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Engine Room Layout with Special Reference to Pipework.

By Lt.-Col. G. R. GRANGE, D.S.O., M.C., B.Sc. (Member).

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Chairman: J. A. Rhynas (Chairman of Council).

Synopsis.

The efficient operation of marine engine installations is largely dependent on the pipe arrangement and installation and on the materials employed.

The high steam pressures and temperatures now in use and the increase in the number and size of auxiliaries have complicated the problem of producing a satisfactory layout, and the cost of re-making leaky joints and overhauling valves can be considerably increased by a faulty arrangement and unsuitable material.

This paper reviews the present practice as regards pipe-arrangement work and the design and installation of the various pipe systems involved, and deals with some of the other problems which arise in a marine installation. The first part of the paper includes the subject of pipe flanges, bolting and jointing. This subject was fully dealt with in a paper read before The Institute in 1939 by F. J. Cowlin and J. P. Chittenden, and valuable information on the subject is also contained in the reports of the Pipe Flange Committee of the Institution of Mechanical Engineers. The remainder of the paper deals with the various problems which arise on the different pipe systems in steam and oil-engine machinery, and with such items as ventilation, lifting gear, ladders and gratings, which require to be embodied in the general machinery arrangement. The paper is subdivided into three parts dealing with the following items:—

(1) The design of pipes and materials used in pipe installation.
(2) The layout and installation of pipe systems.
(3) Miscellaneous details in machinery installations.

(1) DESIGN AND MATERIALS.

The essential features of a satisfactory pipe arrangement may be summarized under the following headings:—

(*a*) Correct pipe circuits for the various duties.
(*b*) Suitable sizes of pipes and valves for allowable pressure drops.
(*c*) Suitable materials.
(*d*) Suitable design and dimensions for the pressures, temperatures and fluids involved.
(*e*) Satisfactory layout as regards expansion, accessibility and method of support.
(*f*) Efficient insulation.

(*a*) Pipe Circuits.

Before proceeding with a pipe arrangement it is necessary to prepare circuit diagrams of requirements. It is preferable to have a separate diagram for each service and a typical diagram for a boiler feed system is shown in Fig. 1.

Types of valve, whether screw-lift or non-return should be indicated, also the direction of flow.

Items such as pumps, condensers are outlined by readily identifiable shapes, and sizes of pipes are shown.

(*b*) Pipe Sizes.

Sizes of pipes are determined by the allowable pressure drops and Table I shows the present-day practice as regards velocity in pipe systems for various services.

TABLE I.

Fluid.	Pressure lb. per sq. in.	Service.	Velocity ft. per minute.
Water	−12 to +12	Bilge ballast	300-400
"	50 " 100	Fire	500
"	200 " 600	Feed	600
Oil fuel	−12 " +12	Oil suction	150
" "	200 " 300	" discharge	250
Lub. oil	−12 " +12	Suction	200
" "	12 " 50	Discharge	250
" "	0 " 0	Drain	40-60
Saturated steam...	100 " 250	Steam pipes	6,000
" " ...	250 " 500	" "	6,500
Superheated " ...	100 " 250	" "	7,000
" " ...	250 " 500	" "	8,000
Exhaust " ...	0 " 10	" "	10,000-12,000
" gas ...	5″ " 15″	Diesel exhaust	About 6,000

In using the above table it must be remembered that there are certain services where pressure drops must be kept to a minimum, and where it may be necessary to work out the actual pressure drop before determining the size of pipe and type of valve.

In calculating the pressure drop the resistance of various fittings may be taken from the following approximate formula:—

Length of straight pipe equivalent to resistance of fitting $=$ Diameter of pipe $\times X$ in ft.

Elbow $X=30$
Tee $X=60$
Sluice valve $X=11$
Angle valve $X=40$
Through valve $X=90$

Among circuits where pressure drop must be kept to a low figure may be mentioned gland steam for turbines, bled steam to feed heaters, and exhaust pipes on oil engines. Once sizes are determined they should be embodied on the circuit diagram of the system involved.

(*c*) Material.

The physical properties of various materials used in the pipe systems of machinery installations are summarized in Table II.

In selecting materials for any particular duty, a number of factors must be taken into consideration.

During the war, copper was in short supply, and in a number of cases steel pipes had to be substituted. Although copper is more expensive, owing to the ease with which it can be worked, the finished pipe is in many cases cheaper than steel, and as no allowance need be made for corrosion there is a considerable saving in weight.

Lap-welded steel pipe is considerably cheaper than hot solid-drawn pipe, but if cold bending is used, the solid-drawn pipe will be found more satisfactory. For high-temperature work over 750° F. it is necessary to use a molybdenum steel for both pipes and flanges,

TABLE II.

Material.	Tensile lb. per sq. in.	Yield Pt.	Brinel No.	Purpose.
		PIPES.		
Brass	60,000	30,000	85	Water.
Copper	31,300	elongation 40% on 2in.		L.P. steam and water ranges.
Cupro-nickel ...	85,000	elongation 40%		Hot water at high velocities.
Monel metal ...	90,000			Corrosive liquids.
Steel butt welded	50,000	30,000		Air and water ranges L.P.
„ lap „	45,000	25,000		All low pressure ranges.
„ solid hot drawn ...	58,000	elongation 25% on 2in.		Low and medium pressure steam ranges.
„ cold drawn	58,000	elongation 25% on 2in.		Medium pressure steam and H.P. air ranges.
0·5 Carbon-molybdenum steel ...	65,000	40,000		High-pressure high-temperature steam ranges.
		FLANGES.		
Red brass ...	30,000	14,000	22	For copper pipes.
Yellow „ ...	60,000	22,000	25	„ „ „
Carbon steel ...	60,000	30,000	120	„ steel „
„ molybdenum steel ...	65,000	40,000	160	„ „ „
Ni. Cr. Mo. steel	90,000	70,000	170	High-temperature pipes.
		BOLTS.		
Naval brass ...	48,000	elongation 20%		Salt water connections.
Alum. bronze ...	70,000	Izod 120ft.-lb.		Ships' side valves.
Wrt. iron ...	45,000	25,000	—	Low pressures.
Mild steel ...	63,000	30,000	120	Normal pipe ranges.
„ „ ...	71,000	35,000	140	„ „ „
Ni. Cr. „ ...	105,000	80,000	—	High pressures and temperatures.
Ni. Cr. Mo. steel	125,000	105,000	—	High pressures and temperatures.
Cr. Mo. steel ...	145,000	Izod 65ft.-lb.		High pressures and temperatures.

JOINTING.

Gasket Material.	Fluid.	Max. Temperature.
Natural rubber insertion ...	Steam, air, water.	Up to 200° F.
Asbestos	Steam, water, oil.	„ „ 750° F.
Fibre, cardboard	Oil.	„ „ 200° F.
Synthetic rubber	Oil.	„ „ 200° F.
Serrated rings (steel, Monel)	Steam.	„ „ 900° F.
Gas filled Monel rings ...	Steam.	„ „ 900° F.
Copper rings	Air.	„ „ 400° F.
Leather	Oil.	„ „ 200° F.

owing to the creep characteristics of this material. Special precautions are necessary in using this steel. The annealing temperature is considerably higher than that for low-carbon steel, and may be as high as 950° C., at which temperature a pipe requires careful support to prevent distortion. Molybdenum steel is particularly susceptible to the presence of copper, which results in intergranular penetration and the consequent development of cracks. Possible sources of attack by copper are to be found in the sand used for packing pipes during bending, copper hammers used in the bending process, and copper being present in the pickle bath. Owing to the high temperature used in annealing, it is important that the annealing furnace should be of the controlled-atmosphere type in order to prevent oxidation, and close temperature control is necessary. The temperature used during hot bending should be controlled by an optical pyrometer.

The suitability of steel pipes for water depends largely on the amount of air present in the water. For instance, in closed-feed circuits where oxygen has been removed, steel pipes are quite suitable, whereas for ordinary hot-water circuits where air is being liberated by the heat, steel will be apt to suffer from corrosion.

Copper pipes should not be used for temperatures in excess of 400° F. owing to the decrease in strength at this temperature.

As regards the use of alloy-steel bolts for high temperature, when selecting material it is essential to select a steel which combines good creep properties with lack of embrittlement when exposed for long periods to high temperature. Generally speaking, embrittlement is associated with the presence of nickel, whereas molybdenum has a tendency to reduce embrittlement. Full information on the subject is contained in a paper by A. M. McKay and R. N. Arnold read before the British Association in 1933. The characteristics of these alloy steels is also largely influenced by the tempering temperature. The following example of an alloy steel suitable for high temperatures shows what figures are acceptable.

Analysis:
- C. 0·3.
- Si. 0·35.
- Mn. 0·4 to 0·7.
- S. and P. 0·05 max.
- Mo. 0·45 to 0·75.
- Cr. 1·0 to 1·5.

Heat Treatment:
- Heat to 840° C. and cool in oil.
- Temper at 550° to 700° C. and cool in air.

Properties:
- Tensile 65 to 70 tons per sq. in.
- Yield 55.
- Izod minimum 35ft.-lb.

Tensile at high temperature:
- 60° – 65 tons.
- 480° – 66 „
- 750° – 55 „
- 840° – 50 „
- 950° – 40 „

(*d*) Design.

While power-station practice, especially in America, has recently embodied the system of welding up whole ranges of pipes and doing away with flanges, the flange is still the standard system by which pipes are jointed in marine installations.

The usual methods of joining the flange to the pipe are shown in Fig. 2. (*b*) is suitable only for low-pressure ranges with pressures below 100lb. per sq. in. (*a*) has the advantage that the joint extends to the bore diameter, whereas in (*b*) the joint is on the pipe external diameter. (*b*) however, has a definite advantage as there is more flexibility in adjusting the exact position of the flange on the pipe, which does not require the same accuracy of pipe length as is required with (*a*). (*a*) has a further disadvantage in that the pipe must be rotated in order to obtain downhand welding. (*c*) is the usual method of welding adopted for high pressures; the dimensions are laid down in the British Standard Tables and by Lloyd's. It has been found in practice that with these dimensions there is a danger of slag inclusions being present in the first run of welding, and (*d*) shows an alternative preparation for welding which has been found to reduce the possibility of slag. It is important that no undercutting takes place at (*X*) during welding. (*e*) is another approved system of welding for all pressures and is preferable to (*d*) where bending stresses are present on the flange. The weld can either be done by hand, a steel sleeve being fitted inside the pipe and machined away after welding, or else by a flash welding machine which forms a butt weld, the two surfaces being forced together by hydraulic pressure after the current has been cut off.

Fig. 3 shows the type of machine used for this work. (*f*) and (*g*) show the ordinary screwed and expanded flange; in the case of (*g*) a seal run of welding is added preferably before expanding. (*h*) shows the riveted flange largely superseded by welding. (*j*) is another example of the butt weld but has a stiffer design of flange largely used in America for pressures above 300lb. per sq. in. (*k*) is a type of joint with loose flanges which has not up to now been much used in marine work, but is largely used in America under the name of the Van Stone flange. The thickened pipe end can either be formed by forging an upset on the pipe or by welding a machined extension to the pipe. (*l*) is a further development of (*k*), a seal run of welding being added after the flange bolts have been hardened up.

Fig. 4 shows typical preparations of the flange face for jointing. (*a*) is the plain parallel face either off the machine with jointing between the faces or scraped up to a face plate and jointed metal to metal. (*b*) is a ground face, the two faces being ground slightly

convex so as to allow a clearance of two to four thousandths on the outside of the joint before the bolts are hardened up. (*c*) Is a relieved joint, the metal along the line of the bolts being machine relieved, and the outside strip of metal being scraped or filed to give a slight clearance before hardening up the bolts. (*d*) is a raised-face joint necessitating considerable thickening of the flange to resist bending. (*e*) is known as the gramophone-finish joint. The metal for a certain distance from the bore is left with a slightly raised face on which are cut a number of serrations either concentric or as a spiral. The usual pitch of these serrations is 28 to the inch. (*f*) shows a plain joint face similar to (*a*) but the joint is made on a serrated ring which may be of mild steel, soft iron or Monel metal.

Valuable information on pipe flange joints is contained in the paper on this subject by F. J. Cowlin and J. P. Chittenden in the March, 1939, issue of the Institute's TRANSACTIONS, Vol. LI, Part 2, pp. 61-88.

Bolts.

Types of bolt for flanges are shown in Fig. 5. Any of these bolts may be screwed either Whitworth or B.S.F., the tendency at the present time being in favour of B.S.F. threads for high-pressure work. In this connection it should be realized that the B.S.F. thread does not necessarily lead to a high bolt stress with a given torque owing to the higher coefficient of friction due to the fine thread angle.

For ordinary low-pressure low-temperature work, type (*a*) is quite satisfactory, but with high pressures and temperatures other types are preferable. Type (*b*) shows a relieved bolt giving a certain elasticity to the joint, as the bolt can be strained to a greater extent without exceeding the elastic limit than is the case with (*a*).

From the methods used in forging bolt heads there are frequently locked-up stresses close to the head, and as mild steel suffers from embrittlement when exposed for long periods to high temperatures, failures close to the head are apt to take place. In addition, where bending of the bolt is possible there is the danger of a notch effect at the junction of the head and bolt shank. For these reasons the author advocates the use of stud bolts of types (*c*) and (*d*) for all joints exposed to high temperatures and pressures. Type (*c*) is a relieved bolt similar to (*b*), but where high temperatures and consequent creep are involved, type (*d*) is preferable as the total creep over a prolonged period will be less than with type (*c*).

Screw threads on pipe-flange bolts may be either screwed with dies, thread milled, rolled or ground. At high temperatures, where seizing of the nut on the thread is frequently experienced, it is preferable to use ground or milled threads.

