Company to several large firms, to quote for the construction of a large vessel of much higher speed, for the Atlantic trade, and the machinery and boilers are to be of similar type to the first four, and are expected to show even more economy. They will, it is thought, reach Sir Charles Parsons' ideal figure of ·6 lbs. per s.h.p. hour. It is quite certain that the Canadian Pacific Steamship Company would not proceed with this type of high pressure steam machinery unless it was quite satisfied as to the success of the earlier vessels so fitted.

It will be understood how important it is to have everything connected with machinery kept up to the highest point of efficiency. The keynote, as stated by Mr. Johnson, in his reply at the Civil Engineers' meeting, on Mr. Yarrow's and Lord Weir's paper, is distilled water for the boilers. The condition of the boilers in the two Canadian Pacific ships after four months' work, shows them to be quite clean and free from any sediment, the feed having been kept pure.

The Practice in the Royal Navy.

It should, therefore, in future, be quite unnecessary to fit steam purifiers, which occupy much room and mean additional fittings, in the steam spaces of the boilers. A steam dryer is all that is required, and this has been found sufficient in the express type boiler of the Italian Navy cruisers and torpedo board destroyers, which boilers are forced perhaps to a greater extent than in any known previous vessels.

In an article in " The Shipping World " of May 16th last, the subject of feed-water treatment for ships was fully discussed, and it cannot be too frequently referred to. In the Royal Navy with watertube boilers, it has for years been an Admiralty order with all new ships, to light up one of the boilers in the contractor's basin, and to evaporate and distil sufficient water to fill up all the boilers with distilled water, after they have been thoroughly cleansed.

I have quite recently had the privilege of making an inspection of an installation of high pressure boilers and machinery after some months' work at sea, and can without any hesitation state definitely that most successful results have been achieved.

The following are from " The Foundry Trade Journal " of October 18th :—

Craftsmanship and Science.—Many people who are familiar with the name of Sir William Bragg, the new President of the British Association, will know him in one or two capacities.

Primarily he is a brilliant physicist in the field of crystal structure. He is also a very charming lecturer at the Royal Institution on the occasion of their famous Christmas lectures to children. Two volumes of these have been published, and those who know one of these will recall the statement that " The production of cast iron was a tremendous step forward, one of those changes in a craft which not only make it a new thing, but even alter notably the history of the world." A statement of that kind coming from such an authority would give any founder new pride in his craft, and no one would be surprised to find his Presidential Address to the British Association dealing with Craftsmanship and Science.

Sir William spoke of the way in which science has promoted craftsmanship. The full appreciation of the use the craftsman makes of science is only appreciated when you consider a modern product of craftsmanship, such, for example, as a ship, and see how much of its construction is not merely dependent on science, but impossible without it. The screw or thrust block, the wireless outfit or the sounding apparatus, the refrigerator or the engine are essentially products of science. Craftsmanship has called upon science not in vain, and science has benefited by the craftsman's experience and knowledge.

There was an echo of the familiar in the claim that the most active modern industries are even founded on recent scientific research, such as electrical engineering, especially radio engineering and illumination, the motor industry, the rubber industry, the flying-machine industry, and that range of chemical industries that deals with dyes, explosives, fertilisers, artificial textiles, etc.

Sir William then seemed to distinguish between those industries which are in an early stage of development, in which design is changing rapidly and consequently in which mass production has not yet begun to take place, and those industries which have been so completely worked out that mass production has resulted. He appeared to argue that new applications of scientific knowledge, new ideas, new processes, new machines, always result in progress, and that mass production represents, so to speak, a static fixed period which is a lull in the process of development.

We cannot help but think that this point of view is unfortunate because it tends to perpetuate the false idea that mass production, or as we should prefer to call it for English purposes, continuous production, and craftsmanship are opposed. We believe that nothing is further from the truth. It is true to a certain extent that a modern luxury motor-car may involve craftsmanship of an order which transcends that put into a medium or low-priced car, but it is at least arguable that craftsmanship expended in producing a luxury car might have been deflected to some other purpose, since a medium or low-priced car meets all ordinary requirements. It may also be true that the mere aggregation of productive machinery at one point, whether it be for the production of soap, matches, or oxygen gas, may involve a large number of workers who are not required, in any sense of the term, to be craftsmen, but even here the qualities of the craftsman, *i.e.*, intelligence, integrity and skill, are required, even if not in the same way. So far as the engineering industry is concerned we feel convinced that mass production requires not only a high degree of industrial organisation, but a high degree of individual skill, just because there is no time or opportunity for little adjustments which are the hall-mark of the products entirely made by hand.

We do not regard mass production as a lull in progress, but rather as a period of minor change instead of major change. The mass production of motor cars does not prevent changes going on in car design and production; they are the features of every annual show. On the other hand, a major change like the introduction of an automatic gear-box or a successful steam car might make such a revolution that mass production would not become possible for some years. Mass production industries require and, indeed, actually use science, just as much as newly-born industries.

Foundry and Engineering Training on the Continent.* By Vincent Delport, Ing.E.C.P.—A number of years ago, it was stated by British members of the engineering profession on more than one occasion that there were no finer engineering ing schools existing than the French schools for teaching theory; but, they added, the engineer trained at these schools was of no practical use until he had passed two or three years in the works, and been confronted with the actual problems that arise in practice.

Recalling personal experience of twenty years ago, the author can state that this appreciation was correct at the time. Since then, however, considerable progress has been made in France in the direction of practical training, although much still has to be done. In the larger schools, general engineering theory still holds a preponderant place in the curriculum, with the result that the poor fellows, who were already worked pretty hard in past years, now have to exert themselves to a still greater extent.

One of the best examples of the really practical school in France is the Ecole Supérieure de Fonderie, or Foundry High

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* A Paper read last Thursday before the London Section of the Institute of British Foundrymen, Mr. W. B. Lake, presiding. The author is European Manager of the Penton Publishing Company.

School, created for the purpose of training foundry engineers. The object of this talk is to explain in some detail the organisation and the working of that school, and also to give some idea of the methods that obtain in Belgium. It is hoped to place the Ecole Supérieure de Fonderie in the general scheme of technical education existing in France at the present time.

What is an Engineer?—First of all it is necessary that everybody should agree on the meaning of the word "engineer." It is understood that in England the engineer is the expert who drives the engine on the non-stop journey from London to Glasgow, also the good friend who drives the engine on the speed track from Catford to Charing Cross. On the Continent, the engineer is the man who has gone through a course of training and obtained a diploma, or degree, at one of the engineering schools. In France, our friend the engine driver is called a "mechanician," and his mate, the stoker, is the "chauffeur." As a matter of fact, anybody in France who has acquired some knowledge of mechanics and who operates a shop can call himself an engineer. Attempts have been made to legislate on the matter and reserve the title of engineer for the benefit of those who have obtained a diploma in one of the recognised schools. It will readily be understood, however, that such legislation would be very difficult to apply; so in order to differentiate one generally adds certain letters, or the name of their training school, after the word "engineer." It is in the latter sense that the author will use the word in the course of this lecture.

The Creation of the Paris High School.—The first idea of a special school for the purpose of training foundry engineers was expounded by M. Ronceray, chairman of the committee of the Association Technique de Founderie, for training and apprenticeship, in a paper which he contributed to the Liége Foundry Congress in September, 1921. Following up this idea, M. Ronceray obtained the active support of the Syndicat Général des Fondeurs de France, the French employers' federation, and the scheme gradually materialised.

The Government gave its support to the scheme through the channel of the department of education, and the director of technical education was delegated to keep in touch with the Syndicat des Fondeurs. It was agreed that if the programme of the Syndicat were accepted, the ministry would share in the financing of the enterprise to the extent of one-half the cost, the other half of the funds being furnished by the foundry owners' federation; furthermore, the necessary lecture rooms, the foundry, and the pattern shop of the Ecole Nationale des Arts et Metiers, of Paris, were to be put at the disposal of the new institution. Since last year, with the exception of the foundry, the school has its own rooms and laboratories in the building of the Ecole des Arts et Metiers. On July 30, 1923, the scheme was definitely laid out by the Syndicat Général des Fondeurs and communicated to the representative of the Government. At the beginning of October, the names of the proposed directors of the future school were drawn up for approval, seven members of the board being designated by the Syndicat des Fondeurs and six by the Ministère de l'Instruction Publique, and on October 23rd the decree was signed authorising the opening of the school with the President of the Syndicat Général des Fondeurs as chairman of the board *ex-officio*. The school was opened on January 7th, 1924.

Candidates to the school are admitted after a competitive examination, which they must pass satisfactorily. Foreigners and non-diploma students can be admitted providing they do not exceed a certain proportion in numbers. At the opening of the school there were eighteen students including one foreigner and one non-diploma student. Regular students pay a fee of 1,500 francs (£12) for their year's studies; foreign students and special students pay 2,500 francs (£20). The course of study is comprehensive and, in fact, represents the last stage in the training of the foundry "engineer" or manager following his apprenticeship.

Recruiting Grounds.—Candidates for the Ecole Supérieure de Fonderie come from two sources; the foundries themselves, and the leading engineering schools. The general method which is followed for the foundry candidates can be summarised as follows:—

First of all the candidates must have spent at least one year's actual practice in a foundry. Dating from next year, this stage will be raised to eighteen months, and eventually to two years, because experience has shown that those who had had the most practice before hand derived the greater benefits from the school studies.

Apprentices are taken in certain foundries, usually between the ages of 13 and 16; during the first year they are given elementary notions on general subjects during one or two evenings a week; this constitutes the general preparatory course. During the next two years, the apprentices and also grown-up workmen who are willing to do so, follow a course of professional training. This course, which constitutes the first stage, is given in the various districts of the country wherever a number of foundries are grouped together. This preliminary course consists of lectures delivered in the evenings according to a programme laid down by the Syndicat Général des Fondeurs. At the end of this period, the apprentice who has at the same time been trained practically in the foundry, has become a qualified workman. If he wishes to improve himself, he then follows for one year a higher course which constitutes the second stage in his training as a specialist. This higher course is also given in each separate district, and generally takes the form of Sunday lectures and exercises. Thus the student becomes familiar with the elements of mathematics, physics, chemistry, drawing, etc. This complete system of instruction is developing according to a scheduled programme.

The workman now having been trained for three or four years, he may be employed in one plant or another. In fact, at any time he may choose not to pursue his studies and to remain in the ranks. But should he decide to reach the last stage and apply for admission to the Ecole Supérieure de Fonderie, he will have to follow the final preparatory course for one more year. The course is given at the various local trade schools twice a week in the evenings and prepare the student for the examination which he will have to pass in order to be admitted to the foundry school. This examination consists of both theoretical and practical tests.

The College-Trained Student..—The second class of candidates are those coming from recognised engineering schools. They must have had six months' actual practice in a foundry. These candidates submit to the practical examination and are exempted from the theoretical part. The other candidates, who have worked up from the shop, only submit to the theoretical tests. The object of the examination is not only to eliminate candidates in excess of the fixed number, but also to be sure they have sufficient knowledge of mathematics, physics, chemistry, drawing, etc., on the one hand, and of foundry practice on the other to enable them to follow the course with profit. Non-diploma students who wish only to follow the course on certain specialities are accepted. The course last seven months from January 1st to July 31st, the day's work lasting from 8.30 a.m. to 6 p.m.