British Standard Specifications for pipe flanges issued in 1931, when dealing with flanges for high pressures and temperatures, laid down that alloy-steel bolts with mild steel nuts should be used and that the bolts should be of the stud-bolt type screwed B.S.F. Certainly the screwing of all alloy-steel bolts to B.S.F. has much to recommend it, as it at once distinguishes these bolts from carbon-steel bolts as long as these continue to be screwed standard Whitworth. The question of carbon-steel nuts, however, requires further consideration in view of the experience gained during the research conducted by the Pipe Flange Research Committee of the Institution of Mechanical Engineers. Their first report contains some very interesting research into the relative advantages of different types of joint and design of bolt. There seems little doubt that for high-temperature conditions an alloy-steel nut, preferably of a different composition from the bolt, has definite advantages over a carbon-steel nut, particularly regarding liability to seize up Various attempts have been made to prevent nut seizure under high temperatures, such as spraying the bolt thread with copper or aluminium, but results have not always been satisfactory.

As regards the scantlings of flanges and size and pitching of bolts, there is far too much diversity of practice in marine engineering to allow of economical production. The British Standards Institution have published standard dimensions for flanges and bolting up to 1,400lb. per sq. in. and 800°, but in certain cases these dimensions have been found unsatisfactory, and many firms have adopted their own standards. In America, standardization of pipe flanges appears to have been carried a good deal further than has been the case in this country. Attempts are at present being made between ourselves and America to standardize certain screw threads, and the time appears ripe to adopt a similar policy as regards pipe flanges.

In deciding on pipe-flange dimensions, it should be remembered that high temperature will have more effect than high pressure in causing leaks. This is especially the case in warming up from cold when water may be present in the pipe. When superheated steam is admitted the water is evaporated, thus cooling and contracting the bottom of the pipe while the remainder rapidly reaches the steam temperature. At the same time, the pipe flange rises in temperature more rapidly than the flange bolts, and the difference in temperature may be of the order of 50° F., increasing the stress on the flange bolts by as much as five tons per sq. in. on an 8in. flange.

Due to the heavy loading on the bolts when warming up, caused by differential temperature effect, there is a tendency for pipe flanges to cup in cases where the joint is kept inside the bolt circle. This has the effect of bringing the load on the inner edge of the bolt heads with possible bending of the bolt.

Fig. 6 shows the method used in the latest German destroyers

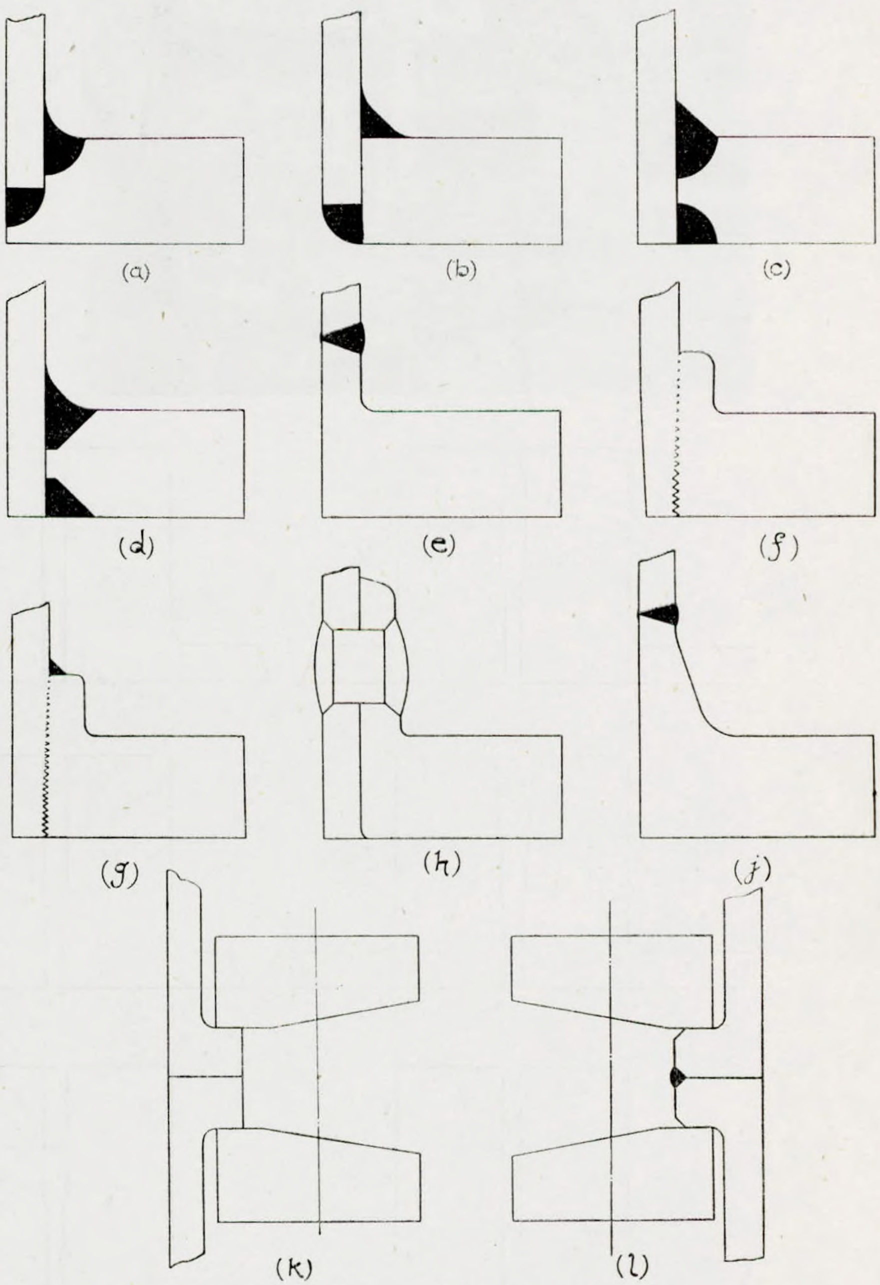

FIG. 2.—*Typical methods of attaching the flange to the pipe.*

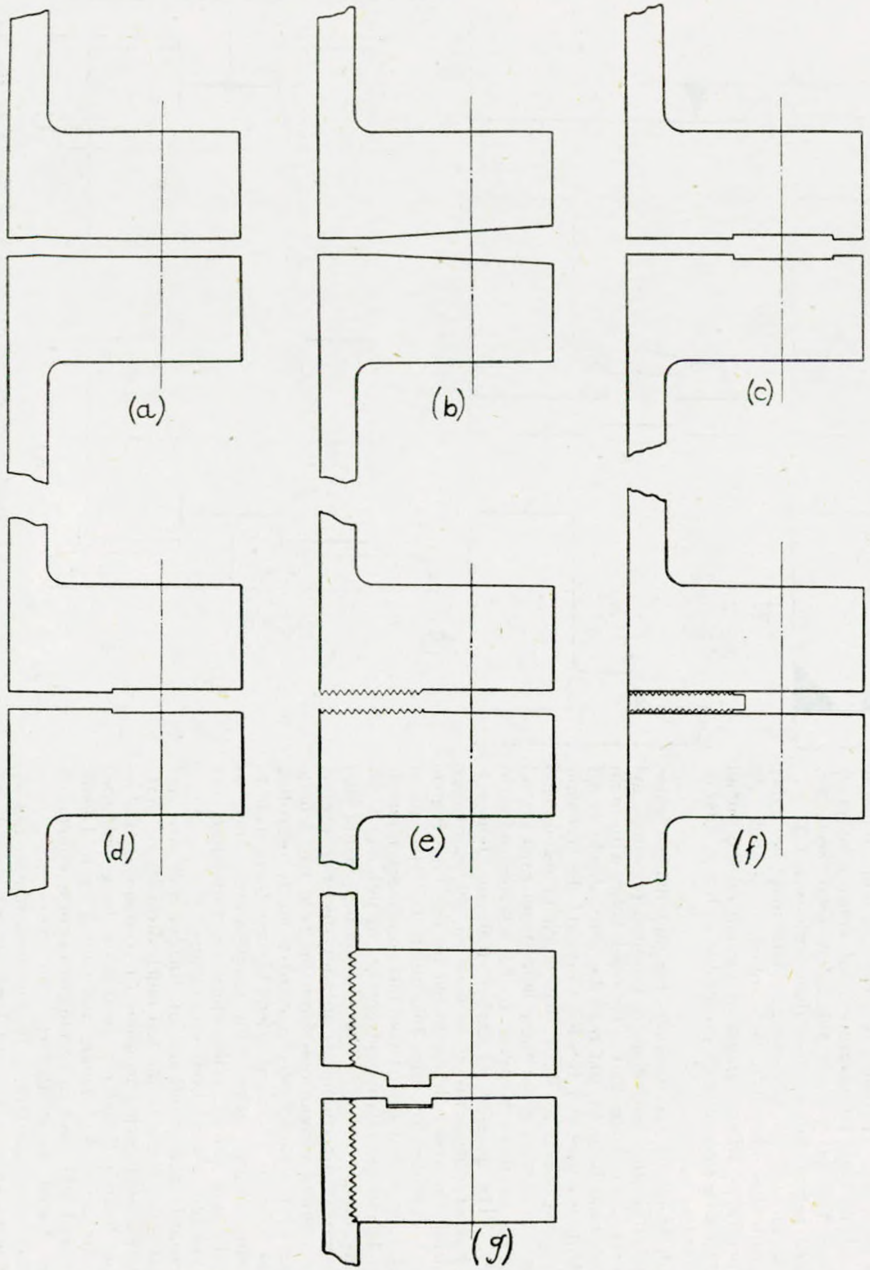

FIG. 4.—*Typical preparations of the flange face for jointing.*

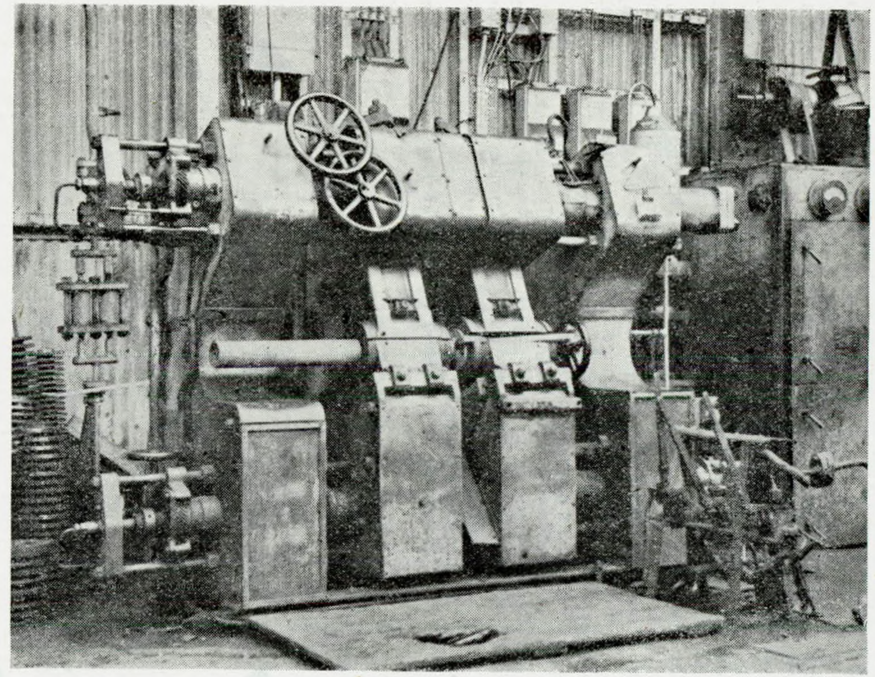

FIG. 3.—*Electrical butt welding machine.*

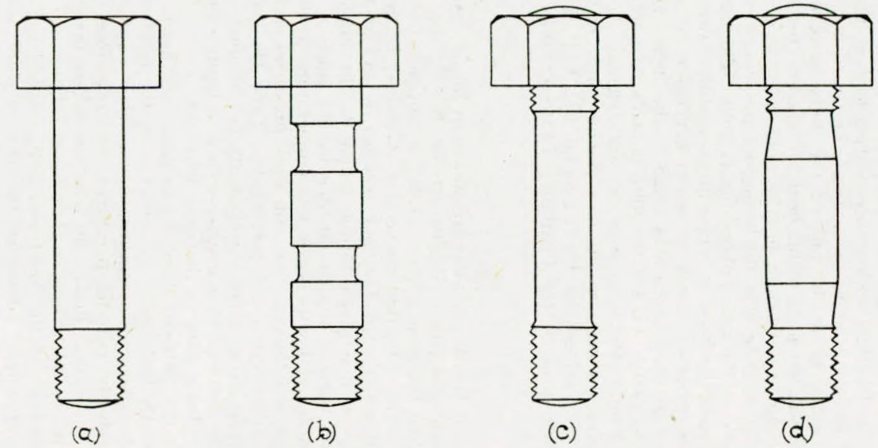

FIG. 5.—*Typical bolts for pipe flanges.*

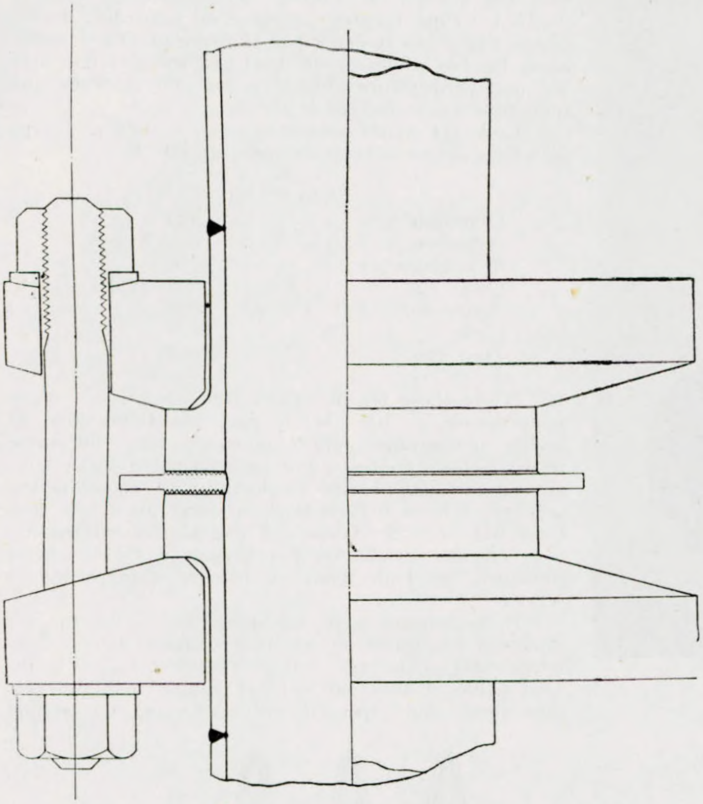

FIG. 6.—*Flange with spherical seats for bolts.*

for overcoming the non-axial loading of bolts in pipe flanges. Loose flanges of the Van Stone type are used with a narrow serrated steel ring forming the joint. Stud bolts are used, the nuts seating on spherically-seated steel washers. In some cases a steel ring is attached to the outside of the joint to prevent any danger to personnel from the blast of a steam leak in case of joint failures. This type of joint is reported to have given very satisfactory results.