The course consists of about 160 lectures on a variety of subjects, practical and theoretical, pertaining to foundry practice, and 70 practical exercises comprising laboratory work in the school's laboratories and actual practice in the foundry and pattern-shop, which are lent for that purpose by the Ecole d'A et M. During each lecture a certain amount of time is devoted to discussion, during which the students can obtain explanations on points which have not been well understood. They are also interrogated by the professors on the subject of the lesson. Each week the students visit a foundry plant, and once a month they report on these visits.

Examinations are Practical in Character.—At the end of the year's work in July a final test has to be passed by the students; this consists of the complete study of a moulding proposition. In 1927 the subject was: "The Moulding of a Tandem Cylinder for Steam Engine," and at the examination for July this year the subject was: "A Locomotive Superheater." The students must submit a complete study of the moulding and discuss it before the board of examiners. They are also questioned on any of the subjects that have made up the whole year's course. In the moulding proposition which the students had to study this year they had to calculate the approximate weight of the finished casting, the weight of metal necessary to make the casting, the thicknesses of metal that would have to be machined, the contractions in various directions. They had to choose the manner in which they would prepare the mould, and give their reasons for their choice. They had to study the making of the pattern and of the cores, state the quality of sand that they would use both for the moulding and for the cores, describe the methods they advocated for filling the mould, and state their reasons, describe the heat-treatment, if any, and calculate the time necessary to make the pattern, the core—briefly, the whole casting. A particularly difficult question was to calculate the reactions on the cores and on the various parts of the mould. The casting that they had to study was supposed to be capable of resisting a temperature of 450° C. This final test serves to classify the students as they come out of the school, but account is also taken of the average marks they have obtained during the year for their various studies, reports, etc. Even if they have satisfactorily fulfilled all these conditions, they are not granted the diploma of foundry engineer until six months after they have occupied a post in a foundry shop.

At that time they have to submit a thesis on a subject of their own choice and which relates to their actual experience in the foundry. It is only if this thesis is considered satisfactory that the diploma is finally granted to the student.

The following article is from "The Shipping World and Herald of Commerce," of November 7th. So also as quoted four brief comments:—

THE FUTURE OF AIR TRAVEL. Though the airship *Graf Zeppelin* has returned in safety to Germany from the United States, opinion as to the future of this new means of transportation must still be suspended. Many expert observers are satisfied that the airship has little or no future even as a means of communication in peace, whatever may be its use in war. "Neon," in his book, *The Great Delusion*, Mr. E. F. Spanner, in successive volumes, and other writers who can claim expert knowledge, either as navigators or naval architects, are still firmly convinced that natural laws are opposed to the airship. The passengers who travelled outwards to the United States in the *Graf Zeppelin* are certainly never likely to forget their unpleasant and even terrifying experiences as the airship plunged and then tilted upwards time and again, every movement suggesting to the passengers that their end had come. It may be too early to form a definite opinion on the possibilities of airship travel, for Commander Burney, M.P., as well as the sponsors of the *Graf Zeppelin*, and many enthusiasts in the United States, are agreed in thinking that the new airships, of improved design, which are now under construction, will completely vindicate the high claims which have been made.

It is quite another matter when we turn from the airship to the areoplane and, in particular, to the seaplane, the latter being obviously the instrument best fitted to meet the needs of islanders, who live in a country which is the pivot of a maritime Empire. The seaplane and the aeroplane have certainly come to stay as complementary agents to the railway, the motor car, and the steamship. Already remarkable progress has been made, not only in Europe and the United States and Canada, but also in Australia in developing regular aeroplane services, and the Air Ministry is now satisfied that the time is at hand when the air route to India will be no longer a dream but a reality, mails as well as large numbers of passengers being carried by air. It is true that practically all these services are being subsidised, and heavily subsidised. This is a development which is new in the history of transportation. It has still to be proved that air travel can be made to pay. There are many factors in this respect which are still unknown, such as the life of an aeroplane engaged on regular services in all weathers and the cost of operation when allowance has been made for depreciation and the wages of the ground staffs. This information cannot be available for a year or two, and in the meantime the construction of both aeroplanes and seaplanes is being improved as the result of experience.

Perhaps the most interesting proposal which has been put forward for some time is that of linking the United States with the West Indies, a matter of no little interest, we imagine, to British shipowners and traders, as well as to the Colonial Office. The success of this scheme might not only react on shipping traffic, but tend to the further Americanisation of these British Islands. The Atlantic Coast Line Railroad, the Florida East Coast Railway, and the Pan American Airways, Inc., intend to inaugurate on January 10th next, a through air-and-rail service between the United States and the West Indies over the first international train and 'plain system in America. The new system, which will operate through five countries will provide a fast *de-luxe* passenger serivce from New York City direct to Havana and through Cuba, Haiti and the Dominican Republic to San Juan, Porto Rico, and will be the first major stage, it is suggested, in the development of a direct passenger system to link the three America's.

This is perhaps the most ambitious scheme of aeroplane and rail co-operation yet planned. The aim is to provide through service from New York City and intermediate points *via* the Atlantic Coast Line Railroad and the Florida East Coast Railway to Miami, thence by giant multi-motor air liners over the Pan-American Airways system to Cuba and West Indies. It is hoped to operate a daily service to Havana, with a saving of 8½ hours and tri-weekly through service to Porto Rico, with a saving of 33½ hours between Havana and Santiago de Cuba and thence through Santo Domingo and Haiti and San Juan. The whole conception is very American, and its development will be watched on this side of the Atlantic with lively interest.

"I feel satisfied that before next year is out we shall be doing such a trade as ought to satisfy anybody. I don't, however, want a boom, for booms are never any good."—Sir WALTER RUNCIMAN, Bt.

"There is at present no evidence of any revival in shipbuilding. The coming winter is likely to be much worse than the last."—Sir ALEXANDER M. KENNEDY.

"From 1919 to 1926, in disputes between Capital and Labour alone, 11,000,000 workers were affected, and 357,000,000 working days were lost. This great loss in production was a loss both of wages and of interest, both of which could have been applied as purchasing power of products of existing plants and also for the purpose of improving productive assets."—Sir JOSIAH STAMP.

"Britain has recovered very largely her world position, and while the old supremacy is not yet completely restored, there is already achieved a definite supremacy. The chief and important tendency of British Industry is towards rationalisation, which means scientific organisation of industry and the balancing of production to consumption."—LORD MELCHETT.

IMPORTANCE OF INDUSTRIAL PEACE.—"Industrial peace is, in a general sense, perhaps of greater importance to shipowners than to any other section of the business community, as transport is almost the first cog in the commercial wheel to be affected by unrest, in addition to which our foreign competitors are keen enough to take advantage of any opportunities which come their way."—SIR FREDERICK W. LEWIS, Bt.

THE ESSENCE OF RATIONALISATION.—"The problems of industry are far too grave to be merely a pawn in a game played for political party advantage. The nation looks to industry to solve its own problems, and it will not look in vain. The age of reason is dawning in the industrial world. Industries are becoming co-ordinated and centralised. Workmen, too, are quietly but surely moving towards a system of union organisation by industry. That is rationalisation, and the nation is beginning to understand the implication of the word."—MR. FRANK HODGES.

From "The Shipping World," November 28th.

PULVERISED FUEL RESEARCH.—Experimental work in connection with the use of pulverised fuel is not being neglected by South Wales Colliery Undertakings. The Amalgamated Anthracite Company has erected and put into operation a plant for this particular fuel. Although as yet in an experimental stage, the operations are said to be on an extensive scale. The National Oil Refineries and a few other local undertakings are experimenting with the fuel for special purposes.

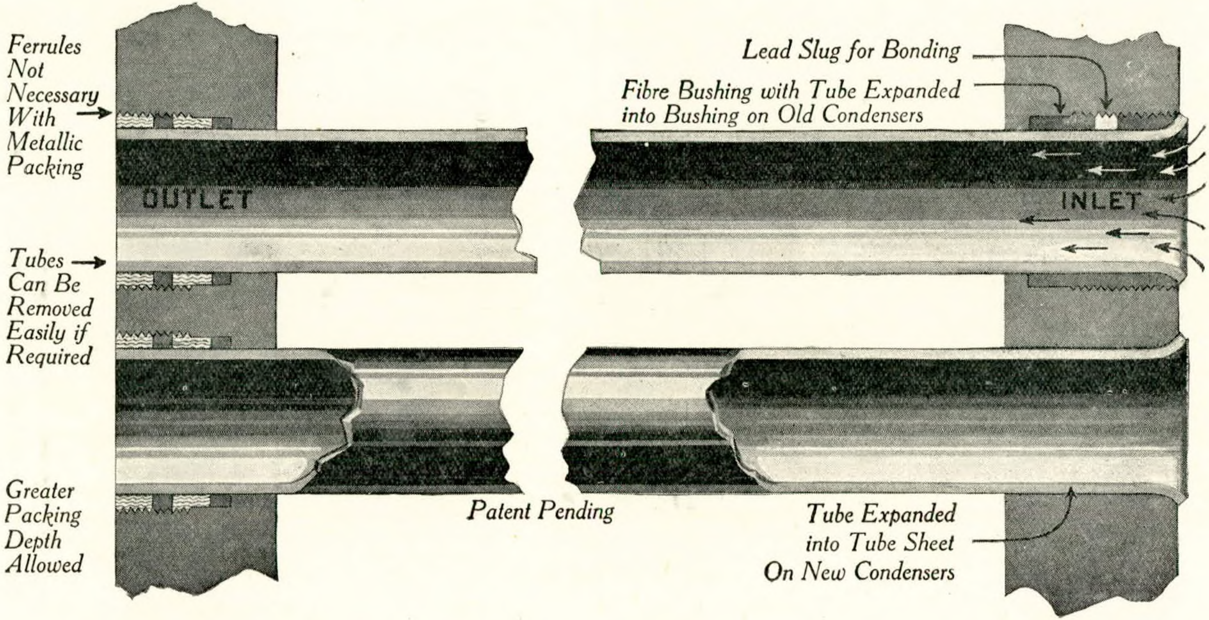
In the third section of his book, " Hints to Coal Buyers," Lieut.-Comdr. C. E. Evans, R.N.V.R., devotes several pages to some interesting remarks on the uses of pulverised coal. As regards its application to marine work, he remarks that " over 30 years ago the late Sir Wm. White, then the Naval Constructor to H.M. Navy, stated that powdered coal would some day supersede all other forms of power derived from coal, particularly for marine purposes, and it may be that his prophecy, made so long ago, is now approaching fulfilment."

Sir Wm. White was President of the Institute in 1893/4, and in his Presidential address, given at our dinner in September 1893, he dealt with the exercise of economy on the part of constructors and the watchful tact of operators, but did not then refer to powdered coal till the later years, as noted above.

An invitation has been extended to our members to visit premises adjoining the Savill Brewery in Maryland Road, Stratford, near Maryland Point station, where demonstrations are being given on the Brand system of pulverised fuel, as per the letter on our notice board. As the invitation did not arrive in time to give it in the December issue for the January demonstrations, members desirous of witnessing a demonstration will require to make application to The B. & L. Powdered Fuel, Ltd., care of Messrs. Savill Bros. Brewery, Maryland Road, Stratford, E.15.

Dear Sir,—I have read with interest the extract from "Marine Engineering and Shipping Age" which you quote under the heating of "Notes," in the December issue of the Transactions of the Institute of Marine Engineers.

The author in his condenser notes says, "Expanding the tubes into the tube sheets appeared at first a radical step, and with straight tubes no doubt might cause trouble, but with curved tubes to take care of expansion this difficulty appears to be overcome, and curved tubes firmly expanded into the tube sheets at each end are by way of being generally adopted."


Ferrules Not Necessary With Metallic Packing
Tubes Can Be Removed Easily if Required
Greater Packing Depth Allowed
OUTLET
INLET
Lead Slug for Bonding
Fibre Bushing with Tube Expanded into Bushing on Old Condensers
Patent Pending
Tube Expanded into Tube Sheet On New Condensers

It may therefore be of interest to state that at the present time there are many condensers in use in Germany, France and Belgium, fitted with straight tubes expanded into the tube sheets at the inlet ends, whilst the stuffing boxes at the outlet ends are packed with suitable flexible metallic packings which seal, and at the same time allow the tubes to expand and contract under temperature changes. This method has also been adopted by several Naval Powers, and I assure you it has proved to be a success. The absence of ferrules gives a better stream line for the cooling water, which naturally improves the efficiency and operation of the condenser.

The author also quotes a writer in the Liverpool "Journal of Commerce," wherein he states that he has yet to find a single case of failure for tubes composed of 70% copper and 30% zinc.

I have been privileged to examine many troublesome condensers and I have found that tubes composed of a mixture of 70% copper and 30% zinc (by analysis) appear to give the most trouble. The very fact that many Superintendent Engineers are going to the expense of fitting condensers with tubes which contain a mixture of copper and nickel surely proves that they have not been altogether satisfied with tubes of the 70% copper and 30% zinc mixture.

Yours faithfully, J. BARTLE HASTINGS (Member).

Engineering Conference, Tokyo, October, 1929.

As it may be possible for some of our members in or near Eastern waters to attend the meetings in Tokyo, the following details of the arrangements are given for general information:—

TENTATIVE GENERAL PROGRAM.

Oct. 25 (F) }
26 (Sa) } Nikko Excursion (A Party): Hakone Excursion (B Party).

27 (S) }
28 (M) } Nikko Excursion (B Party): Hakone Excursion (A Party).

29 (T) Opening Ceremony and General Meeting.
30 (W)* Sectional Meetings.
31 (Th) Sectional Meetings.

* Opening Ceremony of the Tokyo Sectional Meeting, World Power Conference.

Nov. 1 (F) Sectional Meetings.
2 (Sa) Tokyo Excursion and Yokohama Excursion.
3 (S) Kamakura Excursion.
4 (M) Sectional Meetings.
5 (T) Sectional Meetings.
6 (W) Sectional Meetings.
7 (Th)† General Meeting and Closing Ceremony.
8 (F), 9 (Sa) Yokosuka Excursion, Omiya Excursion, Atami Excursion, Fuji, Excursion, Ashio Excursion, Hitachi Excursion, Sendai Excursion, Haranomachi Excursion and Inawashiro Excursion.
10 (S) Free day: Evening—Leave for Nagoya.
11 (M) Nagoya Excursion:
Evening—Leave for Kyoto.
12 (T), 13 (W), 14 (T), 15 (F), 16 (Sa) Stay in Kyoto; Kyoto Excursion. Nara Excursion. Osaka Excursion. Kobe Excursion.
17 (S) Free Day:
Evening—Leave for Miyajima and Kyushu.
18 (M), 19 (T), 20 (W), 21 (Th), 22 (F) Miyajima Excursion and Inland Sea Sailing. Kyushu Excursion, Parties A. B. & C.

Afternoon excursions including plant-visitations, sightseeing and inspection tours in the vicinity of Tokyo are scheduled for the afternoons of October 29th and 30th and November 1st, 4th, 5th and 6th.

SESSIONS.

The opening ceremony of the World Engineering Congress will take place on Monday, October 29th, 1929, and the closing meeting on Tuesday, November 7th, 1929. During the period of the Congress, sectional meetings will be held for the purpose of reading and discussing the various papers presented by members, with a view to assembling the results of the research and practice of engineering and passing resolutions when deemed necessary. The scope of the subjects to be dealt with at the Congress is shown in the following technical programme.

† Closing Ceremony of the Tokyo Sectional Meeting, World Power Conference. (Afternoon).

Technical Programme.

1. General problems concerning engineering:
   Education, Administration, Statistics, Standardisation, International Co-operation of Engineers, etc.
2. Engineering Science:
   Strength of Materials, Thermodynamics, Hydraulics, Electricity and Magnetism, and other Scientific Researches.
3. Precision Machines and Instruments.
4. Architecture and Structural Engineering:
   Architectural Designing, Development of Modern Architecture, Preservation of National Memorials, Housing Problem, Bridge Engineering, Fire Protection, Earthquake-Proof Construction, Framed Structure, Masonry Construction, Reinforced-Concrete Construction, Earth Problem, Mechanical and Electrical Equipments of Buildings, etc.
5. Public Works:
   Harbour Engineering, River Engineering, Canals, Highways, Irrigation, Waterworks, Sewages, City Planning, etc.
6. Railway Engineering:
   Location, Construction, Operation, Rolling Stocks, Machinery, Signalling and Safety Appliances, Electrification, Street Railways, etc.
7. Transportation:
   Land, Water and Aerial Transportation.
8. Communication:
   Telegraph, Telephone, Wireless Telegraph and Telephone, Radio Broadcasting.
9. Power:
   Resources, Waterpower Plant, Steampower Plant, Utilisation of Natural Steam, Tidal Power, Transmission and Distribution, etc.
10. Electrical Engineering:
    Generators and Motors, Transformers and Converters, Measuring Instruments, Electric Switch Gears, Power Cables, Vacuum Tubes, Electrical Heating Appliances, etc.

11. Illuminating Engineering:
    Electric Lamps, Illumination, etc.
12. Mechanical Engineering:
    Heat Engines and Boilers, Hydraulic Machinery, Pneumatic Machinery, Machine Tools and Machines for Manufacturing, Machines for Conveyance, Ordnance, Mechanism and Machine Design, Heating and Ventilation, etc.
13. Refrigerating Industry:
    Refrigerating Machinery, Refrigerating Plants, Insulation, Cold Storage, Ice-Making Industry, Transportation of Refrigerated Goods, Refrigeration in Chemical Industry, Agriculture and Hygiene, etc.
14. Textile Industry:
    Textile Raw Materials, General Spinning, Silk Throwing, Rayon Spinning, Weaving, Knitting, Textile Finishing, Textile Machinery, Mill Management, etc.
15. Shipbuilding and Marine Engineering:
    Theoretical Naval Architecture, Construction of Ships, Governmental and Classification Society's Regulation Rules for Shipbuilding and Marine Engineering, Main and Auxiliary Machinery, Equipments of Shipbuilding Yards, Ship Equipments, Life-Saving Appliances, etc.
16. Aeronautical Engineering:
    Aerodynamics, Aeroplanes, Dirigibles, Aero-engines, Air Propellers, Equipments, Instruments, etc.
17. Automotive Engineering:
    Chassis, Bodies, Automotive Engines, Motor Car Equipments, etc.
18. Chemical Industry:
    Acid and Alkali Industry, Artificial Fertiliser and Fixed Nitrogen, Electrochemical Industry, Compressed and Liquified Gas Industry, Ceramics, Explosives and Coal Tar Products, Cellulose Industry (Paper, Celluloid, Artificial Silk), Sugar Industry, Brewing and Alcohol Industry, Fat and Soap, Paint and Varnish, Rubber Industry, etc.
19. Fuel and Combustion Engineering:
    Solid, Liquid and Gaseous Fuels and their Appliances.

20. Mining and Metallurgy:
    Economic Geology, Mining (Ores, Coal and Petroleum), Dressing, Iron and Steel, Metal and Alloys, Mechanical Technology, etc.
21. Engineering Materials.
22. Scientific Management.
23. Miscellaneous.

Directions Regarding Papers.

1. Papers shall be typewritten, using double spacing, on one side of the page only. Papers, should as far as possible not exceed 8,000 words. Papers, accompanied with two copies, should reach the Secretary of the World Engineering Congress not later than April 1st, 1929.

2. No special restriction is put upon the number of papers to be presented by a single contributor.

3. Each paper shall be accompanied by an abstract in English, preferably not to exceed 500 words. A brief description of the author's career should also be attached.

4. Drawings and diagrams shall be made in jet black ink on white paper. Letterings shall be in plain block letters. Special attention should be paid in order to facilitate reducing the size of drawings and diagrams suitable for the papers. Photographs should be clear prints ready for reproduction without re-touching.

5. The Technical Programme indicates the scope of the subjects to be dealt with, but not necessarily the titles of the papers.

6. Advance copies of papers will be ready for distribution before the opening of sessions.

7. Papers presented at the Congress will be published either in full, or in abstract, in the Transactions of the World Engineering Congress.

EXCURSIONS AND INSPECTION TOURS.

The excursion programme is so arranged that the members may be afforded every opportunity of seeing Japan in her different aspects. In the programme are included visits to a number of important industrial and engineering establishments as well as the most attractive places of the Island Empire. The excursions are conducted in several groups in any of which members are entitled to join at their own choice.

(A) *Pre-Congress Excursions.*

Two excursions are scheduled before the opening of the Congress, one to Nikko and the other to Hakone. These are pleasure trips and are intended for promoting intimacy among the members and their families.

The trips are made in two groups, each party visiting the two places alternately during the four days, *i.e.*, October 25th, 26th, 27th and 28th, 1929.

Nikko and Hakone Excursions.

Party A.

Oct. 25 (F): Morning—Leave Ueno Station, Tokyo. Noon—Arrive in Nikko, Sightseeing. Night—Stay at the Nikko Hotel.

Oct. 26 (Sa): Morning—Auto trip to Lake Chuzenji (Alt. 1,400m.), Kegon Falls, etc. Afternoon—Return to Nikko. Evening—Return to Tokyo.

Oct. 27 (Su): Morning—Leave Tokyo Station. Noon—Arrive at Odawara, whence to Miyanoshita by automobile. Afternoon—Arrive in Hakone and sightseeing in Gora Park, etc. Night—Stay in Hakone.

Oct. 28 (M): Morning—Auto trip to Lake Ashinoko, Mishima, etc. (sightseeing near the foot of Mt. Fuji on way to Mishima). Afternoon—Leave Mishima by train. Evening—Return to Tokyo.

Party B.

Oct. 25 (F): Morning—Leave Tokyo Station. Noon—Arrive at Odawara, whence to Miyanoshita by automobile. Afternoon—Arrive in Hakone and sightseeing in Gora Park, etc. Night—Stay in Hakone.

Oct. 26 (Sa): Morning—Auto trip to Lake Ashinoka, Mishima, etc. (sightseeing near the foot of Mt. Fuji on way to Mishima). Afternoon—Leave Mishima by train. Evening—Return to Tokyo.