The practical details involved in pipe fitting are beyond the scope of this paper, but two points are considered worth mention. A large number of pipes can usually be completed in advance to sketches prepared from the pipe arrangement, but closing lengths will always require to be made from sketches or templets taken from place. Where templets are used, it has been usual to make these from wood. This is not a satisfactory material owing to distortion and shrinkage, and Fig. 7 shows an improved templet made from light steel tubing, such as is used for electric conduits. The knuckle joints are made of aluminium, and the whole templet for a pipe up to 12ft. 0in. in length weighs 36lb.

On tightening the bolts on a highly-stressed flange, it is important that all bolts should be equally stressed to a designed stress. There are two methods of accomplishing this. The first is to measure the bolt extension by a micrometer or other gauge, and to tighten all bolts to a designed extension. The second method entails using a spanner with some form of measuring device, which measures the applied torque.

Fig. 8 shows a type of spanner in which the load applied is passed through a small hydraulic cylinder which registers the load on a gauge. In calculating the bolt loading from the applied torque, the co-efficient of friction with B.S.F. threads has been found to be about 0·12.

As regards the production of the gramophone-finish joints this can be machined in a facing machine, using either a comb to produce concentric grooves or a single tool to produce a spiral. Fig. 9 shows a hand machine using a comb which can be used at the site and gives satisfactory results.

(*e*) **Satisfactory Layout as regards Expansion Accessibility and Method of Support.**

The expansion of steam pipes and the use of expansion bends are dealt with under the section on steam pipes. In certain cases no room is available for inserting a bend, examples being the receiver pipes between turbines or between the cylinders of reciprocating steam engines, or on a Diesel engine exhaust manifold. In these cases the bellows-type of joint is found to be satisfactory. An example of this joint is shown in Fig. 10, including a sliding internal sleeve to minimize turbulence. Fig. 11 shows a further development of this type of joint designed for the receiver pipe between a large H.P. and L.P. turbine. In this case sufficient space was not available for a full-sized bellows joint, but by forming a venturi in the pipe and locating the bellows at the throat of the venturi, the overall dimensions and cost are reduced, and provided the slope of the venturi is correct little pressure drop will be experienced.

Good accessibility entails all valves being situated where they can be readily operated and overhauled, and all flange joints being located at points where they can be rejointed, with ample space for getting a spanner on to all nuts. Long ranges of pipes should preferably be placed on the same vertical plane in order to facilitate hanging. Branches from exhaust lines should face upward in order to prevent water coming down into auxiliaries: this is especially important in the case of fast-running auxiliaries, such as electric engines.

On low-pressure lines tee pieces and branch pieces can be reduced in number by welding branches on to the main range.

Where valves are to be either full open or completely closed, and a minimum pressure drop is required, valves should be of the full-bore type. Where close speed regulation is required, as in the case of forced-draught fans, a slow-opening type of valve is an advantage.

For high steam temperatures, special materials in the valves, seats and spindles are essential; stainless steel and Monel metal give good results. Fig. 12 shows a valve with a stellited face which gives good wearing qualities. On high-pressure steam valves the acme thread should be used on valve spindles.

The hanging of pipes having considerable expansion requires careful consideration. All ranges of pipes which have vertical movement when hot should have hangers embodying a spring which will continue to take the load when hot, as shown in Fig. 13. Pipes given considerable freedom of motion for expansion are apt to cause trouble due to vibration, and lateral stays fixed perpendicular to the line of expansion are frequently necessary. While main steam pipes are usually anchored at watertight bulkheads which sometimes involves stiffening of the bulkhead to take the thrust, there is the alternative of carrying the pipe through the bulkhead in a watertight gland, allowing the complete range from boiler to engine to expand as a single unit. This method is used in some American

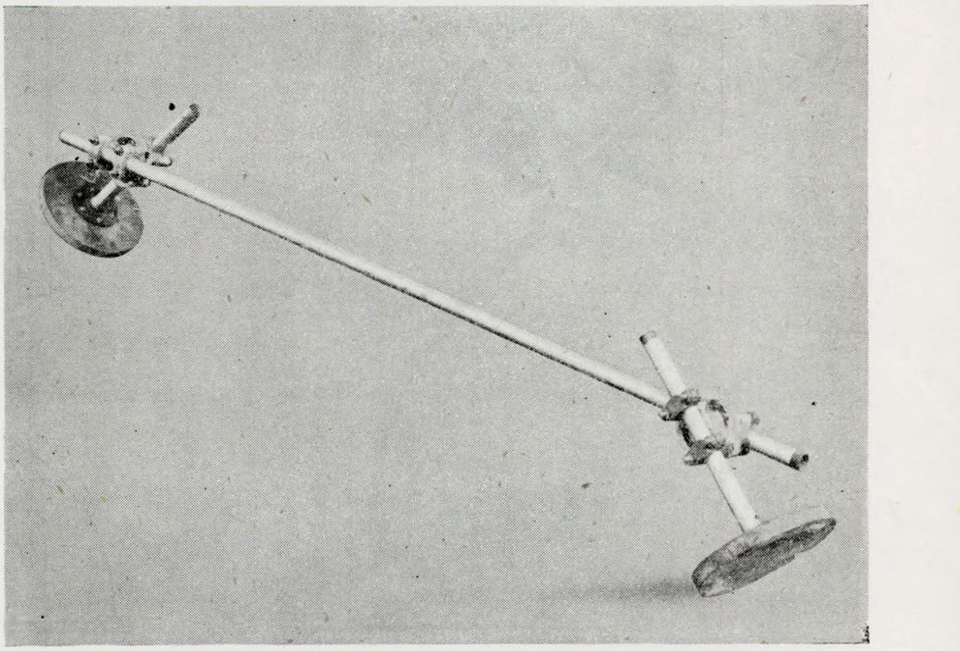

FIG. 7.—*Pipe templet.*

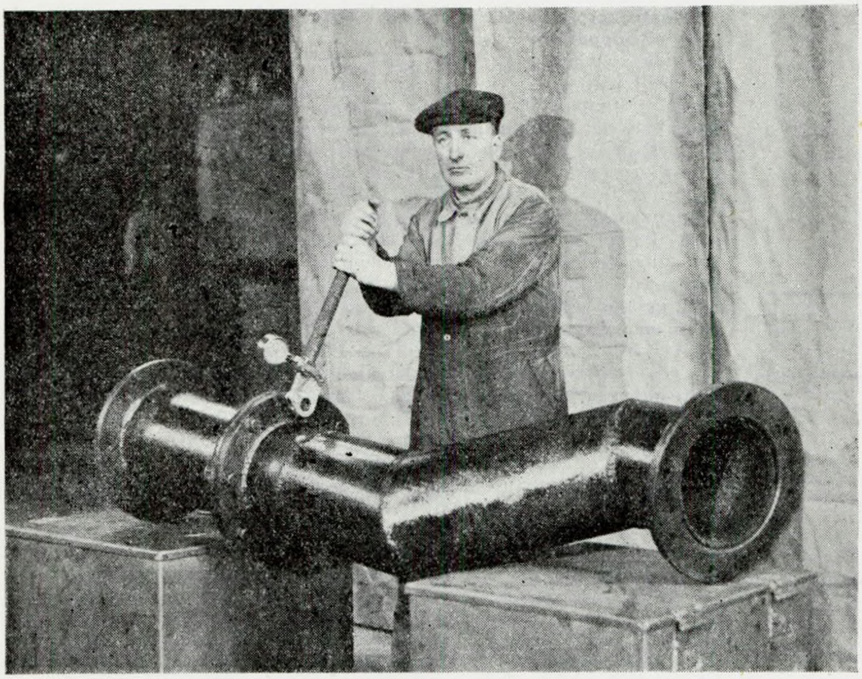

FIG. 8.—*Spanner for measuring applied torque.*

warships and frequently reduces the total length of pipe.

(f) Efficient Insulation.

The loss due to inefficient lagging of hot surfaces is considerable. A surface at a temperature of 450° F. above the surrounding still air loses 2,000 B.Th.Us. per sq. ft., and if air is flowing past the surface at 1,000ft. per minute the loss is doubled. Pipe lagging is classified according to its conductivity, and is defined as the rate of heat transfer along the line of maximum heat gradient per unit area per unit temperature difference per unit thickness per unit time measured in B.Th.Us.

Table III shows conductivity for certain insulating materials at a mean temperature of 100° F.

TABLE III.

Diatomite	0·51
Asbestos	0·36 to 0·50
85% magnesia	0·42
Glass silk	0·26 to 0·35
Aluminium foil (Alfol)	0·28
Cork	0·35
Hair felt	0·26

While these conductivities hold good for a mean temperature of 100° F., it does not follow that at higher temperatures these materials have the same relative conductivities. For instance, at a mean temperature of 500° F. the conductivity of magnesia has only risen from 0·42 to 0·59, whereas glass silk rises from 0·26 to 0·59. Glass silk and aluminium foil are both efficient insulators, but owing to their delicate structure are both liable to heavier depreciation in service.

It is impossible to lay down any rules for the thickness of insulation, as it depends on two factors which vary with every case. The first factor is the total value of the heat lost per annum with different thicknesses and types of insulation, and the second

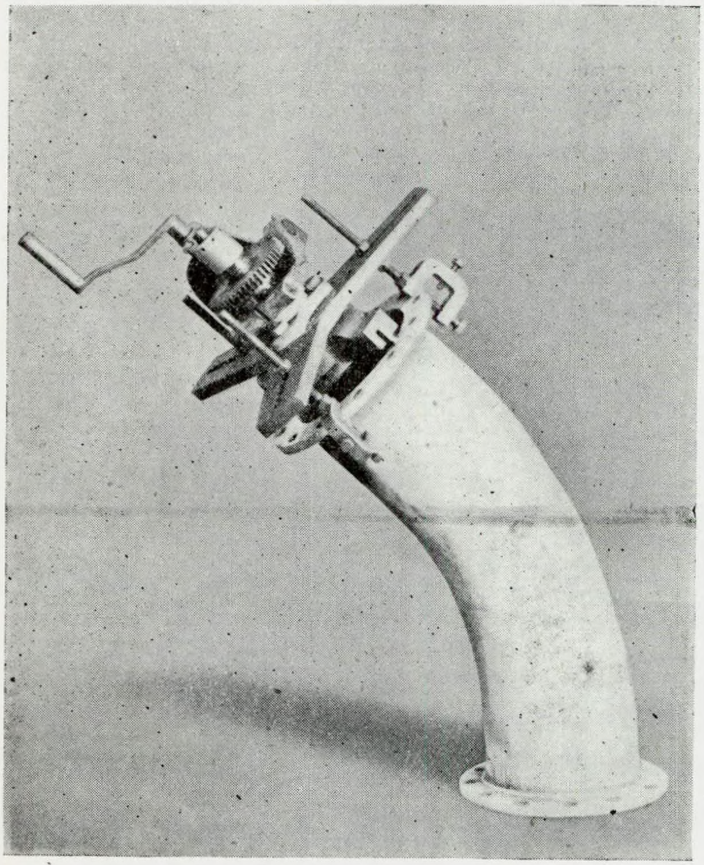

FIG. 9.—*Hand-operated serrating machine.*

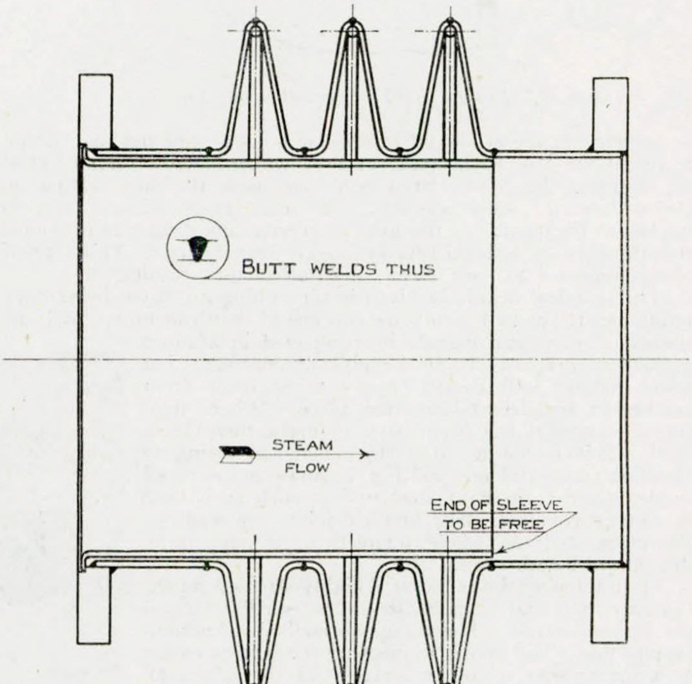

FIG. 10.—*Bellows joint.*

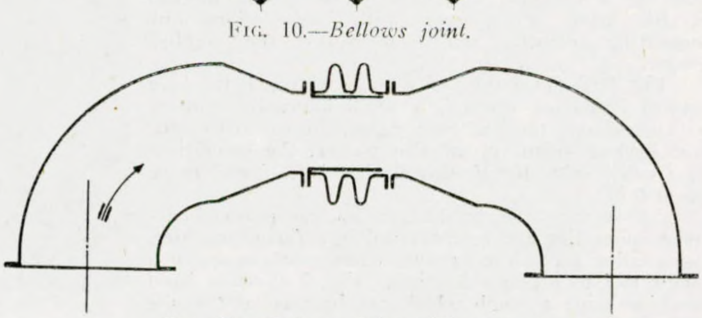

FIG. 11.—*Bellows joint with venturi.*

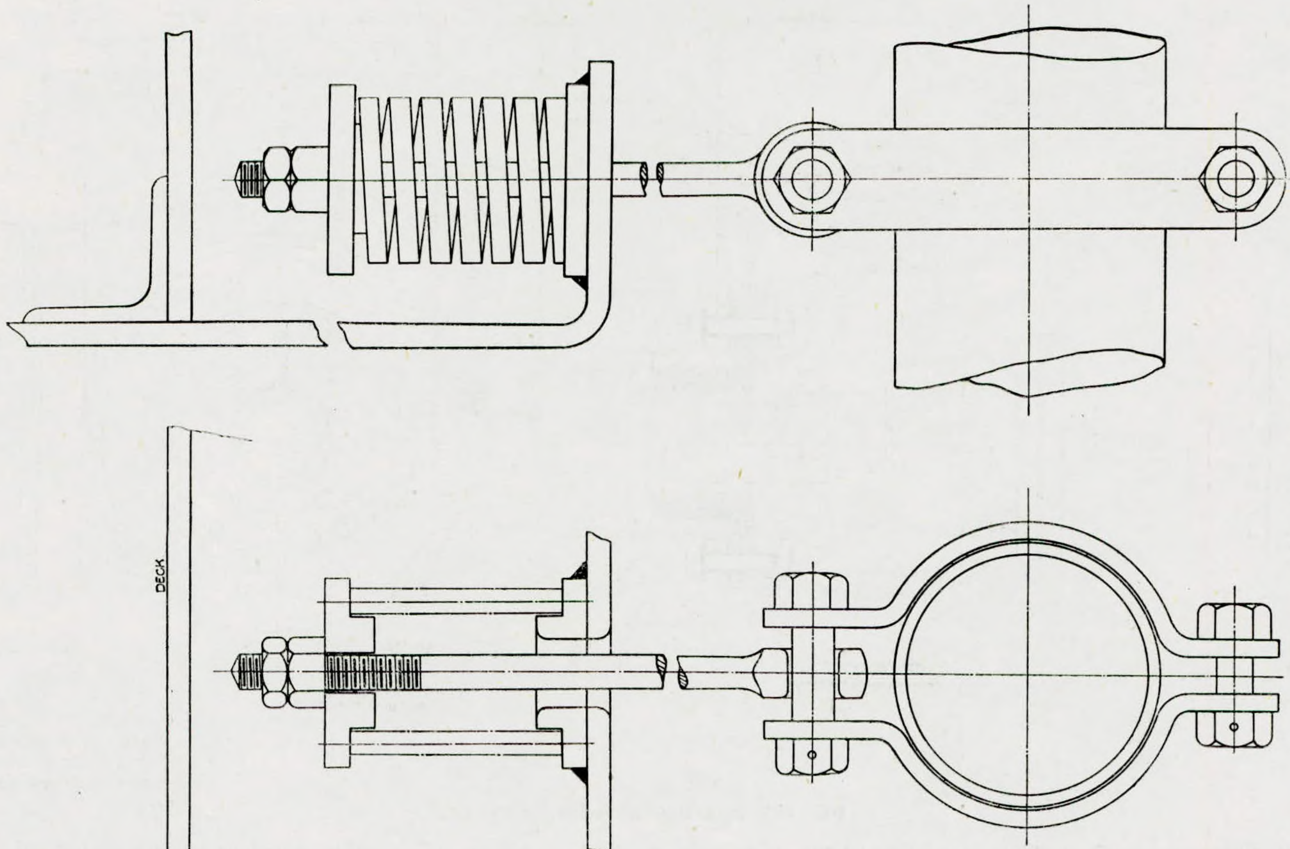

FIG. 13.—*Spring-loaded pipe hanger.*

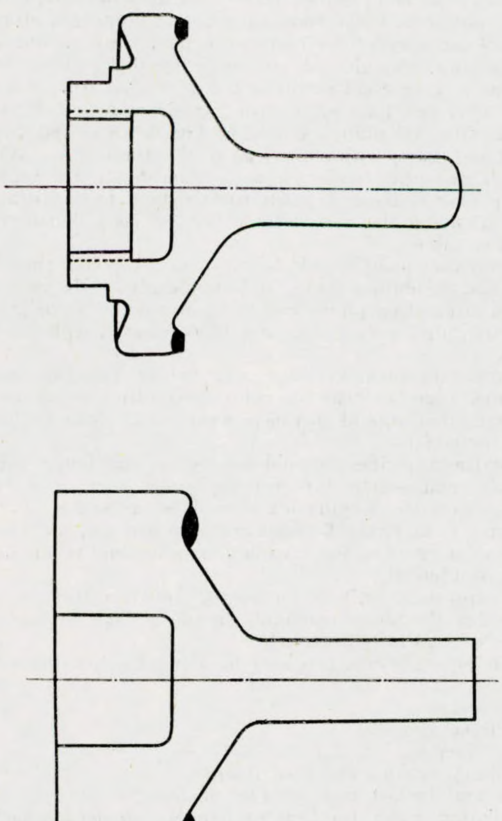

FIG. 12.—*Valve with stellited face.*

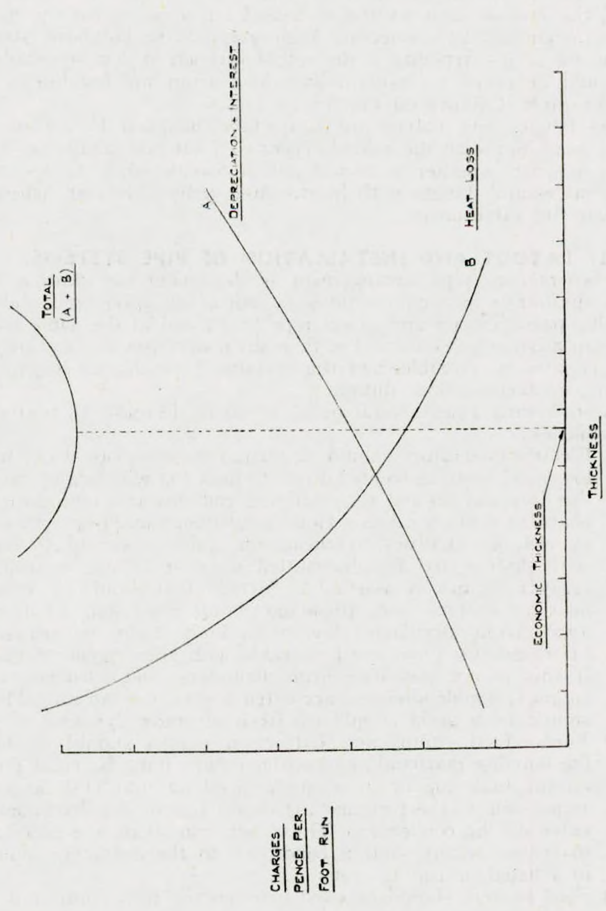

FIG. 14.—*Optimum thickness of insulation.*

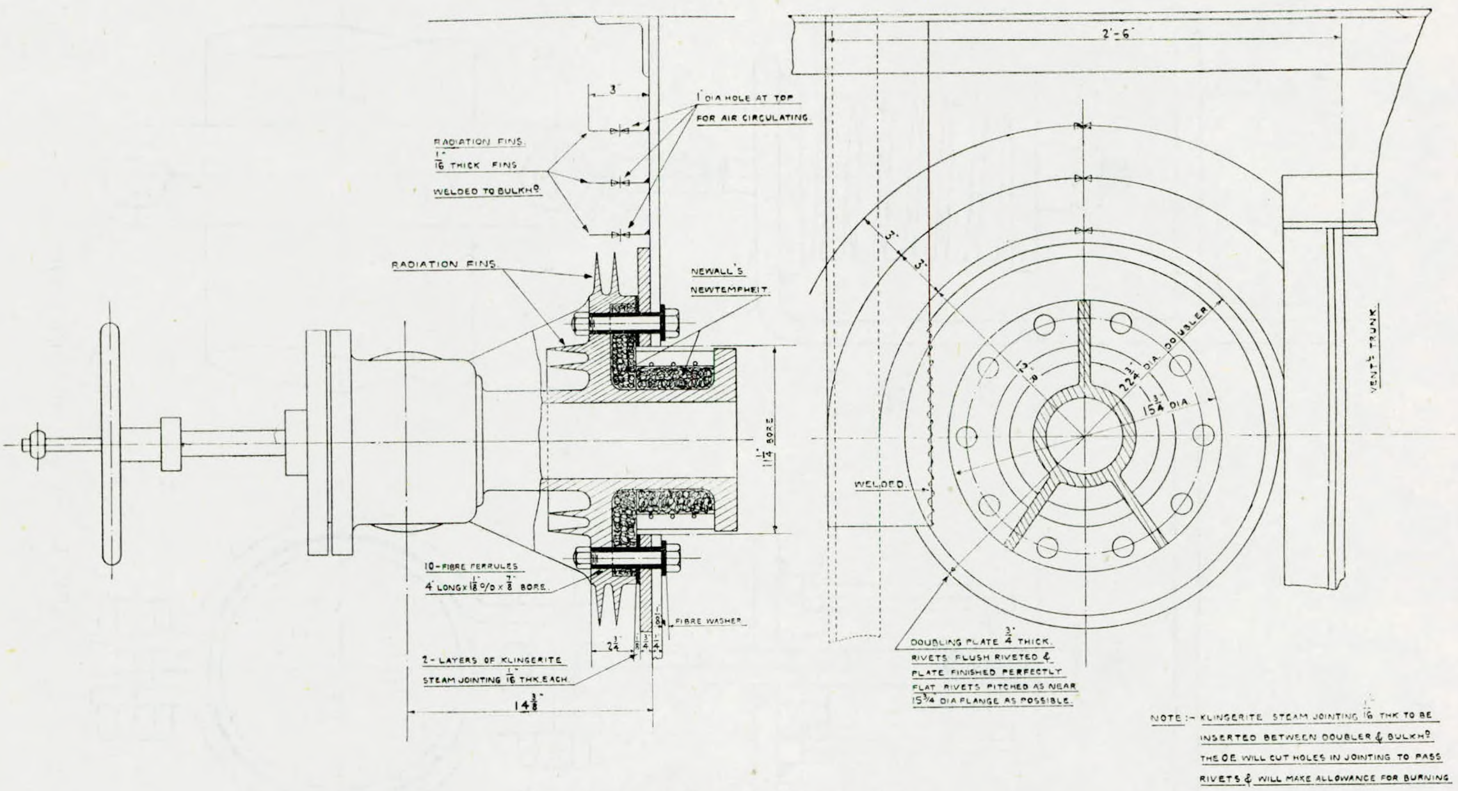

FIG. 15.—*Insulation of bulkhead valves.*

factor is the annual charge (interest and depreciation) on the cost of the insulation. If curves of these values are drawn as shown in Fig. 14, the lowest point of the combined curve will give the most efficient thickness. In connecting high-temperature bulkhead steam valves to the ship's structure in the neighbourhood of accommodation, care should be taken to insulate the valve from the bulkhead. A typical example is shown on Fig. 15.

Pipe flanges and valves are frequently insulated by means of asbestos mats, but with the reliable types of joint now available, it is open to question whether it would not be worth while to consider lagging valves and flanges with hard-setting cement, leaving asbestos mats over the valve cover.

(2) LAYOUT AND INSTALLATION OF PIPE SYSTEMS.

A satisfactory pipe arrangement is dependent on locating the various auxiliaries in such positions as will allow good accessibility, reasonable passageways, and direct pipe leads, and at the same time, will group auxiliaries connected with main propulsion as near to the control position as possible, and the remaining auxiliaries in groups depending on their various duties.

The following rules should be observed in deciding on positions for auxiliaries :—

(i) Electric generators should be on the engine-room floor, with low rigid seatings welded direct to tank top with engine centre line fore and aft and all generators ends towards main switchboard to shorten cables. Good headroom should be arranged, as well as facilities overhead for quick overhaul together with floor space for dismantled gear to be put in orderly array for quick re-assembly. Switchboard should be located near generators and, to avoid damp condition, positioned away from auxiliaries known to emit steam on occasion. Short exhaust pipes are preferable with Diesel generators or, if this is not possible, large diameters, and silencers near engines; double silencers are often a good investment. There should be a good supply of fresh air near dynamos.