Oct. 27 (Su): Morning—Leave Ueno Station, Tokyo. Noon—Arrive in Nikko, sightseeing. Night—Stay at the Nikko Hotel.

Oct. 28 (M): Morning—Auto trip to Lake Chuzenji (Alt. 1,400m.), Kegon Falls, etc. Afternoon—Return to Nikko. Evening—Return to Tokyo.

NOTE.—Nikko is a Mecca for tourists. The gorgeous shrines and temples of Nikko, the stately cryptomeria avenue, the mountains, walks, lakes, waterfalls and other places of interest there, are acclaimed by both foreigners and Japanese. The district is especially attractive in October, when its foliage is a brocade of brilliant colour. The shrines and temples and the mausolea of the illustrious Iyeyasu, founder of the Tokugawa Shogunate (1600-1868), and of Iyemitsu, his grandson, almost as renowned, are famous the world over. Lake Chuzenji (Alt. 1,400 m.): The mountain walk to Chuzenji is a favourite trip for Nikko visitors. Graceful Kegon Waterfall, the outlet of the lake, one of the most beautiful natural objects of the district, and other waterfalls are seen on the way. Hakone: Few visitors to Japan fail to visit the Hakone district, noted for its mountain scenery, invigorating climate, and its hot springs. The district, popularly known as Mt. Hakone, is the crater of an extinct volcano. Lake Ashinoko (Alt. 1,400 m.): Famous for its reflection of Mt. Fuji. On this walking or motor-car trip the route is through Kowakidani and Ashinoyu, both noted for their mineral springs, and along the lakeshore the road is a noble cryptomeria avenue, leading to the site of the ancient Hakone Barrier gate, where in olden days the passports of travellers were examined.

On the way to Mishima, members can command the picturesque view of Mt. Fuji beyond the mountain slopes of Hakone. The panoramic view of the world famous Fuji-San from the train is beyond description.

(B) *Inter-Congress Excursions.*

Tokyo Excursion.

Nov. 2 (S): Inspection of the Post-Earthquake. Reconstruction work.

Yokohama Excursion.

Nov. 2 (S): Inspection of the Post-Earthquake. Reconstruction work.

Kamakura Excursion.

Nov. 3 (Su): *Meiji Setsu* (National holiday to commemorate the Emperor Meiji). Morning—Leave Tokyo Station for Kamakura. In Kamakura, sightseeing.

NOTE.—Kamakura is visited by the traveller if only to see its famous Daibutsu, the most impressive bronze image of Buddha in the world. There are, however, many places in Kamakura and its vicinity worth visiting. Historically, Kamakura is noted as the place where Minamoto Yoritomo, the first Shogun of Minamoto Clan, set up his government at the end of the 12th century, and during the ensuing 200 years the town was an active administrative centre.

Afternoon Excursions.

During leisure hours between sessions of the Congress, members will visit several important scientific institutes and engineering and industrial factories in the vicinity of Tokyo, including the Institute of Physical and Chemical Research Institute, the Imperial Industrial Laboratory, the Aeronautical research Institute, the Shibaura Engineering Works, the Tokyo Electric Works, beer breweries, power stations, cement factories, confectionaries, etc.

Special arrangements will be made for ladies in connection with sightseeing and shopping in Tokyo.

(C) *Post-Congress Excursions.*

Yokosuka Excursion.

Nov. 8 (F): Morning—Leave Tokyo Station. Noon—Arrival in Yokosuka; visit the Naval Engineering Works, the Naval Dockyards, etc. Evening—Return to Tokyo by train.

Omiya Excursion.

No. 8 (F): Morning—Leave Ueno Station, Tokyo; in Omiya. Visit the Omiya Engineering Works of the Japanese Government Railways, the Katakura Filature Mills, etc. Evening—Return to Tokyo by train.

Atami Excursion.

Nov. 8 (F): Morning—Leave Tokyo Station. Noon—Arrive in Atami; inspection of the Tanna Tunnel Work. Night—Spent at hotels with hot springs.

Nov. 9 (S): Return to Tokyo by train.

Fuji Excursion.

A pleasure trip to the lake district of Mt. Fuji. The number of participants of this trip is limited to 50: (30 in hotel and 20 in Japanese inns).

No. 8 (F): Morning—Leave Tokyo Station for Gotemba whence to Lake Shoji by automobiles and boats; visit Lake Yamanaka, Lake Kawaguchi, Lake Sai-ko, and Lake Shoji. Night—Spent at a hotel and Japanese inns.

Nov. 9 (S): Visit to the Panorama Peak near Lake Shoji from where the magnificent view of Mt. Fuji is to be commanded. Noon—Leave Lake Shoji to Otsuki by automobiles and boats. Evening—Arrive in Shinjuku Station, Tokyo.

Ashio Excursion (For men only: limit 20).

Nov. 8 (F): Morning—Leave Ueno Station, Tokyo. Late afternoon—Arrive in the Ashio Copper Mines; visit to the Dressing Mills. Night—Spent in Mining Camps.

Nov. 9 (S): Inspection of the Mines and the Smeltery. Evening—Return to Tokyo by train.

Hitachi Excursion (For men only: limit 20).

Nov. 8 (F): Morning—Leave Ueno Station, Tokyo. Noon—Arrive in Sukegawa; inspection of the Hitachi Copper Mines and the Smeltery. Night—Spent in Japanese inns at Sukegawa.

Nov. 9 (S): Evening—Return to Tokyo by train.

Haranomachi Excursion (Limit 50).

Nov. 7 (Th): Night—Leave Ueno Station, Tokyo. Night—Spent in train.

Nov. 8 (F): Late morning—Arrive in Haranomachi. In Haranomachi—Visit to the Radio Station (The Haranomachi Radio Station is a transmitting station constructed by radio engineers of the Department of Communications. First operated for the Trans-Pacific Radio Communication on March 26th, 1921). Evening—Leave Haranomachi. Night—Spent in train.

Nov. 9 (S): Morning—Return to Tokyo.

Sendai Excursion (Limit 50).

Nov. 8 (F): Night—Leave Ueno Station, Tokyo. Night—Spent in train.

Nov. 9 (S): Morning—Arrive in Sendai: In Sendai—Visit the Metal Research Institute, Tohoku Imperial University; pleasure trip to Matsushima, one of the scenic trio of Japan. Evening—Leave for Tokyo through Sendai. Night—Spent in train.

Nov. 10 (Su): Morning—Arrive at Ueno Station, Tokyo.

Inawashiro Excursion (limit 50).

Nov. 8 (F): Night—Leave Ueno Station, Tokyo. Night—Spent in train.

Nov. 9 (S): Morning—Arrive in Inawashiro: In Inawashiro —Visit Lake Inawashiro, the Inawashiro Hydro-Electric Power Plant; train trip to Aganogawa Gorge, famous for brilliant autumnal beauty. Evening—Change train at Niigata. Night—Spent in train.

Nov. 10 (Su): Morning—Return to Tokyo.

Western Japan Excursions.

This is one serial trip, but members are at liberty to join the party at any place they prefer. Schedules at the places on the programme are given independently for the convenience of members wishing to visit particular places only.

Nagoya Excursion.

Nov. 10 (S): Night—Leave Tokyo Station.

Nov. 11 (M): Morning—Arrive in Nagoya: In Nagoya—Inspection of industrial factories and engineering works in the City and the vicinity. Night—Leave for Kyoto. Night—Spent in train.

Note.—Nagoya Castle, one of the most famous castles in Japan, formerly occupied by the Tokugawas; the Cloisonné Factory; the Violin Factory; the Porcelain Factory; the Engineering Works, etc. The visit to the large dam of the Kisogawa and the Hydro-Electric Plant can be included in the programme at members' request.

Kyoto Excursion.

Nov. 12 (T): Morning—Arrive in Kyoto from Nagoya: In Kyoto—Sightseeing.

Nov. 13 (W): All day—Sightseeing in Kyoto.

Nov. 14 (Th) Morning—Leave Kyoto for Nara.

Note.—Kyoto, being the ancient capital of Japan (Emperor Kammu, 782 A.D. to Emperor Komei, 1847 A.D.) has a number of famous places and old sites near the City.

Nara Excursion.

Nov. 14 (Th): Morning—Arrive in Nara from Kyoto: In Nara—Sightseeing. Evening—Return to Kyoto.

Note.—Nara, being the old capital of Japan (up to 800 A.D.), abounds in old architectures and art pieces. Among the points of interest are the Horyuji Temple, one of the oldest wooden structures in the world built in about 600 A.D. and the Daibutsu, the biggest bronze image of Buddha in the world made in the year of Tempei, about 750 A.D. etc.

Osaka Excursion.

Nov. 15 (F): Morning—Arrive in Osaka from Kyoto: In Osaka—Sightseeing. Evening—Return to Kyoto.

NOTE.—Osaka, being the commercial and industrial centre of Japan, is the most interesting city for engineers. Among the places to be visited are the steel works, the glass factories, the Osaka locomotive works, the tabi (Japanese Footwear) factories, the spinning mills, the dye factories, the Industrial Research Institutes, etc.

Kobe Excursion.

Nov. 16 (S): Morning—Arrive in Kobe from Kyoto: In Kobe—Sightseeing.

NOTE.—Textile Factories, Spinning Mills, etc.

Nov. 17 (Su): Evening—Leave Kyoto for Miyajima.

Members wishing to continue the trip to Kyushu are requested to take one of the following two routes: (a) Miyajima excursion by train. (b) Inland Sea Sailing.

Miyajima Excursion (Limit 100).

Nov. 18 (M): Morning—Arrive at Miyajima Station: Ferry to Miyajima. In Miyajima—Sightseeing. Evening—Leave Miyajima Station for the Kyushu trip.

NOTE.—The Sacred Island, one of the scenic trio of Japan, is considered one of the most beautiful shrine sites in Japan, reached by ferry, a short walk from the station. It is widely known for its shrine, Itsukushima, which at high tide appears to float upon the water, for its singular red "Torii" in the sea, and for the deep-red richness of its November maple foliage.

Inland Sea Sailing (Limit 100).

Nov. 17 (S): Evening—Leave Kyoto; leave Kobe by steamer.

Nov. 18 (M): Sightseeing voyage.

NOTE.—The Inland Sea, extending for about 390 km. along the S.W. coast of the main island, from Kobe to Shimonoseki, is dotted with scores of islands of all shapes and sizes, and the seascape view is ever changing as one voyages on its historic waters. The sea varies from 12 km. to 65 km. in width.

Kyushu Excursions.

On the morning of November 19th, both the Miyajima and the Inland Sea Parties will arrive in Shimonoseki, where the members are divided into three new parties.

Party A. (Limit 70).

Nov. 19 (T): Morning—Leave Moji. Afternoon—Arrive in Beppu (A Spa). Night—spent in Beppu with Party B.

Nov. 20 (W): In Beppu—Visit the hot-spring ponds and geysers. Afternoon—Return to Moji. Evening—Leave for Nagasaki.

Nov. 21 (Th): Morning—Arrive in Nagasaki. In Nagasaki—Visit the Mitsubishi Dockyards and Engineering Works. Night—Leave for Moji.

Nov. 22 (F): Morning—Arrive in Moji. Visit the Government Steel Works in Yawata.