(ii) Turbo feed pumps and extraction pumps should be near the starting platform; extraction pumps must be right down on the tank top or in a special well let into D.B. as near as possible to the fore and aft centre line of the float control valve on the condenser. These two conditions are necessary to ensure steady suction conditions to the extraction pumps in a listed or rolling ship.

(iii) Feed heaters should be sited between the feed pump and the boilers, and should have a short lead for bled steam to reduce the pressure drop. A good space should be allowed for withdrawing and cleaning tubes. Heaters must be fitted with inlet, outlet and bye-pass valves, thermometers, drains and air release connections together with a water gauge glass.

(iv) Evaporators should be grouped together with associated pumps to give good facilities for de-scaling coils and a short lead of closed feed evaporator vapour pipe to L.P. heater.

(v) Lubricating oil pumps should be low down to reduce suction head and noise, with short lead to the drain tank. When two pumps are fitted with one as a stand-by to the other, each pump should have its own suction pipe to the drain tank, thus avoiding the considerable loss of head due to fitting a suction valve.

(vi) The oil-fuel plant should be close to the boiler control position and to settling tanks, and should always be in duplicate.

(vii) Main circulating pump should be located so as to give short lead to ship's side valve, and to condenser with low resistance.

(viii) Pumps connected to bilge and ballast systems should be grouped together near the mains, and with good access to sea suction; they should also have withdrawal space for impellers if centrifugals.

(ix) Centrifugal purifiers should have good ventilation with space for a bench nearby for cleaning bowls.

(x) When possible, auxiliaries should be arranged so that the flooring is in straight gangways fore and aft, and gives easy access for examination, cleaning, painting and repair of underfloor equipment.

Some compromise will be necessary between these conflicting requirements, but the above essentials should always be kept in view and the lesser of two evils accepted.

The main pipe systems involved in a marine installation are as follows :—

(*a*) Main steam.
(*b*) Auxiliary steam.
(*c*) Boiler feed.
(*d*) Auxiliary exhaust and bled steam.
(*e*) Bilge and ballast and oil fuel suctions.
(*f*) Circulating water for heat exchangers, condenser, jacket and piston cooling.
(*g*) Lubricating oil.
(*h*) Fire, sanitary systems and wash deck.

(*i*) Sea inlets and overboard discharges.
(*j*) Fuel oil system (pressure lines).
(*k*) Compressed air system.
(*l*) Drain system.
(*m*) Oil engine exhaust.

Main Steam and Auxiliary Steam.

The essential requirements for these systems are sufficient flexibility to take up expansion without over-stressing, good drainage, good anchorage to resist thrust, low-pressure drop, good pipe joints, and good tube material.

The question of flexibility is that which gives the designer most concern. The stresses which can be set up in high-temperature pipe lines of complex shape are of a very high order, and when associated with the loss of strength of the steel at elevated temperature present a serious problem in many ships. The accepted method now is to stress the pipes to a reasonable amount when cold, so that when brought to their working temperature this initial stressing gives relief to the heated pipe, and avoids dangerously high stressing when hot. To stress a cold pipe is quite a simple matter. It is done by providing a gap of a pre-determined amount between chosen mating flanges, and pulling up this gap when making the joint; it is referred to by many authorities as the "cold pull up". There is no rule-of-thumb figure for "cold pull up"; it must be calculated for all installations. The pipe with cold pull must be judiciously selected and the calculations are of a decidedly complex character. A good description of these calculations is to be found in *Piping Handbook* by Walker and Crocker. It is a mistake to specify larger bore steam pipes than are actually required for any given installation, as the larger and thicker the piping the more difficult it is to keep the heat stresses within acceptable limits. Hangers for main steam pipes should be of the spring-supporting type and their positions carefully selected and laid down on the drawings.

Many installations cannot be satisfactorily settled by using plain pipes in association with "cold pull up", in which case it is necessary to provide flexibility by some other means. In the author's view the best alternative is to fit corrugated or creased pipes. In many systems this type of pipe has made safe working stresses which otherwise it would have been dangerous to permit at sea. The corrugated pipe has only two disadvantages, namely, the pressure drop across a given length of corrugated pipe is several times higher than that for a plain pipe, and there is a risk of steam noise in the bend. These disadvantages must be accepted and the boiler pressure raised accordingly to give the required pressure at the turbine. The corrugated pipe has been blamed for steam pipe noises which, in some cases, are due to associated valves. Expansion joints with packed sliding sleeves are now thankfully discarded.

Drainage is of equal importance. It is good practice so to arrange the steam piping that the manœuvring valve is the water shed and all main steam piping forward of these valves drains to the boiler, and all aft to the turbine. It is most important that main steam pipes led to the wings of the machinery spaces, to secure flexibility, should have an upward slant, so that with a listed ship these outflung pipes do not form a water pocket. All high-pressure steam-pipe drains should be trapped drains and be fitted with a good type of automatic trap that will function over many voyages reliably and trouble free. Lack of faith in traps has called for bye-passing arrangements, and this more than doubles the number of small high-pressure valves in the system with consequent high upkeep and delay.

Boiler Feed System.

This system is the most important on any marine installation, but with careful forethought and design can be made simple and trouble-free. The life of the boiler depends upon the feed system, and any auxiliary aids in controlling operation and in maintaining the feed free of oxygen and in an alkaline condition, are fully justified by the results.

The feed system falls into two main parts—that on the suction side of the turbo feed pump, and that on its discharge side. The author believes that the suction or low-pressure side, apart from joints, is that requiring most care in a modern installation. It is proposed to deal with a feed system for a turbine and water-tube boiler installation, i.e. that commonly referred to as a closed-feed system. The objects of such a system are:—

(*a*) To keep the feed water free from oxygen.
(*b*) To withdraw condensate from the condenser at the highest temperature possible consistent with the vacuum maintained.
(*c*) To de-aerate all make-up feed.
(*d*) To withdraw the incondensable air and gases at the lowest temperature.
(*e*) To deliver the feed to the boiler at as high a temperature as is economically safe.

To achieve the foregoing the following auxiliary units are necessary:—

Feed control valve.
Air ejector.
Extraction pumps.
Feed pumps.
Drain coolers.
Two or three feed heaters.
Feed tank or tanks.
Boiler feed regulators.

The feed control valve is preferably housed in the main condenser well; it can be housed in a small tank by itself, but this alternative need only be adopted when satisfactory positioning of the valve, in association with the extraction pumps, is impracticable. This valve enables the fixed volume of feed water in the system to deal with the varying volume of water in boilers and condensers at varying rates of evaporation. The aim should be to position the extraction pumps on the same fore and aft centre line as this valve, and in a single-screw vessel where two pumps are specified, these should preferably be arranged one behind the other on a fore and aft line.

In twin-screw vessels with port and starboard main condensers well spread, where the extraction pump is normally dealing with one condenser but has the capacity for dealing with two condensers, the suction conditions of the port pump when dealing with its own and the starboard condenser in emergency are not ideal by any means, and under heel conditions it is doubtful if the starboard condenser would be adequately served. All valves on the extraction pump suction should be of the water-sealed gland type as shown in Fig. 16.

The air ejector is usually multi-staged steam jets with inter-coolers, the final stage discharging the extracted air to atmosphere. It is usual to arrange this unit higher than the condenser with no loops in the piping, and to drain all the jets to the condenser except the final stage which should be an open drain to atmosphere. The ejector air discharge pipe must be within sight of the starting platform.

The air ejector should be supplied with steam at boiler pressure to avoid the use of reducing valves. The air ejector should have suctions from both ends of the air cooler within the condenser. The ejectors should invariably be circulated by the extraction-pump discharge, and a re-circulation provided so that at stand-by and manœuvring periods sufficient feed is passed through to this unit to condense the jet steam. The re-circulating connection should be taken from the extraction-pump discharge line after the L.P. heater if the L.P. heater is on the suction side of the turbo feed, but if all feed heaters are on the discharge side of the turbo-feed pump, then the re-circulating connection can be tapped off after the air ejector or drain cooler.

Drain Coolers.

These are best positioned low down on—or just below—the floor plates. The only point to watch in the piping arrangement is that the feed outlet from the cooler is carried well above the highest point of the cooler itself to ensure the cooling surface always being drowned.

The turbo-feed pumps should be positioned side by side on the floor plates, and the height of the feed tank from which it takes its emergency suction positioned to suit. Turbo-feed pumps below the normal floor-plate level are a nuisance in overhauling. These pumps will be supplied with steam at full boiler pressure and temperature, and it should be borne in mind that this type of pump cannot create a satisfactory suction head. The extraction pump delivers through the air ejector and drain cooler to the feed pump suction at 10/15lb. per sq. in. and an assessment of the losses in these units, together with that in the piping, should be made to ensure satisfactory operation. In the event of the extraction pump failing, it is necessary to provide an emergency suction to the feed pump direct from the main feed tank or from a distilled water tank. This tank must be at such a height that the water flows to the feed pump by gravity. This emergency connection should be arranged to cut in automatically should the extraction pump fall out. This can be conveniently done if the emergency suction is taken from a high tank by inserting a differential pressure valve held shut by the extraction pump discharge, against the static head from the tank. As soon as the extraction pump discharge pressure falls below a predetermined amount the static head opens the valve and allows water from the high tank to supply the feed pump.

With the advent of economisers in association with feed regulators, it was thought that, with the sudden closing of the feed

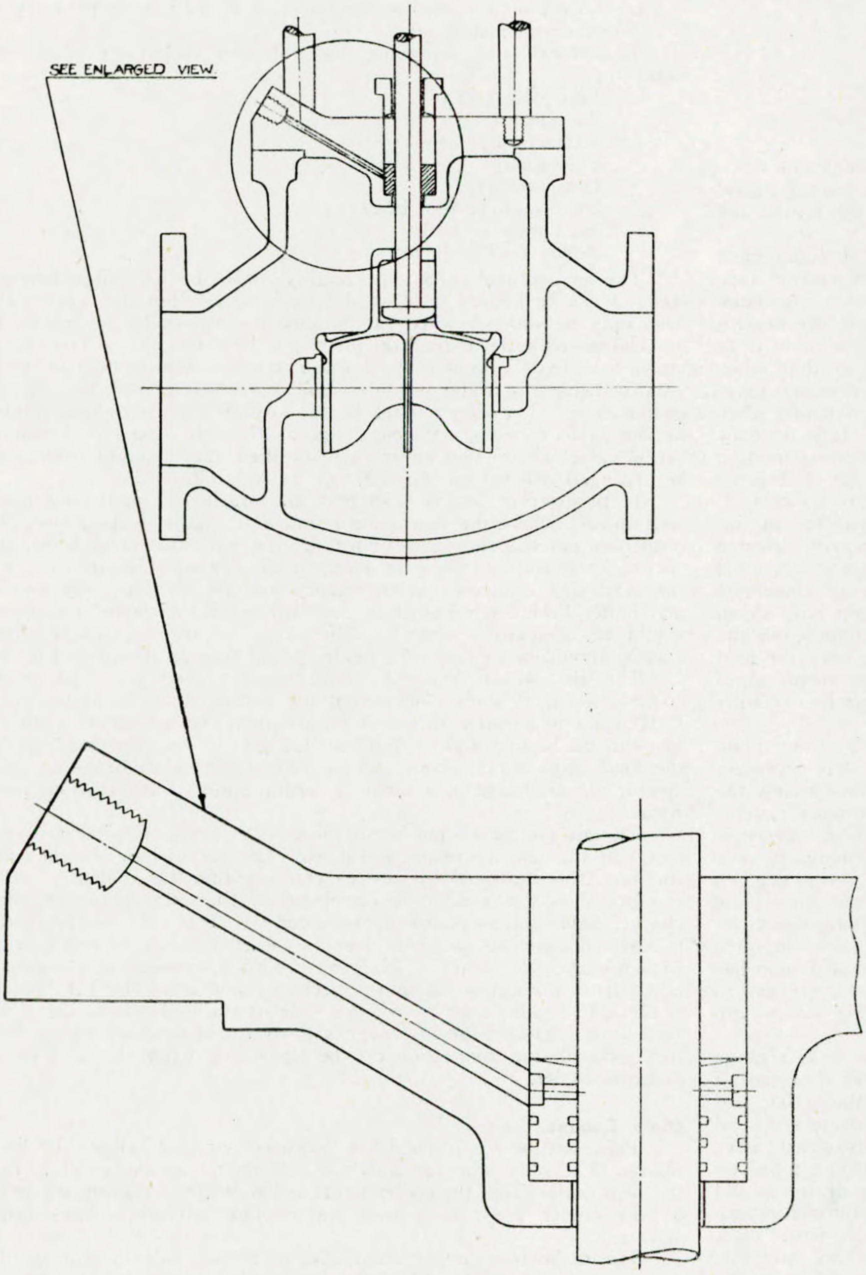

FIG. 16.—*Water sealed valve gland.*

regulator and the long feed line due to the economiser, dangerously high shock pressures might be encountered. Tests were undertaken in association with Messrs. G. & J. Weir, Ltd., and it was established that in the vessels under consideration shock pressure of dangerous amounts did not exist. It is, however, important to examine such systems for shock conditions before final plans are put into production. Feed heaters are better arranged on the discharge side of the feed pump, although there are certain operational advantages in having the L.P. heater on the turbo-feed pump suction, the principal one being that even during manœuvring periods when the bled steam is shut down, the L.P. heater can be used for dealing with the turbo-feed pump exhaust in association with the re-circulating valve. This exhaust is at a very high temperature (500/540° F.) and if led to a condenser inadequately baffled, trouble with the condenser and perhaps the L.P. turbine may result.

The feed heaters are usually multi-flow tubular type with inlet, outlet and bye-pass valves, and the feed piping presents no problems. Bled steam pipes can, however, be troublesome in spoiling an otherwise orderly pipe arrangement. To avoid this the heaters should be close together and reasonably close to the turbines, the bled steam should, wherever possible, drain towards the heaters, and N.R. valves should be arranged at bled points on the turbine.

Auxiliary Exhaust and Bled Steam.

In many modern installations where most of the units are motor driven, the auxiliary-exhaust system consists of the exhaust from the turbo-feed pump, the vapour from the evaporators and the returns from the oil-fuel heaters and tanks. In such cases the quantity of exhaust steam from the feed pump and evaporator can be effectively dealt with in the L.P. heater, and bled steam from a turbine stage at suitable pressure and temperatures supplies the H.P. feed heater. The turbo-feed exhaust and evaporator vapour to L.P. heater are branched to the condenser through a spring-loaded valve set to the shell pressure of the L.P. heater.

In other installations, where the majority of the power units are steam driven, the auxiliary-exhaust system can be a most extensive pipe arrangement. Particularly, is this so when every effort is made to conserve the heat in the exhaust steam by using it to heat the feed water. This type of design with reciprocating steam pumps is usually associated with a combination of water-tube and Scotch boilers, and steam deck machinery. The feed system is divided into two separate systems—one a closed system for water-tube boilers, and the other an open system for the reciprocating exhausts for the Scotch boiler feed system. The diagram of such a system shows the complication of connections and the number of auxiliary heat exchangers required.

Bilge Ballast and Oil Fuel Suctions.

These systems vary with the particular requirement of each owner. Some want big ballast and transfer pumps, and others are happy with pumps of reasonable size. Some again want a ring main system for oil fuel suction and discharges, whilst others want separate suction and discharges to each tank. Not so many years ago the transferring arrangement for oil fuel was a maze of pipes, valves and safeguards, but to-day, with more experience to our account, the transferring arrangements are generally simple and straightforward with very much greater security against mistakes than in the old system. The author's view is that a simple ring main system is preferable to any other, and gives the personnel all the facilities that are required to trim the vessel, to operate the boilers and to empty any tank for repair. In the case of oil-fuel bunkers which are alternatively used for water ballast, the tank suction valve is of the Scott Ross type; with this type of valve chest it is impossible to discharge the oil fuel overboard by the ballast pump or discharge ballast to the settling tanks by the transfer pump. The bilge and ballast systems are not such as require detailed description. For the former, the size, number and position of the suctions are governed by the Registration Society and the latter consists of one main from end to end of the machinery space. Since, however, they form the underfloor pipe arrangement, the pipe leads must be laid out with care, and in the author's view pipes should be run one above the other in tiers and not spread out on the plan view like a spider's web.

Circulating Water Pipes.

In steamers, the circulating water pipes to and from the condensers are by far the largest size pipes to be handled. They are usually short and only the overboard discharge pipe is conspicuous; even this need not come above the floor plates if the "scoop" effect, possible in fast vessels, is utilized. In most merchant vessels the athwartship arrangement of the condenser is far from ideal for the entering water condition, and considerable disturbance, aeration, and loss of head can take place in the condenser inlet water end due to this. Practical considerations of overhaul make a side branch on this box a necessity and the air freeing pipes should be of ample size. With the almost universal adoption of two-flow condensers for merchant vessels, the discharge branch also comes off this water box and terminates in a valve at the ship's side; this should be a full bore valve and arranged low down on the ship's side.

The large circulating inlet valves, ballast and sanitary sea suctions, should all be arranged on a common inlet box, built integral with the hull, and a generous-sized air pipe with valve should be arranged from the top of this box. Such an arrangement avoids too many perforations in the shell of the vessel, permits valves of standard shapes and sizes to be utilized, and effects a certain amount of de-aeration of the circulating water before passing it to the pump.

The oil and water coolers should be circulated from the main circulating pump discharge, and care must be taken to ensure that the limited head available from this pump is fully utilized by placing the coolers at the right height and that the pipes do not impose undue resistance. In passenger ships it is not unusual to take the hot-salt-water pump suction from the overboard discharge, in which case pipes should be of copper and all fittings, including the pump casing, of gunmetal.

In Diesel vessels it is now universally accepted that fresh-water cooling for jackets and fresh-water or oil cooling for piston are a prerequisite for satisfactory operation of the vessel. This is also true of auxiliary Diesel engines supplying the power for pumps, etc. It is also becoming standard practice to work the fresh-water cooling systems on a closed circuit, the pump discharging through the oil, and water coolers through the engines and back to the pump suction with no intervening tanks, except a small head tank of about ½-ton capacity placed above the highest point to be cooled and connected to the cooling-pump suction piping. For circulating the auxiliary engines in dry-dock, the same system works well if the oil coolers are circulated with the fresh water used for cooling the jackets; as the temperature rises, so much of this water can be discharged overboard and make-up drawn from the fresh-water main. By this system special double bottom tanks set aside for dry-dock operation are not required.

Lubricating Oil.

For all types of machinery the lubrication systems are almost identical. The oil is returned to a drain tank in the double bottom of the ship or arranged as a separate tank sitting on the tank top. When the former is necessary then the tank should be separated from surrounding oil fuel and sea by cofferdams. The return pipes should be arranged as remote as possible from the pump suction pipes and the oil flow given as long a path as possible before reaching the suction pipe. This gives some assistance to the oil coolers and materially affects de-aeration. The bottom of the drain tank should have a sloping bottom to form a sump, or alternatively a "hat box" should be let into its bottom, and a hand pump suction arranged at this lowest point readily to get rid of water. Adequate sounding arrangements are very necessary. The return pipes to the drain tank should be generous in size and adequately vented to atmosphere to avoid hold up of flow. The drain tank must be of adequate size to allow for a circulation rate which is not injurious to the oil.

There should be invariably a working pump and a standby pump, and each should have its own suction pipe to the drain tank. If this is done there need be no suction valve on the pump, and if the pumps are arranged to sit on the top of the drain tank the suction conditions are then the best possible. In motor-driven or turbine-driven pumps of the gear type, this is most important for satisfactory and quiet operation. The discharge valve on the pumps should be of the non-return type when no suction valve is fitted. Magnetic strainers are often specified and are probably profitable in geared turbine vessels, although the author has rarely found metallic particles after the first circulation of oil at the builders. Much damage can be done to new machinery by inadequate precautions when first circulating oil. It is an excellent practice to use a flushing oil charge on new machinery. This flushing oil is much less viscous than the working oil, and washes foreign matter into the drain tank from where it is cleaned out by hand when the flushing oil charge is barreled for return to the suppliers.

From the pumps the oil is discharged through coolers and filters to the bearings, and often a gravity tank with about five minutes' supply stands sentinel over the system should the oil pump fail from any cause. The relative position of the filters and coolers is often a cause of some controversy; the author believes that the filters should be the last fitting through which the oil passes before reaching the bearings, but many contend that the oil is better filtered when it is warm and before it reaches the coolers from the pump. Another point that many marine engineers reject is that the oil should not pass through the oil coolers until it has reached a temperature of 100/110° F. If the oil is pumped through oil coolers while its temperature is low there can be only one result, and that is gummed-up oil coolers and disappointing performance from otherwise satisfactory coolers. Oil-cooler tubes should be square pitched, not diagonally pitched such as used in condensers. There should be warning devices in all lubricating-oil systems and when a gravity or sentinel tank is fitted visual means should be provided at the starting platform to show that this tank is full and overflowing. The best and safest warning is that which shuts down the machine when the oil pressure falls below a predetermined amount; pressure gauges at turbine and gearing bearings for oil supply is a waste of money, test cocks direct from the bearings being by far better tests. When it is necessary to fit valves to individual bearings of a group these should be of the "non-shut off" type so that in no circumstances is it possible to shut off all oil to the bearing.

Maintaining the oil in a satisfactory condition is of the utmost importance, and to this end equipment must be included in any installation. This should include renovating and waiting tanks with heating coils, and centrifugal purifiers.

Fire, Sanitary and Deck Services.

These services are usually capable of being dealt with by several pumps in most installations, and the discharge piping can best be dealt with by arranging a discharge manifold in the engine room. The sanitary service pump is usually on continuous duty, discharging to the sanitary tank. This tank should have dished and not flat ends, as the author has found that the ends of these tanks when flat are rarely satisfactory. The tank should be well protected from freezing in cold climates, otherwise considerable inconvenience and repairs will result. Means for draining the whole system in Arctic conditions are desirable. The discharge head of pumps on fire duty should be adequate to give powerful jets of water to the highest or furthest point from the pump. As these pipes run up the engine casing before emerging on deck, lagging with felt is desirable to avoid sweating.

Compressed Air System.

This system is largely confined to Diesel-engined vessels and consists of auxiliary air compressors and air receivers in number and capacity to suit the power and manœuvring conditions of the vessel. The relative capacity of these was, at one time, a source of keen controversy, but to-day the subject has become more stable and we do not find the great difference in power and capacity in these units which prevailed in the early days of Diesel propulsion.

Whether the compressors are steam- or motor-driven depends upon the characteristics of the installation as a whole. If steam is available it is economic to have steam-driven compressors, as this eases the manœuvring load to be handled by the electric generators, and since the compressors work at infrequent intervals, their steam consumption is not a serious matter in the economy of the vessel. Where, however, large auxiliary generating plant is necessary for other purposes, then the compressor can with advantage be motor-driven.

An examination of the air compressor and air receiver capacity in nine recent single-screw Diesel vessels with powers varying from 1,800 to 6,700, shows that two in number receivers and two in number auxiliary compressors are standard, that the starting air pressure varies little from 500lb. per sq. in. to 600lb. per sq. in., and that the total air receiver capacity is 280 cu. ft. in the lowest power and 350 cu. ft. for the largest power. The capacity of each auxiliary compressor in the same series varies from 100 cu. ft. to 145 cu. ft. per min. It would, therefore, appear possible to standardize completely this equipment which caused so much controversy a few years ago The author would with confidence fit in all single-screw Diesel vessels up to 4,000 s.h.p. two compressors each of 100 cu. ft. and two air receivers each of 140 cu. ft., and from 4,000 to 8,000 s.h.p. two compressors each 150 cu. ft. and two receivers each 170 cu. ft. with pressure in each case of 600lb. per sq. in.

The pipe arrangement is not a very extensive one, all the pipes being of small bore except that from the air receivers to the engine starting valve. Spigot and faucet flanges with a copper joint ring are accepted practice. Air receiver mountings are inlet and outlet valves, relief valves, and drain valves with manhole at one or both ends. Receivers can be welded or riveted; the latter has given trouble-free service to date.

Air to whistle is usually taken at reduced pressure and the reducing valve should be of the type which can deal with a varying inlet pressure and constant outlet pressure, as the receiver during manœuvring periods will fall in pressure and the whistle may well be in use at such times. The whistle pipe must be at least 1½in. diameter to conform to the requirements of the classification society for sound signals. It is much too large for its duty.

Drain System.

This is one arrangement comprising pipes of small bore which can make or mar the performance figures of the main machinery.

The loss of feed water attributable to lack of conservation of drains can be a serious matter in all modern steamer performances. If the make-up feed requirements can be kept to a nominal figure the result in the overall consumption figure is well worth a complete drain system.

The fitting of reliable steam traps on all steam lines is the first step towards economy of feed water and freedom from inadequate drainage of important lines and auxiliaries. There are numerous makes of traps, some good and some not so good, and the author's view is that many not so good have been fitted because of the price question; this has given rise to the lack of faith in steam trapping quite prevalent to-day.

The main steam lines to turbines should form a water shed, one part of which drains to the boiler and the other from the manœuvring valves to the engine. It is too much to hope for a constant fall to either. Drains from boiler stop valve and engine casings then should be adequate provision in such cases and both of these should be trapped and led to the feed tank; a bye-pass round the traps is a safeguard for a defective trap.

The astern manœuvring valve should have a double shut-off valve to prevent a leaky astern manœuvring valve passing steam to the astern turbine with turbines running ahead. A drain valve should be fitted between this valve and the manœuvring valve to take away the leakage, and this drain should be led to bilge and to condenser. If the astern valve leaks it will be obvious at the bilge drain, when it can be switched to the condenser; superheater header drains are open drains and led to a funnel of adequate dimensions and thence to the feed tank. Turbine drains should all be trapped drains and led to the condenser except the H.P. turbine, which is an open drain to funnel and thence to feed tank.

Feed heater drains are all controlled by orifice plates of suitable dimensions and each heater drains to the next lower pressure heater with which it is in series and finally to the drain cooler and condenser.

Gland steam leakage at the vapour hood should not be accepted as complying with modern requirements of habitability or economy. Fig. 17 shows a system for the control of gland steam leakage at the vapour hoods. By this system habitability is improved, feed water is conserved and there is a slight gain in heat transfer to the feed water. This system consists of coupling up all the turbine vapour hoods to a small tubular condenser which is maintained at a pressure slightly sub-atmospheric, say 1″ Hg. by means of a steam jet air ejector. All the main feed from the extraction pump passes through this condenser and condenses the gland vapour and the jet steam, the condensate being led to a feed tank. The amount of steam used in the ejector is negligible.

The evaporator drains should be led to the appropriate feed heater with branches to condenser and feed tank for exceptional occasions. Drains from ship's heating and other ship's services, such as galleys, should be led to a trap in the machinery space; this helps to avoid steam blowing into the feed tank and controls automatically the amount of steam these services can take, insofar as it must be condensed before it can pass the trap.

Soot blowers must drain to bilge, but if some form of automatic drain valve is fitted the loss from this cause should not be serious. All drains which are suspected of sea water contamination or oil contamination should be led to the hard or first distilled tank for re-evaporation before entering feed circuit again.