Party B (Limit 30).

Nov. 19 (T): Morning—Leave Moji. Afternoon—Arrive in Beppu (A Spa). Night—Spent in Beppu with Party A.

Nov. 20 (W): In Beppu—Visit Hot Springs and Geysers. Afternoon—Leave Beppu for Moji. Evening—Separated from Party A on way to Omuda. Night—Spent in train.

Nov. 21 (Th): Morning—Arrive in Omuda, visit the Miike Colliery and the Miike Harbour. Evening—Leave Omuda for Moji whence to Shimonoseki by Ferry. Night—Spent in in Shimonoseki.

Nov. 22 (F): Visit the Government Steel Works in Yawata.

Party C (Limit 100).

Nov. 19 (T): Morning—Leave Moji. Noon—Arrive in Hakata, visit the Kyushu Imperial University. Evening—Return to Moji, whence to Isahaya by train. Night—Spent in train.

Nov. 20 (W): Morning—Arrive Isahaya, whence to Unzen (A Spa) by automobile. Day and night—spent in Unzen.

Nov. 21 (Th): Morning—Leave Unzen for Nagasaki. In Nagasaki—Visit the Dockyards. Night—Leave Nagasaki.

Nov. 22 (F): Morning—Arrive in Moji, visit to the Government Steel Works in Yawata.

Note.—Nagasaki ranking seventh among the cities of Japan, has the distinction of being one of the oldest ports of the Empire opened to foreign trade (1570). Among its notable industries are the Mitsubishi Engine Works and Dockyards and the Takashima Colliery, which produces high grade coal.

Beppu.—Natural hot water is so abundant in Beppu that it is provided at the railway station for travellers' hand washing, and besides baths in many private houses, bathing facilities are installed in every school, police station and in the prison. Extraordinary sights are the ten or more solfataras or pools of the district which boil and bubble and steam. The Beppu sand baths are renowned for their miraculous cures.

Unzen.—The place is famous for the picturesque scenery. The bird's-eye view of the rugged coast line from the mountain is a feast to the tourists' eyes. Golfers may find an ideal links here.

The visit to the Government Steel Works in Yawata marks the close of the official excursions of the Congress.

Notice Regarding Excursions.

1. Members from overseas will be provided with Free Passes for use on the Japanese Government Railways. A Free Pass entitles a member and one member of his family (one only) with him to travel without payment on any of the Government railway lines in the country during the Congress. Free Passes do not cover express fares and sleeping car charges.

2. Travel expenses, including charges for sleeping cars, tram-cars, automobiles and rikisha, and cost of meals en route, are payable to the W. E. C. Tokyo Office upon arrival of members in Tokyo.

3. Hotel expenses are to be paid individually.

4. Applications for excursions are to be sent to the W. E. C. Excursions Committee, W. E. C. Office, Marunouchi, Tokyo, not later than October 1st, 1929. Members are requested to send in their applications without delay, as the application lists close as soon as the allowable number is reached. An application form is attached at the end of this announcement.

HOSPITALITIES.

A number of banquets, tea parties and garden parties are being arranged for participants of the Congress. A Grand Official Banquet is to be given on November 7th, 1929, the last day of the Congress. Two outstanding features of the social functions are a Garden Party at an Imperial Detached Palace and a Grand Banquet given by the Prime Minister. A Ladies' Entertainment Committee will be organised to take care of the ladies accompanied by members of the Congress.

The Nippon Yusen Kaisha (N. Y. K.) has offered a special reduction of 15 per cent. from the regular passage fares for the Congress passengers coming by the N.Y.K. lines from different ports of the world, with the exception of those of the Pacific coasts. A reduction on the Pacific lines is now under negotiations by the companies concerned.

APPROXIMATE TRAVEL EXPENSES OF EXCURSIONS.

Name of Excursion.	Travel Expenses Exclusive of Hotel Charges.	Hotel Charges with Meals per Night	Night spent at Hotels
PRE-CONGRESS EXCURSIONS.			
	Yen	Yen	
Nikko (Oct. 25, 26, 27 and 28)	15.00	S 11.00 to 18,00 D 22.00 to 47,00	One Night
Hakone (Oct.25, 26, 27 and 28)	15.00	S 12.00 to 22.00 D 25.00 to 35.00	One Night
INTER-CONGRESS EXCURSIONS.			
Tokyo (Nov. 2)	5.00		
Yokohama (Nov. 2)	5.00		
Kamakura (Nov. 3)	8.00		
POST-CONGRESS EXCURSIONS.			
Yokosuka (Nov. 8)	2.00		
Omiya (Nov. 8)	2.00		
Atami (Nov. 8-9)	4.00	S 10.00 to 17.00 D 22.00 to 40.00	One Night
Fuji (Nov. 8-9)	25.00	S 9.00: D 18.00	One Night
Ashio (Nov. 8-9)	5.00	Mining Camp 10.00	One Night
Hitachi (Nov. 8-9)	5.00	J 10.00	One Night
Haranomachi (Nov. 7-8-9	20.00		
Sendai (Nov. 8-9-10)	25.00		
Inawashiro (Nov. 8-9-10)	20.00		
Nagoya (Nov. 10-11)	20.00		
Kyoto Nov.11-12-13)	7.00		
Nara (Nov. 14)	10.00	S 10.00 to 22.00 D 25.00 to 65.00	Five Nights from Nov. 11 to 15 at (Kyoto)
Osaka (Nov. 15)	10.00		
Kobe (Nov. 16)	10 00		
Miyajima (Nov. 17-18-19	25.00		
Inland Sea Sailing Nov. 17-18-19	25.00		
Kyushu (Party A) Nov. 19-20-21-22)	40.00	S 5.00 to 7.00 D 11.00 to 15.00	One Night
Kyushu (Party B) (Nov. 19-20-21-22)	25.00	S 4.00 to 8.00 D 11.00 to 30.00	One Night
Kyushu (Party C) (Nov. 19-20-21-22)	40.00	S 5.00 to 12.00 D 11.00 to 20.00	One Night

Note—*S=Single Room, D=Double Room, J=Japanese Inn.*

During the Congress, members will be provided with Government Railway Free Passes (1st Class). Each pass entitles a member with one member of his family (one only) to travel without payment.

The similar privilege will be granted by the South Manchuria Railways for the Congress travellers.

IMPORTANT INFORMATION.

Passage Fares (From European Ports).

Nippon Yusen Kaisha (N.Y.K.—Fares—London to Kobe or Yokohama, 1st class, £110; 2nd class, £76. Marseilles to Yokohama, 1st class, £106; 2nd class, £66.

Peninsular and Oriental Steam Navigation Co.—Fares—London to Kobe to Yokohama, 1st class, £110; 2nd class, £76. Marseilles to Yokohama, 1st class, £106; 2nd class, £74.

Hugo Stinnes Linien.—Fares—Hamburg or Rotterdam to Japan, 1st class, £90-75.

Hamburg America Line.—Fares—Hamburg or Rotterdam to Japan, 1st class, £90-75.

Norddeutscher Lloyd.—Fares—Hamburg or Rotterdam to Japan, 1st class, £90-75; 2nd class, £58-53.

(From U.S.A. and Canada).

Nippon Yusen Kaisha (N.Y.K.).—Fares—Seattle to Yokohama, 1st class, $195. San Francisco to Yokohama, 1st class, $300; 2nd class, $175. Honolulu to Yokohama, 1st class, $226; 2nd class, $133.

Osaka Shosen Kaisha (O.S.K.).—Fares—Seattle to Yokohama, 1st class, $195.

Dollar Steamship Line.—Fares—Seattle to Yokohama, 1st class, $300. San Fraicisco to Yokohama, 1st class, $300.

Canadian Pacific Steamships Ltd.—Fares—Vancouver to Yokohama, 1st class, $300; 2nd class, £210-185.

Trans-Siberian Route.—Fares (Approximate)—Moscow to Tokyo (via Warsaw), 1st class, £45; Berlin to Tokyo (via Warsaw), 1st class, £55; Paris to Tokyo (via Warsaw), 1st class, £63; London to Tokyo (via Warsaw), £64.

Should any special information or tickets be wanted, application should be made as early as possible to World Engineering Congress, Nihon Kogyo Club Buildings, Marunouchi, Tokyo, Japan. Any members who are willing to write papers to be read at the Conference might kindly let us know as early as possible.

A communication has been received from The Air Express Service, Croydon, stating that they will arrange for the carriage of passengers to the Engineering Conference in Japan, and those who can go are desired to book their passage as soon as possible.

It is pointed out that time will be saved travelling by air, rather than by land and sea.

Boiler Explosion Acts.

REPORT No. 2,953. S.S. *Clearway*.

Report No. 2,953 deals with the failure of a stop valve on the S.S. *Clearway* on September 5th, and the cause was investigated and reported upon by Mr. J. H. Ferguson, B.T. Surveyor, Barrow-in-Furness.

The S.S. *Clearway* was built to Lloyd's Class 100 A1 by Messrs. Alex. Hall and Co., of Aberdeen, in 1927 for the James Dredging Company, of London, and was a steam hopper barge fitted with a crane and grab dredger. The vessel was delivered at Southampton by the builders in March, 1927, and was laid up and idle until purchased by the present owners in April, 1928.

The after capstan, with the stop valve in position, was supplied to the builders of the dredger by the original owners, who had obtained it from another grap dredger which they purchased at auction from the Government base at Richborough, and which they had subsequently dismantled. It was refitted prior to despatch to Aberdeen in 1926, but no replacements were then made. This capstan was originally fitted on board a Government ship in 1915, and the makers of it have stated that, when new, a stop valve of a different pattern was provided; therefore, the history of the one in question could not be traced.

It was Mr. Parr's duty to attend to the after capstan when shifting billet during dredging operations at Whitehaven, and he stated that the slack end of the mooring wire rope sometimes got caught between the stop valve cover and the end of the deck steam pipe guard plate, which is 8 inches broad and $\frac{3}{8}$ inch thick, in such a way that the valve cover tended to slacken back as the wire passed by. Any such restricting of the wire rope would have the effect of starting the cover to be unscrewed, if not properly jointed, and further movement would most likely be made when working the hand wheel on opening the valve, and not returning when closing it. The spindle of the valve was found to be bent after the explosion and was renewed before an inspection was made, but the cover when once started could be unscrewed easily by the hand wheel with the valve fully open, and it is possible that the previous spindle was stiffer to work and could move the cover unintentionally when opening it.

The steam pressure was about 150 pounds per square inch at the time, but the exhaust from the crane and the windlass forward was blowing back through the drains on the after capstan and any sound of leakage from the valve cover was not noticed. Moreover, the night was dark and there was no light aft, and it was after hauling in on the capstan several times during the previous four hours that the explosion occurred.

The owners have had a securing clip fitted to the hexagon part of the cover, and the mooring wire is now stowed on the other side of the deck so that there is no chance of the accident recurring.

Observations of Mr. A. E. Laslett, Engineer Surveyor-in-Chief.

In this case, the cover of the small stop valve was screwed into the body of the valve, and had become partly unscrewed owing to a moor rope passing between it and the guard plate, so that when the hand wheel was operated to open the valve, the cover and spindle became detached from the valve chest and allowed steam to escape. Efficient guards should be provided to protect steam valves but means should also be provided to prevent the covers slacking back when they are of the screwed type.

This safeguard has now been fitted to the cover in this case.

REPORT No. 2,924. Steam Trawler *Tyndrum.*

This refers to an explosion from a manhole on the boiler of the Steam Trawler *Tyndrum*, on June 20th, 1928. The circumstances were examined into and reported by Mr. Jas. Jarvie, B.T. Surveyor, Hull.

The *Tyndrum* is a steam trawler of 192 tons gross and is engaged in North Sea fishing. In June last the boiler was opened out for cleaning purposes and was closed during the afternoon of the 19th of that month. It appears that the custom is to open the boilers of this company's trawlers for rough cleaning every six weeks and for proper cleaning every twelve weeks. About three o'clock in the afternoon of the 19th June, Jacob Cowling Massay, and William Ramm, the chief and second enginemen respectively, put on the bottom manhole door together. A new joint had been procured from the office and was fitted in place. After filling the boiler and fitting the top door, both fires were lit, and steam was allowed to rise with the damper closed, there being no one in attendance until about 3.30 a.m. the next morning when Ramm came aboard. There was then about 25 lbs. per square inch showing on the boiler pressure gauge. Ramm saw to his fires and then tried to tighten up the nuts on the bottom door, but states that he was unable to tighten them much. This is likely because the water in the bottom of the boiler was evidently still cold as, to help circulation, some of the water was blown out from the bottom. Steam was then gradually raised until at 6 a.m. there was 180 lbs. per square inch showing on the gauge. Massay, the chief engineman, came aboard at about 4 a.m. and at 6.30 a.m. the vessel left Scarborough for the fishing grounds about five miles away. There does not appear to have been any sign of leakage from the bottom door joint, and at about 7.15 a.m. Ramm, who had been on deck, came below and, lifting the boiler door spanner, went into the stokehold with the intention of trying the nuts again. Fortunately for him he did not reach the door before the joint blew out and the engineroom and stokehold became filled with steam. The trawler was ultimately towed back to Scarborough, and, when the pressure was off the boiler, it was found that about three inches of the jointing material of the bottom door had been blown out.

Later when the *Tyndrum* was visited it was found that the bottom door was a very bad fit, there being a space of about $\frac{3}{8}$ inch all round between the spigot and the flanging in the end plate.

The manhole has now been fitted with a new door, which is a good fit. It might be pointed out that, in the case of many trawlers, insurance does not of necessity carry with it any systematic survey of the machinery and boilers. In the case of the *Tyndrum* there is no evidence that the boiler had been inspected by anyone, excepting the superintendents appointed by the owners.

Observations of Mr. A. E. Laslett, Engineer Surveyor-in-Chief.

The condition of this manhole was such that inspection by a competent person would undoubtedly have resulted in repairs being recommended. Apparently the insuring companies do not concern themselves with the condition of the vessels insured.

The engineman very fortunately escaped injury, but the vessel was disabled.

REPORT No. 2,952. Steam Trawler *Strathcarron.*

Report No. 2952, deals with the whistle valve chest on the boiler of the Steam Trawler *Strathcarron*, which gave way while leaving port. The enquiry into the case was conducted by Mr. W. L. Mennie, B.T. Surveyor, Aberdeen and reported upon.

The *Strathcarron* is a steam trawler of 209 tons gross, and was built and registered at Aberdeen in 1913. The vessel was employed by the Admiralty from August, 1914, until November, 1919, when she recommenced fishing operations.

On the 4th September, 1928, the *Strathcarron* was lying at the Fish Market, Aberdeen, and at 9 a.m. on that day, the catch having been discharged, preparations were made to remove the trawler under her own steam to another berth in the Albert Basin, Aberdeen. At 9.12 a.m. the second hand, who was in charge, gave three blasts on the whistle, and a few minutes later, when he was blowing one short blast, the wire leading to the whistle valve lever broke. The wire was found to have been wasted by corrosion, and it was temporarily repaired with twine. At 9.25 a.m. the second hand was again about to sound the whistle when the chest was blown off the boiler. The engines were at this time going full ahead and, as the engineman and fireman had left the engine room immediately after the explosion, the engines were not under control. The wheel-house was directly over the boiler but, in spite of the difficulty occasioned by the escaping steam, the trawler was successfully steered out to sea and manœuvred until the engines stopped when she was towed back to harbour.

On examination, it was found that the four $\frac{5}{8}$ inch studs securing the whistle valve mounting to the boiler shell had fractured, and the mounting had been blown off the boiler and rested against the plate which formed the top of the light and air casing and the floor of the wheelhouse. The whistle pipe was bent, but there was no indication of water hammer having taken place and the drain pipe was clear. The studs were not wasted and had broken inside the holes in the valve chest flange, and the nuts and the lagging which had covered the flange remained in position on the chest. All four studs had old flaws, and in two of the studs these were complete fractures, but in the others were partial. No sound of escaping steam had been heard previous to the explosion, and there was no indication on the boiler plate or the flange of the chest that leakage had been taking place. The studs were probably overstressed either when the chest was jointed or when the nuts were tightened at some later date. The owners have no record of any rejointing of the chest, but the repair is of a minor nature and it is doubtful whether a record of such a repair would be kept. The boiler was built in 1913 for a working pressure of 180 lbs. per square inch and was tested on completion by hydraulic pressure to 360 lbs. per square inch. Had the studs been defective at that time it is probable that this test would have disclosed the fact. It is the boilermakers' ordinary practice to make these joints with gauze wire, but no such joint could be found after the explosion. The valve chest flange and the nuts on the studs securing the chest to the boiler shell plate were covered with lagging, which was not removed at the annual survey, and therefore the studs were not hammer-tested at that time.

The owners are arranging to remove the lagging from all similar chests on the boilers of their vessels.

Observations of Mr. A. E. Laslett, Engineer Surveyor-in-Chief.

The arrangement appears to have been such that a considerable load could be put on the studs, securing the whistle stop valve to the boiler, by the wire for operating the valve which admitted steam to the whistle. As the securing studs were unsound they broke and the mounting was blown off the boiler. The chest was a small one and theoretically the $\frac{5}{8}$ inch studs were amply strong enough for their purpose, but in practice it is often found that in screwing up such small studs they are over-stressed in the effort to make the joint tight. Having regard to the nature of the explosion it is fortunate that the results were not far more serious.

———o———

The Sir Archibald Denny Award.

Essay by "Cyclops" (E. Goodsen, Member).

Title: Turbine Gland Sealing System.

The double reduction geared steam turbine is a great advance on the direct drive used in the early days of marine propulsion. By this system, but one detail of it remains substantially the same as on the ships of fifteen years ago, namely, the introduction of live steam to the astern turbine glands when running at full speed, whilst the excess pressure in the H.P. ahead gland, and to a lesser extent, the I.P. and L.P. ahead glands, leaks off to the condenser.

Carbon packing was introduced to mitigate the latter condition, but personal experience indicates that in the majority of cases the leakage past the joint reduces its efficiency to that of the labyrinth type of packing, and at least one case is on record where a reversion to labyrinth packing has been made. It is *possible* to make the gland housing joint steam-tight. One case where lead wire was formerly used to prevent leakage being now almost perfect after some strenuous filing, atmospheric pressure being maintained in the gland pocket with the leak off valve but two turns open, after four months running. This is an exception, however, and the possibility of utilizing the leak off steam from the ahead glands to seal the astern glands has suggested itself as an appreciable economy.

There are difficulties to be overcome, but it is thought that they are not insuperable, and the following lay out is suggested as a basis for experiment.

Fig. 1 shows the arrangement of gland steam and leaks off for the H.P. and L.P. double reduction geared turbines as fitted to the N.S.3. Standard Ships.

Fig. 2 shows the suggested arrangement applied to the same engines, and it will be seen that the piping required is approximately of the same length but of greater diameter, with a marked reduction in the number of valves, so that the cost of the installation would be about the same in each case. The larger diameter of pipes is intended to reduce the fluid friction to a minimum and so obtain as nearly as possible a constant pressure throughout the line.

The action is as follows: When the turbines are at rest, the steam valve is open and supplies sealing steam to all glands, the length and shape of each pipe being similar to ensure even distribution. The steam and leak off valves are manipulated as required when manœuvring until full speed is attained, when the H.P. ahead gland will supply the necessary steam to keep the astern glands sealed, being augmented if necessary with the live steam, or reduced by opening the leak off valve.

It will be argued that the pressure in the ahead gland will necessarily be greater than in the astern pockets, which is granted, but experience with carbon packing shows that a pressure of two or three pounds per square inch in the pocket is beneficial, in that it keeps the vapour ring against the side of the groove in the packing box, thus preventing leakage.

Extended spindles should be provided from the steam and leak off valves to the starting platform, being of stiff construction and fitted with Tee handles to permit rapid handling whilst manœuvring. A suitably ported cock with a worm and quadrant operating gear would be an ideal arrangement instead of the two valves, but the difficulty of keeping it steam and air tight whilst easily workable would probably debar its use.

An additional advantage of this system will probably be found in the more rapid manœuvring possible without loss of vacuum, due to badly adjusted gland valves, especially in the case of large installations with two sets of engines, each comprising H.P., I.P., L.P. Ahead and H.P., L.P. Astern Turbines with their attendant steam and leak off valves. The auxiliary leak off from the H.P. ahead inner pocket to the I.P. turbine could be retained as an emergency fitting as at present.

A further suggestion, applicable to either system, is that a separate steam line be used for each engine, as this would obviate the necessity for continuous adjustment whilst manœuvring, due to the lack of sensitivity of the reducing valve when but one is fitted. In regard to this point, with the suggested system it should be possible to use high pressure steam direct to the steam sealing valve, as there are no intermediate valves on the glands, and a small supply pipe, say, half inch bore or less, could not cause undue pressure on the glands, even if it were inadvertently opened.

Another slight economy which might be effected is that of extracting some of the heat from the steam before using it for sealing purposes, by means of a small pipe coil in the feed line, with a by-pass arrangement for use when warming through and manœuvring, but this would possibly be of insufficient use to warrant the expense of fitting, especially with the suggested

Fig. 1.

Existing Arrangement.