Oil fuel heater and tank heating coil drains should be trapped drains, and led to an observation tank and thence to hard water tank or, if contaminated as observed at observation tank, to bilge. Drainage of the whistle steam pipe is necessary to ensure that the first blast is clear and understandable. The trouble with whistle drainage is due, in many cases, to insufficient lagging, but it is extremely difficult to keep molecules of water from flowing down the steam pipe, and when the whistle is blown the steam in its passage picks up these droplets and pushes them through the whistle. The author suggests that some circulation through the whistle pipe would avoid this condensation, such as taking steam to a small continuous-duty pump from near the whistle and so keep the temperature of the pipe walls high.

Safety valves and waste steam pipe drains should be led to a hard water tank.

Oil-engine Exhaust.

The exhaust pipes from main Diesel engines are so proportioned that the back pressure on the engine is not excessive and any silencer, heater or waste heater inserted into the flow must be designed with that consideration in mind. Further, the exhaust must be expelled at the funnel top, free from sparks or matter likely to damage passengers' clothing or lifeboat covers. Many devices, from spiral flow vessels to water jets in a lead-lined tank, have been tried to effect this, with varying success. It can, however, be said that water jets are not the answer as the trouble which corrosion brings in its train outweighs the advantages. The spiral or vortex flow in all probability gives the best results for the money expended.

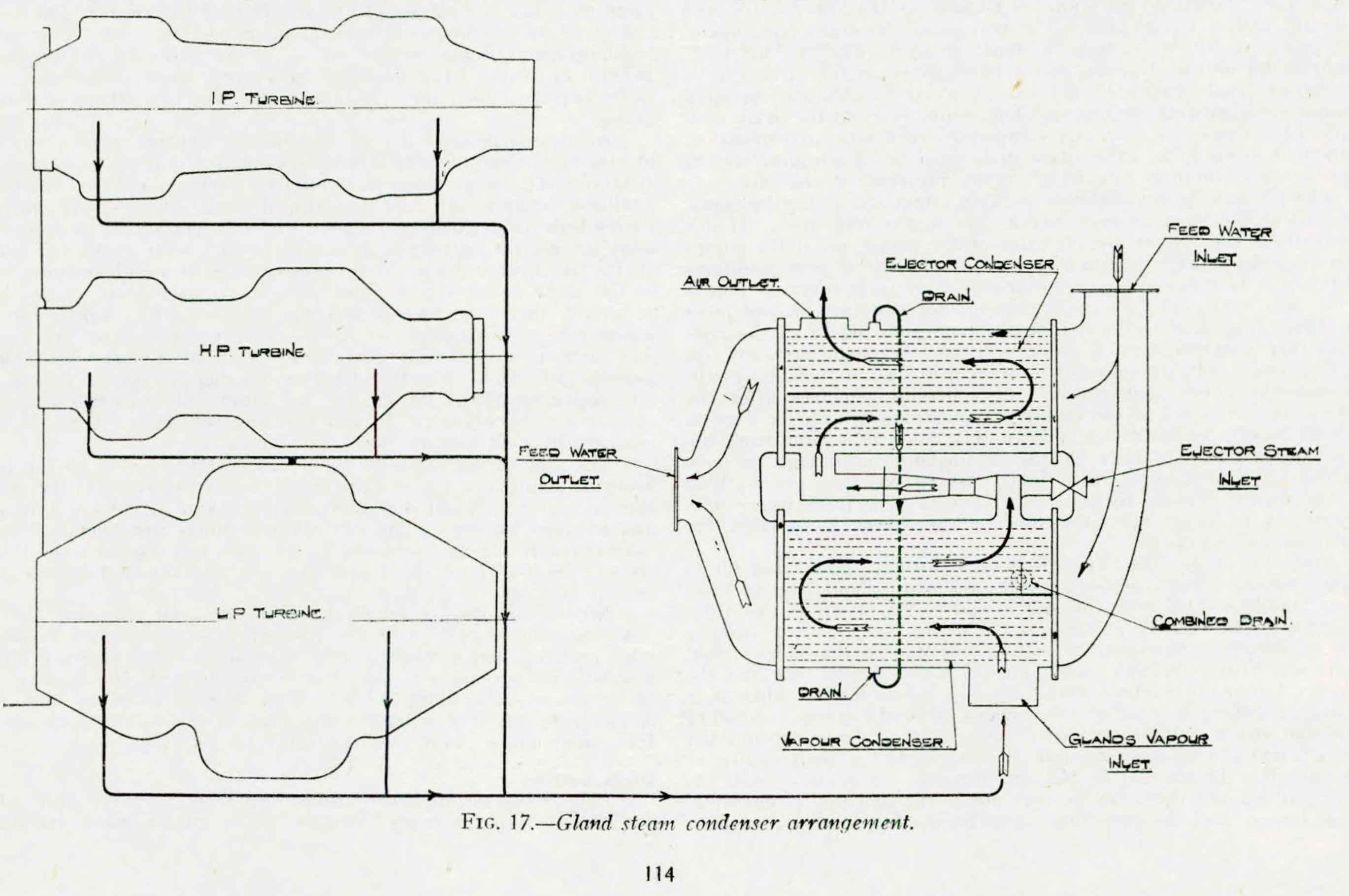

FIG. 17.—*Gland steam condenser arrangement.*

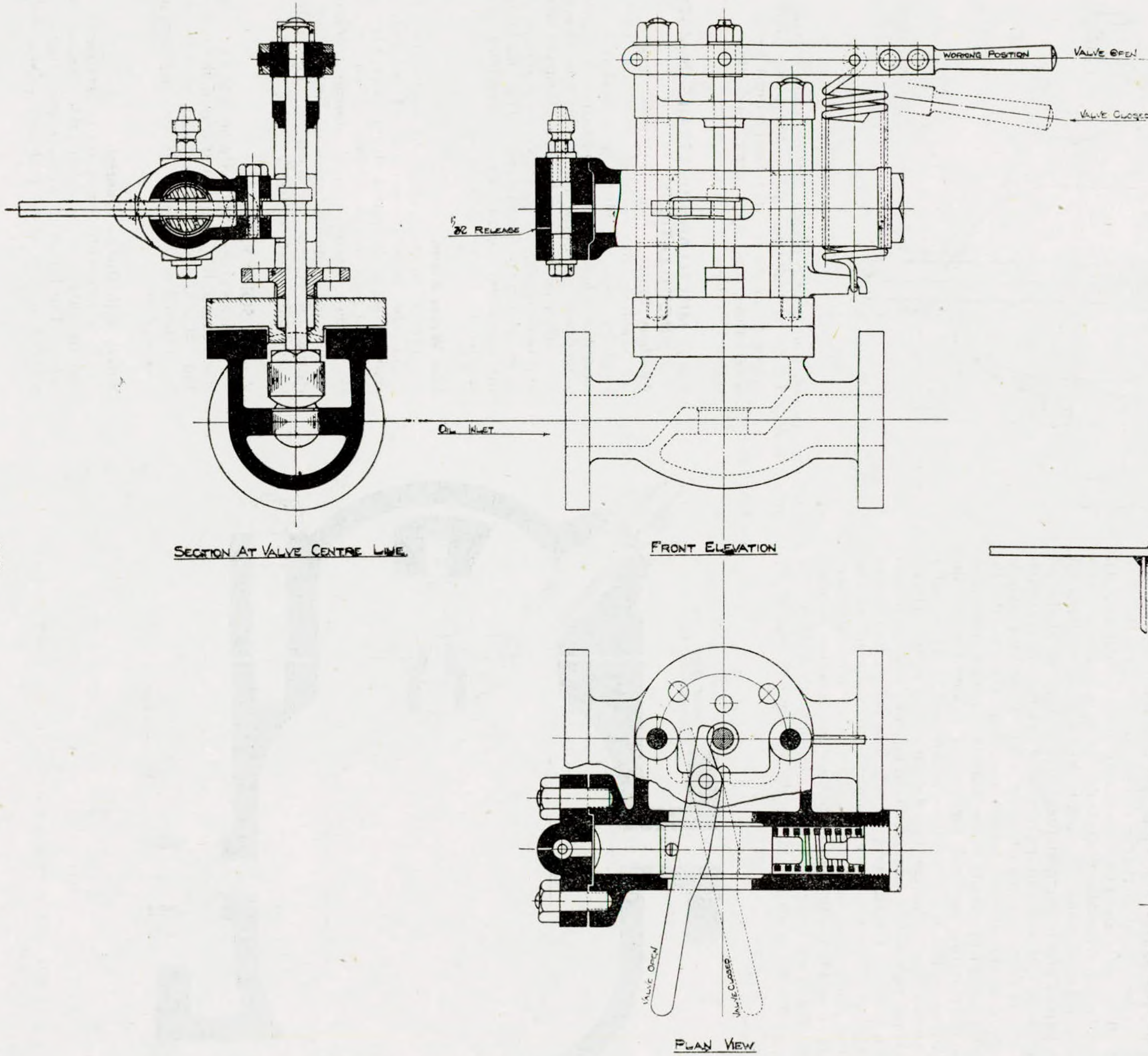

FIG. 19.—*Low water alarm.*

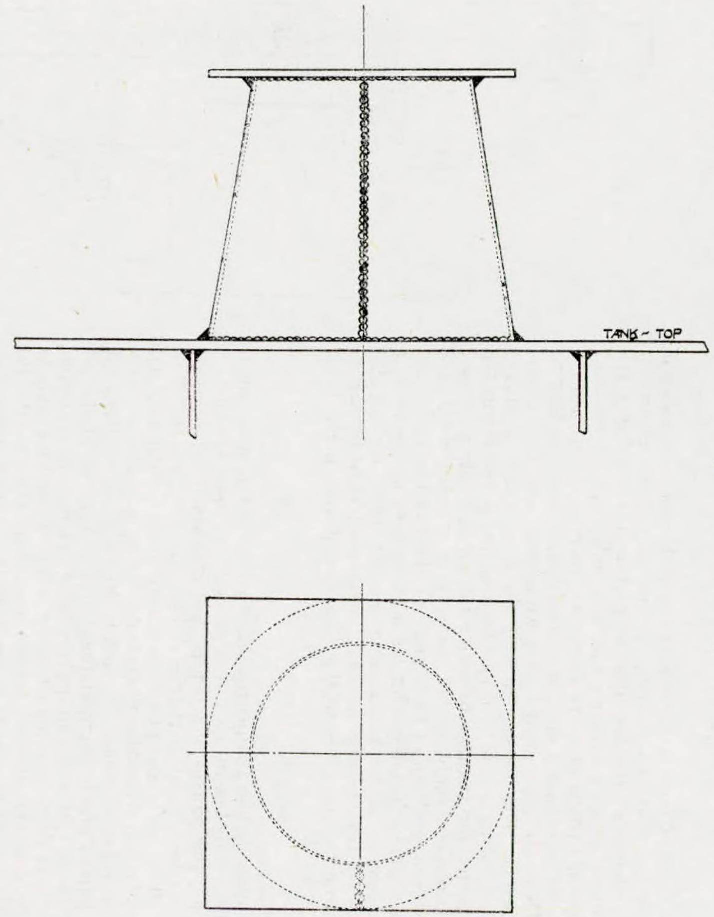

FIG. 18.—*Typical coned fabricated seat.*

Expansion troubles both in the engine manifold and main exhaust pipes have been successfully solved by the use of bellows expansion joints. Thermometers of the dial type at each cylinder exhaust are worthwhile fittings, as they give an excellent indication of the load on each cylinder, and probably more accurately than indicator cards.

Auxiliary-engine exhausts are often troublesome pipes to lead to the funnel. Their size has grown with experience and this accentuates the problem. The conservation of the heat in the auxiliary exhaust from generating sets is best done by inserting a simple tubular or coil water heater for heating the water for all domestic purposes. This gives a constant supply of hot water at practically negligible cost. The expansion problem of these pipes can best be met by inserting next to the engine a length of flexible metallic hose of the correct bore. Two silencers on each auxiliary-exhaust pipe are usually necessary to avoid troublesome noises. These need only be simple single-baffle silencers, one close to the engine, and one in the main funnel.

Oil Fuel Discharges.

This is another system comprising small pipes, and as these small pipes are dealing with hot oil-fuel at a pressure in some systems of 300lb. per sq. in., the flanges and bolting are important. It is usual practice to have the hot oil discharge fittings in cast steel, to have the plant and all its units and filters on a tray and in duplicate, and all piping must be led above the floorplates. It is now almost standard practice to centralize control at each boiler front, with a shut-off valve to each burner and a re-circulating valve at the end of the oil fuel pressure main. Means can be provided which automatically shuts off the fuel if there is a loss of water in the water-tube boilers. The steam supply to the oil-fuel heaters should be thermostatically controlled so that the steam supply to the heaters is varied automatically with the temperature required for correct atomization of the fuel at the burners. The worst trouble encountered is when water gets into the burner line. This can best be got rid of in the settling tank by providing reasonably generous heating coils and a syphon valve to syphon water to the bunker gutters before the oil-fuel pumps are connected to it. For this reason settling tanks should not be arranged at the ship's side, as the cooling effect of the sea makes heavy demands on steam for the proper settling out of water, in addition to the possibility of ingress of sea water through leaks in the shell. Water can also be cleared from the burner line by the re-circulating valves, but failing proper means being provided on the settling tanks, this is an annoying and exasperating process. The drains from the oil-fuel heater must be led to some observation and filter tank, and these should be trapped drains.