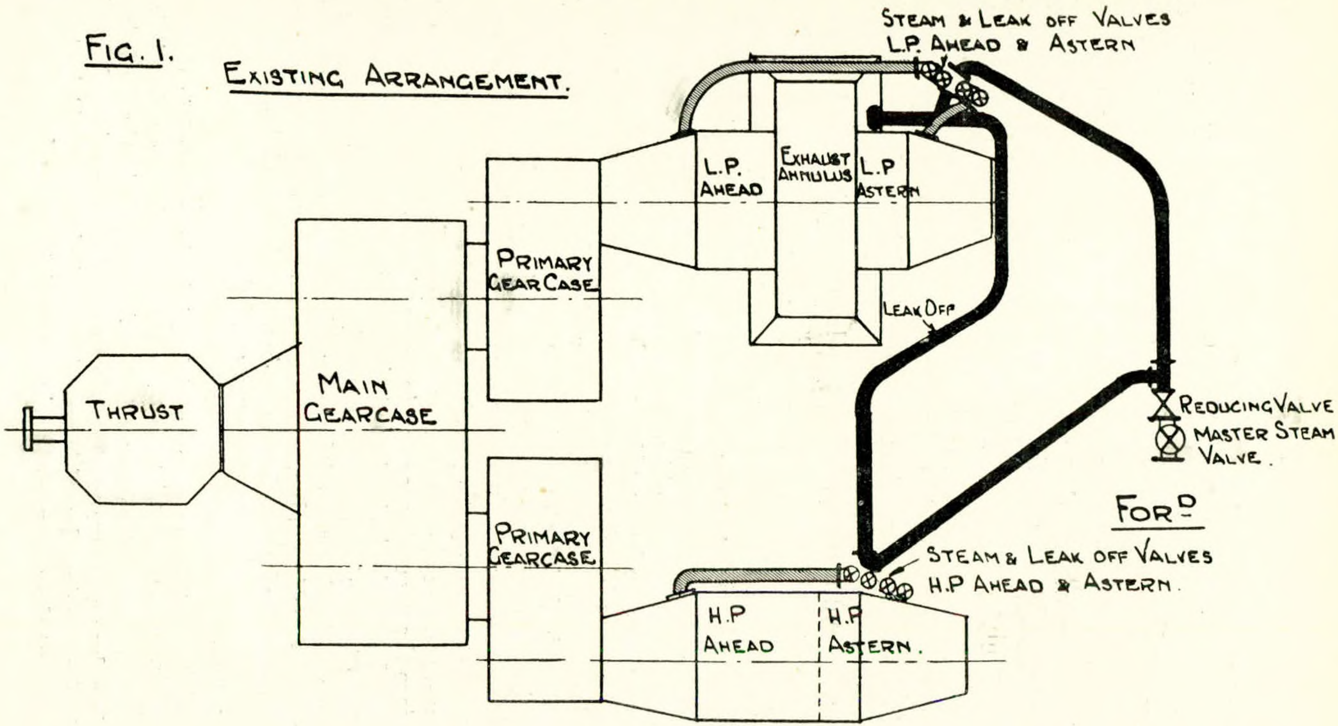
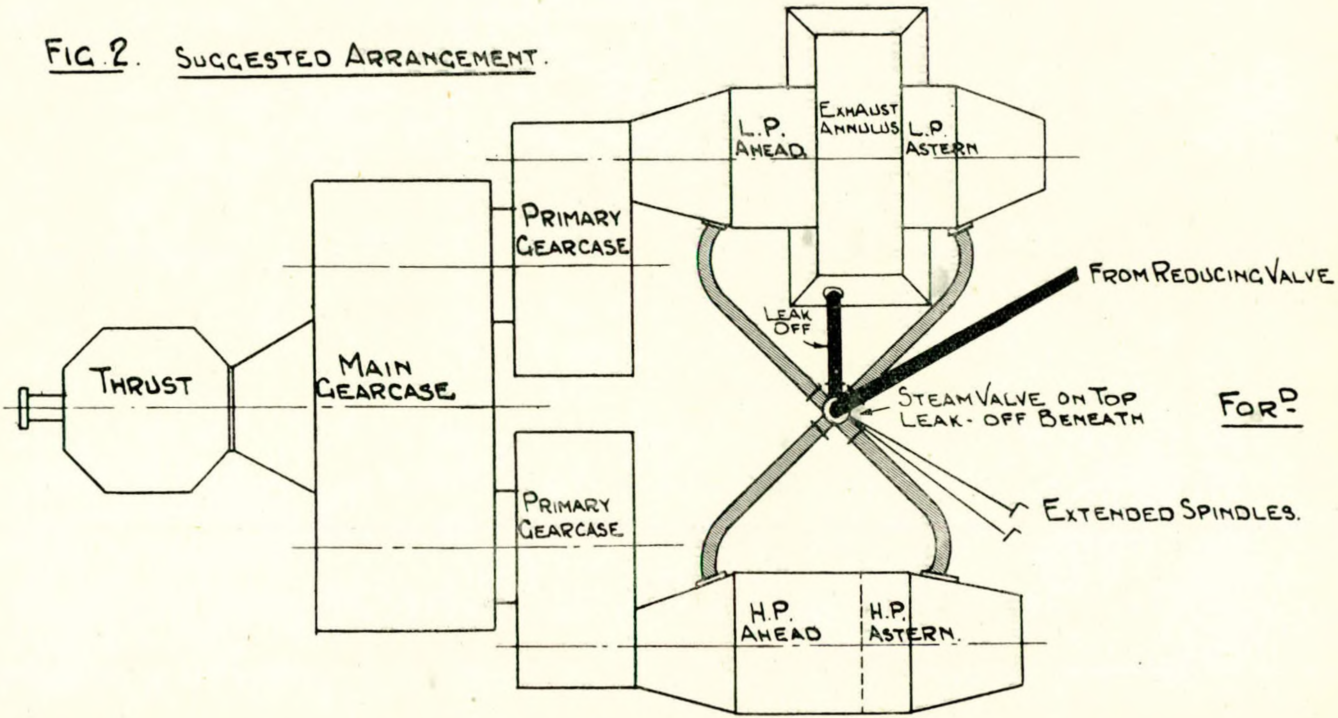


FIG. 2. SUGGESTED ARRANGEMENT.



arrangement. Exhaust steam is not recommended for sealing as it fouls the packing and blades.

Restriction plates might be found necessary at one or more of the glands to equalise the pressures of full speed running, and it is probable that whilst manœuvring, a slight pressure would accumulate in some of the pockets, but this latter condition applies equally to the orthodox arrangement, except when manipulated by a very efficient operator, as the condition of ' one man per valve ' does not obtain outside the maker's trial trips.

The actual loss through gland leakage varies considerably with the condition of the glands. In the type illustrated a 2.300 S.H.P. installation, the H.P. ahead leak-off valve is $1\frac{1}{2}$in. diameter, giving an aperture of about one square inch for a pressure drop of 14 lbs. per sq. in. when the gland is in reasonably good condition. The loss of this steam for driving purposes is unavoidable and very minute, considered as a percentage, but its introduction to the condenser at a relatively high temperature has a deleterious action on the tubes, as well as increasing the circulating and dry air pump duties. The sealing steam for the astern turbine glands is at present taken from the main steam line and reduced to about 25 lbs. per sq. in. before being admitted through the gland steam valves, the amount used being approximately the same as that taken from the H.P. ahead gland.

In effect this is like running a pipe line from the main steam supply to the condenser, but with the suggested arrangement the leakage from the ahead glands would seal the astern glands under normal full speed conditions, the live steam connection being retained for manœuvrings with an emergency leak-off to the condenser to cope with any excess of steam from the H.P. ahead gland in the event of the joint leaking or the packing breaking.

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Books added to Library

Motorshipping. By A. C. Hardy, B.Sc., F.R.G.S., A.M.I.N.A., A.M.I.Mar.E. Published by Chapman and Hall, Ltd., Henrietta Street, London, W.C.2. Price 15s.—In this volume the author appoints himself to the task of writing on the new era of motorshipping.

The first chapter deals, according to the text, with motorshipping developments, but it really resolves itself into an attack upon Superintendent Engineers, Naval Architects, and others who act as consultants and advisors to shipowners. These he divides into two classes, those with " B " class minds who, in their abysmal ignorance, prefer to use steam engines despite the allurements of the Diesel, and those with " A " class minds of a much higher functioning order, who have embraced the motorship and all its works. That is ultimately the point of his observations which are unnecessary in a book of this class. As we cannot admit the author's ability to pass judgment on the subject, we shall put it down as inflammation of an " A " class mind.

Mr. Hardy also trifles with the idea of motorships as a psychological study, and compares their success with the problematical success of a new book or play. The claims for recognition demanded by the Diesel engine surely rest on a substantial foundation, and are not dependent on a public whim. Such inconsequential futilities might well be expugned from future editions.

The work deals with the influence of motor vessels on world trade routes, and the author writes with authority on the subject. Considerable information on types of vessels that have been built to date is given with interesting comparisons. He mentions that one well-known motorship earned in a single year £500,000 more profit than a somewhat similar steamship. Frankly, we do not believe it.

There is a great deal of useful information in the book, but the vital questions, costs of renewals and repairs which must be added to first cost, are left alone. Until there is more information available on these matters there will still be superintendents and owners to whom the Diesel does not appeal.

The Motorship Reference Book for 1929. Compiled by the staff of the " Motorship." Published by Temple Press Ltd., 5-15, Rosebery Avenue, London, E.C.1. Price 5/-.

This exceedingly handy work contains a vast amount of information on types of Diesel engines and motorships, and the relative particulars that one usually needs to know in connection therewith.

The principal types of Diesel engines now in use are briefly described and illustrated and their particular characteristics outlined.

Full information of the principal bunkering stations throughout the world is given, and a register of the world's motor craft of 2,000 tons gross and upwards, is embodied.

Some interesting particulars of auxiliaries and fuel and lubricating oils are also available.

It is significant of the advance in motorshipping to observe from the book that in 1919 the motorships in service equalled 752,000 gross tons; in July 1928 the figure had reached 5,432,302 gross tons. At December 1922 the motor vessels under construction totalled 288,057, while at September in 1927 and 1928 the totals were approximately $1\frac{1}{2}$ million tons.

Election of Members.

List of those elected at Council meeting of January 7th, 1929:—

Members.

Charles Archibald, 8, Byron Street, Poplar, E.14.

Robert Beeman, Eng. Capt., C.M.G., R.N., Admiralty, Whitehall, S.W.1.

Frederick Thomas Bovingdon, 135, East India Dock Road, Poplar, E.

George McConnochie Campbell, Insurance Engineers, Ltd. Armitage Chambers, Victoria Street, Nottingham.

John George Charlton, *c/o* Indo-China S.N. Co., Ltd., Hong Kong, China.

Robertson Cook, 11, Bellevue Crescent, Ayr.

William Ernest Barrell Dainton, 162, Uttoxeter New Road, Derby.

James Lumsden Dean, Armitage Chambers, Victoria Street, Nottingham.

Marinus J. Elenbaas, Asiatic Petroleum Co., St. Helens' Court, Marine Dept., Singapore, S.S.

Alexander Frew, *c/o* Mackinnon, Mackenzie and Co., P.O. Box 163, Calcutta, India.

Robert Lewis Gibb, Springwood, Stanley Road, New Ferry, Cheshire.

James Inglis, Power Station Supt., *c/o* British Enka Silk Factory, Aintree, Liverpool.

Edward Langley Knowles, Canford, Landseer Road, Sutton, Surrey.

Aubrey Richard Langton, 12, Yorke Road, Reigate, Surrey.

Ernest Markham, 324, Harrogate Road, Leeds.

Leonard William MacGregor, 3, Courtland Avenue, Lee, S.E.12.

Thomas McGregor McNie, North Bridge, Baghdad, Iraq.

Bert Parsons, Insurance Engineers, Ltd., Armitage Chambers, Victoria Street, Nottingham.

Harold Leslie Read, 77, York Road, Ilford, Essex.

Harold Percival Rhodes, Tainui, West Farm Avenue, Ashtead, Surrey.

James William Russell, 10, Weston Street, Balmain East, Sydney, N.S.W.

James Smith, Eng. Lieut. Comdr., R.N., ret., *c/o* Messrs. Stanley and John Thompson, Ltd., 80, Bishopsgate, E.C.2.

John Sturrock, Reay House, Apollo Bunder, Bombay, India.

William Gordon Turner, 69, Wanstead Park Road, Ilford, Essex.

Companion.

Bertie Warwick, Capt., *c/o* Houlder Bros. and Co., Ltd., 53, Leadenhall Street, E.C.3.

Associate Members.

Richard Scott Kellie, *c/o* Hoare and Co. (Engineers) Ltd., Colombo.

Harry Morrison, 2, Albany Street, N. Kelvinside, Glasgow.

Associate.

William Sweyn Macqueen, Dores, Wentworth Road, Vaucluse, Sydney, N.S.W.

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Board of Trade Examinations.

List of Candidates who are reported as having passed examination under the provisions of the Merchant Shipping Acts.

For week ended 1st December, 1928:—

NAME.	GRADE.	PORT OF EXAMINATION.
Morrow, Samuel H.	1.C.	Belfast
Spratt, Leslie H.	1.C.	Cardiff
Hart, Ivor K.	2.C.	,,
Williams, Charles M.	2.C.	,,
Armstrong, David	1.C.	Glasgow
Carmichael, Joseph	1.C.	,,
McFadyen, Robert M	1.C.	,,
McInnes, John	1.C.	,,
Smeaton, Thomas H.	1.C.	,,
Caskie, Arthur J.	2.C.	,,
McMurray, Samuel H.	2.C.	,,
Thomas, Albert J.	2.C.	,,
Hamilton, James	1.C.M.	,,
Connell, Archibald	1.C.M.E.	,,
Galbraith, Fergus McW.	1.C.M.E.	,,
McCarroll, George P.	2.C.M.	,,
Donald, William I.	1.C.	Liverpool
Duval, Frederick C.	1.C.	,,
Howe, John	1.C.	,,
Mylchreest, Daniel W.	1.C.	,,
Walker, Harold V.	1.C.	,,
Williams, David T.	1.C.	,,
Wynn, George W. C.	1.C.	,,
Carmichael, John	2.C.	,,
Carmichael, Rudolph W.	2.C.	,,
Jones, John O. L.	2.C.	,,
Granger, George C.	1.C.M.	,,
Butcher, George F.	2.C.M.	,,
Forster, Thomas	1.C.	North Shields
Grier, William S.	1.C.	,,
Williams, William T.	1.C.	,,
Brown, Ernest	2.C.	,,
Elfert, William E.	2.C.	,,
Galloway, James K.	2.C.	,,
Seed, William B.	2.C.	,,
Smith, Arthur D.	2.C.	,,
Storey, Arthur N.	2.C.	,,
Wile, William W.	2.C.	,,
Leffler, Laurentz	1.C.M.E.	,,
Tait, Thomas	2.C.M.	,,
Neill, David	1.C.	Leith
Rundle, George	1.C.	,,
Thomas, Andrew M.	1.C.	,,
McKee, Walter	2.C.	,,
Milne, Ernest S.	2.C.	,,
Murray, Alexander	2.C.	,,
Scott, Keith	2.C.	,,
Tulloch, Thomas	1.C.M.E.	,,
Mackrow, Clifford M.	1.C.M.E.	London
Archibald, Charles	1.C.	,,
Sarfas, Frank E. A.	1.C.	,,
Scott, Edgar V.	1.C.	,,
Clark, Philip C.	2.C.	,,
Marshall, Reginald E.	2.C.	,,
Nickless, Henry W.	2.C.	,,
Beattie, Robert P.	2.C.M.	,,

For week ended 1st December, 1928—*continued.*

NAME.	GRADE.	PORT OF EXAMINATION.
Cockburn, Robert H.	1.C.	Southampton
Drew, William F.	1.C.	,,
Gibbs, Cecil H.	1.C.	,,
Joyce, Alexander H.	2.C.	,,
Nash, Alfred J.	2.C.	,,

For week ended 8th December, 1928 :—

Hamerton, Claude S.	1.C.M.E.	London
McLeod, John	1.C.M.E.	,,
Potts, Vernon	1.C.M.E.	,,
Kavanagh, James	2.C.	Dublin
Ovenden, George H.	1.C.M.E.	Glasgow
Strongman, Charles	1.C.M.	,,
Henderson, Archibald B. ...	1.C.M.E.	,,
Sharp, William	1.C.	,,
Carmichael, John	2.C.	,,
Campbell, Alexander	2.C.M.	,,
Huscroft, Norman	1.C.	Hull
Rockett, Edgar	1.C.	,,
Tennison, David	1.C.	,,
Doubtfire, Cyril P.	2.C.	,,
Groom, William S.	2.C.	,,
Wilkinson, Charles E.	2.C.	,,
Aitken, Francis G.	2.C.E.	,,
Budd, John C.	1.C.	Liverpool
Capewell, Bernardine, T. E. ...	1.C.	,,
Davies, James M.	1.C.	,,
Johnson, Charles K.	1.C.	,,
Mansell, William H.	1.C.	,,
Trew, Leonard W.	1.C.	,,
King, Alan	1.C.E.	,,
Gibb, Robert L.	1.C.M.E.	,,
Price, David J.	1.C.	London
Taylor, John M. S.	1.C.	,,
Wadley, Horace N.	1.C.	,,
Munro, George A.	2.C.	,,
Pacey, Oswald G. S.	2.C.	,,
Youldon, Joseph S. H.	2.C.	,,
Askew, Joseph C. J.	1.C.	North Shields
Martin, Robert	1.C.	,,
Scongal, George	1.C.	,,
Almond, Charles W.	2.C.	,,
Orr, James O.	2.C.	,,
Robson, Ernest A.	2.C.M.	,,
Youngs, William E.	2.C.M.	,,
Lumley, Francis J.	1.C.	Sunderland
Richardson, William	1.C.	,,
Stafford, Stanley	1.C.	,,
Atkinson, Gilbert M.	2.C.	,,
Glansfield, James R.	2.C.	,,
Harwood, George E.	2.C.	,,
Innes, Stanley P.	2.C.	,,
Perkins, Joseph R.	2.C.	,,
Thompson, John E.	2.C.	,,
Dumble, Thomas R.	2.C.M.	,,
Jefferson, John	2.C.M.	,,
Reed, Theodore	1.C.M.E.	,,

For week ended 15th December, 1928 :—

NAME.	GRADE.	PORT OF EXAMINATION.
Davies, Emrys G.	1.C.	Cardiff
George, William R.	1.C.	,,
Wallace, John D.	1.C.	,,
Kyd, Thomas	2.C.	,,
Rees, Ivor W.	2.C.	,,
Elliott, George P.	1.C.M.E.	London
Burrage, Edmund E.	1.C.M.	,,
Woodhams, Francis E.	2.C.	,,
Macro, Harold S.	2.C.	,,
Wise, Leslie R. L.	2.C.	,,
Stewart, Hector R. C.	1.C.	Glasgow
Tasker, Wilfred E.	1.C.	,,
Fairley, Francis F.	2.C.	,,
Pollock, Hector C. W.	2.C.	,,
Weldon, Stuart W.	2.C.	,,
Ross, William	2.C.M.	,,
Smith, Donald V.	1.C.M.E.	North Shields
Dennison, Alfred	1.C.	,,
Dean, William H.	2.C.	,,
Laverick, Thomas	2.C.	,,
Longstaff, Harold N.	2.C.	,,
Richardson, Edwin L.	2.C.	,,
Reed, William E.	2.C.M.	,,
Davidson, Alexander	1.C.	Leith
Holdsworth, Cecil F. H.	1.C.	,,
Green, William H.	1.C.	Liverpool
Quirk, Philip T.	1.C.	,,
Thompson, Wilfred J.	1.C.	,,
Clouder, Reginald C.	2.C.	,,
Gee, George	2.C.M.	,,
Nobbs, David M.	2.C.	Southampton
Read, Edmund H.	2.C.	,,
Du Boulay, Herbert J. H. ...	2.C.M.	,,

For week ended 22nd December, 1928:—

NAME.	GRADE.	PORT OF EXAMINATION.
Mitchell, William R.	1.C.M.E.	London
Toplis, Edward	1.C.M.E.	,,
Turner, Herbert	1.C.M.E.	,,
Beattie, Andrew C.	1.C.M.E.	Glasgow
Welsh, David C.	1.C.M.E.	,,
Smith, Hugh	1 C.	,,
Wilson, James S. K.	1.C.	,,
Crawford, David	2.C.	,,
Hendry, James	2.C.	,,
Murphy, Arthur	2.C.	,,
Robertson, Alexander	2.C.	,,
Rose, John A. F.	2.C.	,,
Beck, Adam J.	2.C.M.	,,
Jolly, Robert	2.C.M.	,,
Logie, George McP.	2.C.M.	,,
McWilliam, Robert A.	2.C.M.	,,
Callow, James M.	1.C.	Liverpool
Curphey, George A.	1.C.	,,
Duurloo, Lawrence M.	2.C.	,,
Skelton, Elliott	2.C.	,,
Dykes, Alexander H.	1.C.M.	,,
Waite, John W.	1.C.M.E.	,,
Stewart, William A. A.	1.C.	London
Jaques, Cyril L.	2.C.	,,

For week ended 22nd December, 1928—*continued.*

NAME.	GRADE.	PORT OF EXAMINATION.
Kearnay, James J.	2.C.	London
Kiell, Francis J.	2.C.	,,
Macdonald, Thomas	2.C.	,,
Pym, William P. G.	2.C.	,,
Robinson, John T.	2.C.	,,
Manson, Fred	1.C.	North Shields
Herridge, Maxwell, C.	2.C.	,,
Matthews, Walter D.	2.C.	,,
Russell, John M. B.	2.C.	,,
Heppell, John D.	2.C.M.	,,
Anderson, James H.	1.C.	Sunderland
Brotchie, George	1.C.	,,
Newton, John	1.C.	,,
Stephenson, John N.	1.C.	,,
Witten, Richard A.	1.C.	,,
Stewart, John R.	2.C.	,,
Tighe, Joseph P.	2.C.	,,
Wanless, Edward	2.C.	,,
Botwright, Leonard R.	2.C.M.	,,
Russell, Frank	2.C.M.	,,
Scott, Thomas	2.C.M.	,,
Milroy, William G.	1.C.M.E.	,,

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Refrigeration for Ships.

Continued from page 947.

Author's reply to Chairman's contribution: There is no real objection to ammonia machines being used for marine work, provided they are housed in a separate compartment and adequate arrangements made for dealing with a serious leak of gas should it occur.

General experience with the liquid cooling or multiple effect machine is that it introduces complications which the engineer accustomed to the ordinary cycle does not like, and experience does not uphold the suggestion that there is a saving in either gas or oil.

There can be little doubt that the installation of a small automatic refrigerating machine to deal with independent cupboards is a step in the right direction and even if 20 or more are required in a large passenger liner, the saving in pipe leads, insulation and wasted power will more than be repaid.

The suggestion put forward regarding the welding of pipe joints has not so far as we know, been actually applied on ships, but it is a practice which is now being used on large buildings where special hot water and heating insulations are used.