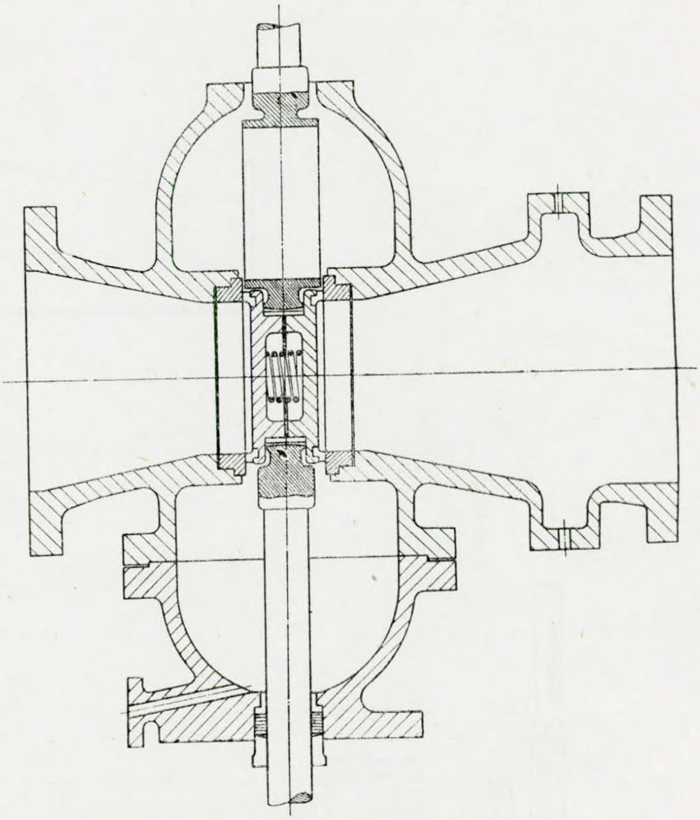

Fig. 20.—*Venturi sluice valve.*

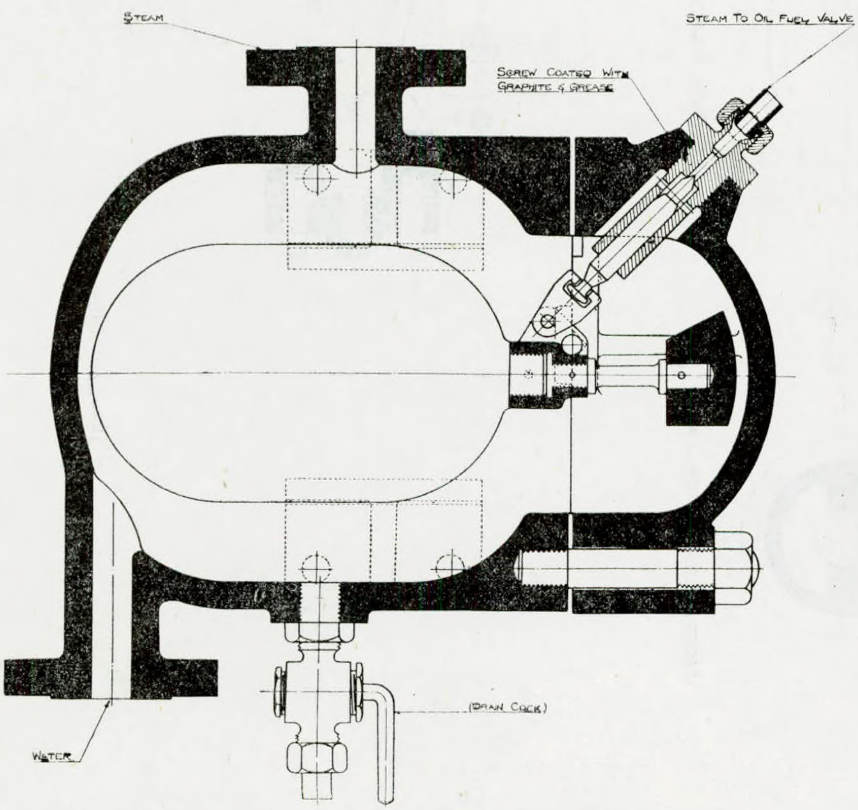

Fig. 19A.—*Float chamber assembly (low water alarm).*

(3) MISCELLANEOUS DETAILS IN MACHINERY INSTALLATIONS.

Auxiliary Seats.

Welding has largely replaced riveting for auxiliary seats, resulting in considerable saving in weight and lower maintenance charges. There is still a tendency to follow too closely the riveted design and sufficient use is not made of curved surfaces to improve rigidity. Fig. 18 shows a simple seat made from a circular coned plate. This design results in the maximum rigidity with a minimum of material and length of run of weld.

Low Water Alarm.

Fig. 19 shows a type of low water alarm for water-tube boilers consisting of an external float chamber set to operate a steam valve when the water reaches a predetermined level. When the valve opens the steam operates a small plunger connected to a shoulder on a spring-loaded oil-fuel master valve, so cutting off fuel to the burners. This valve can be tripped and reset by hand.

Venturi Sluice Valve.

Sluice valves frequently become too large for the space available. By making use of the type shown in Fig. 20, a saving in space and cost can frequently be achieved without any serious increases in resistance to flow.

Valves with Distant Control.

It is frequently necessary to arrange for the control of valves at a considerable distance from the valve. The Board of Trade require that it should be possible to close all oil-fuel tank valves from outside

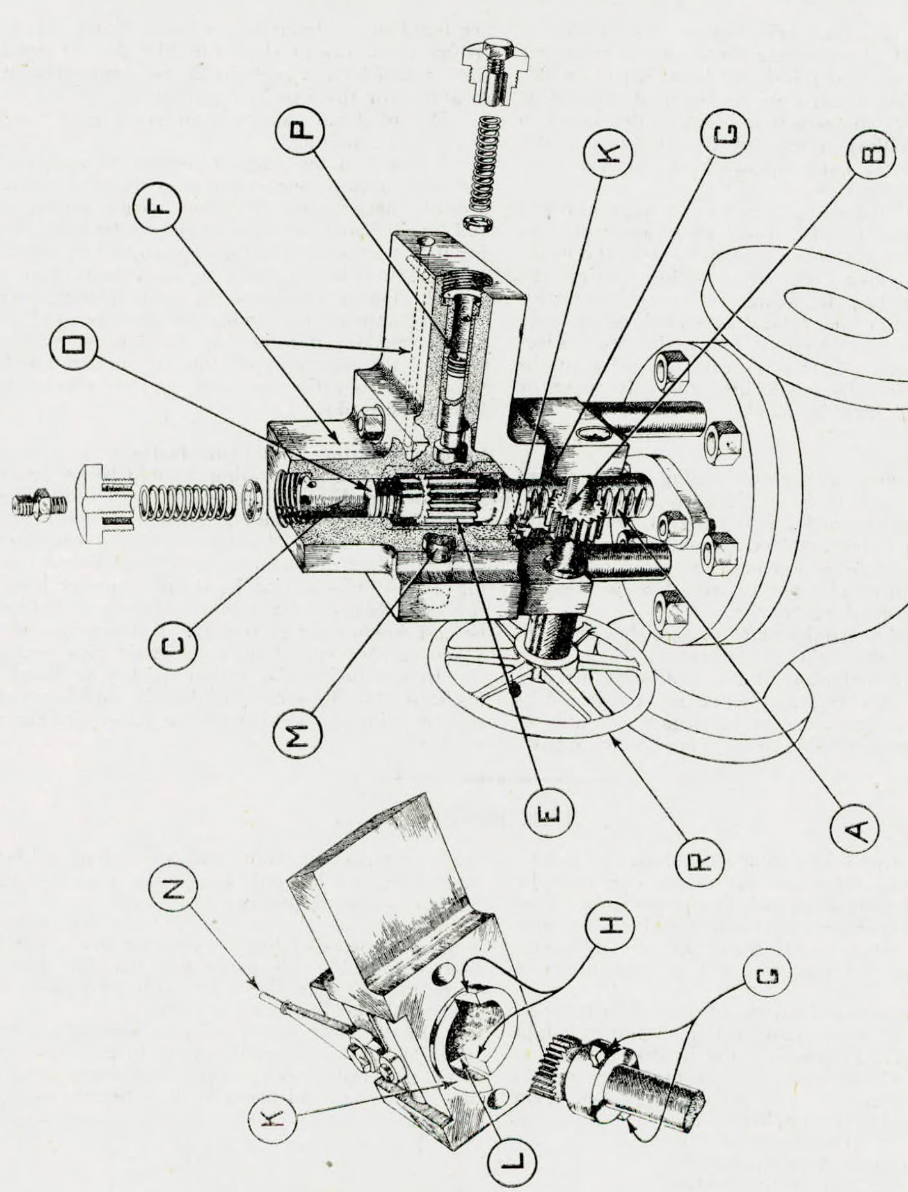

FIG. 21.—*Hydraulic controlled valve.*

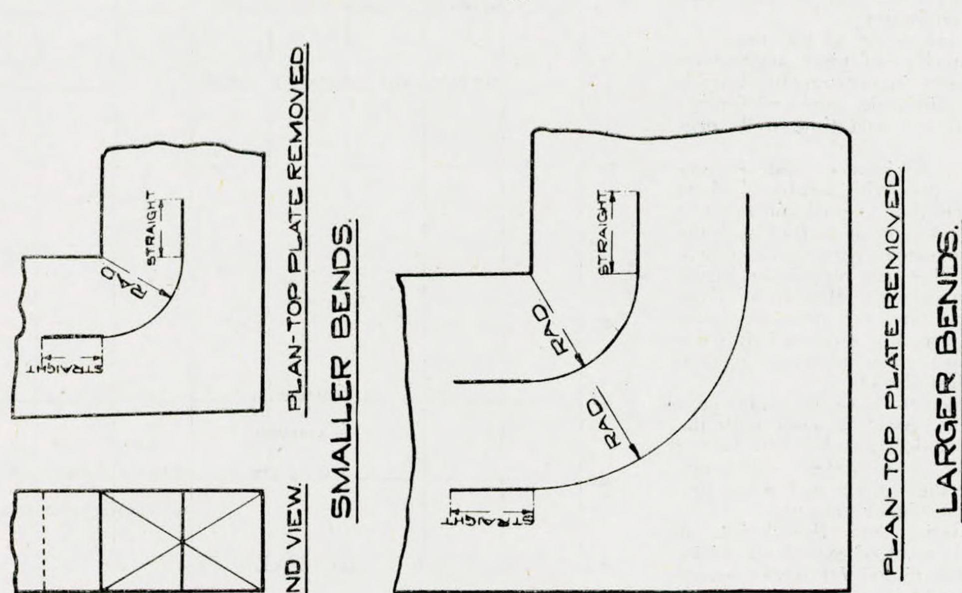

FIG. 22.—*Elbows in air trunking.*

the machinery space and other occasions arise where distant control is necessary. The usual method of operating these valves is by extended spindles, together with universal joints and bevel wheels which are expensive to install and liable to seize-up owing to distortion or expansion in case of fire. Fig. 21 shows a type of valve developed to overcome the difficulty of installing a multiplicity of gearing and extended spindles. This valve is hand operated at the valve by means of the handwheel *R* and the rack *A*.

The long-distance closing of the valve, however, is hydraulic and all the valves open on the system can be closed simultaneously. In closing with long-distance control, oil under pressure enters the cylinder *C* and acts on the piston *D* closing the valve. While closing, the pinion *E* slides in a rack attached to the plunger *P* and the two projections *G* slide in slots *K*. After the valve has seated, oil acts on plunger *P* and the attached rack rotates pinion *E* and the two projections *G* engage the helical faces at *K*, thus locking the valve in the closed position.. The hand lever *N* is for locking the valve open or closed by moving the horizontal rack by hand.

Ventilation.

The old type of cargo steamer with reciprocating steam engine and large engine-room casings was usually ventilated by natural ventilation, but modern machinery works under much higher temperature conditions and in more confined spaces, and oil vapour from fuel and lubricating oil together with leakage of exhaust gas from oil-engine exhaust necessitates more frequent changes of air than is possible except by using a system of forced ventilation.

The capacity of fans should be sufficient to change the air from 30 to 60 times per hour depending on the circumstances.

In making a layout of the distribution of the ventilating air in a Diesel installation having two-cycle machinery, due regard should be paid to the position of the scavenge-pump inlet which is liable to short circuit a good deal of the ventilating air. Where sharp elbows are fitted in air trunking, splitters should be fitted at each elbow to reduce resistance as shown in Fig. 22. If exhaust fans are installed they should have a capacity 20 per cent. greater than the supply fans to allow for the rise in temperature.

Where steam vapour is present supply trunking should be lagged to prevent sweating.

There is a tendency at present to reduce the height of funnels, and with funnel temperatures reduced to about 300° F. there have recently been cases of funnel gases coming down on to the deck and being drawn into the engine-room ventilation system. The cure for this is either to heighten the funnel or else to discharge the funnel gases at sufficient velocity to keep them clear of the deck. Induced draught makes discharge at high velocity possible without a large plus pressure in the combustion chamber and velocities of 30 to 40ft. per second are normal. If the hot air from the stokehold is discharged through slots on the aft side of the funnel, it will help to reduce the negative pressure at that point which tends to pull the funnel gases down.

Ladders, Gratings and Floor Plates.

Floorplates and gratings should be arranged for definite purposes and not merely to fill in vacant spaces. Bilges should be left uncovered where possible and gratings fitted instead of floorplates at the sides of oil tanks. Floors should be strong enough to land heavy gear on when overhauling, and with Diesel machinery a heavy landing platform is advisable at the cylinder level with good transport facilities ashore. The general scheme of ladders and gratings should be laid down at an early stage in the design, as it is difficult to design a satisfactory layout once the main pipe system has taken shape.

In conclusion the author wishes to thank a senior member of his staff, Mr. Lawrence Blake, for his assistance, especially in connection with the section of the paper dealing with the various pipe systems.

Discussion.

Mr. W. Sampson (Vice-Chairman of Council), opening the discussion, said that the great value of the paper lay in the fact that the whole of it was based on wide knowledge and long experience. One was often struck by the great difference between machinery layouts, but a good layout and pipe arrangement made all the difference between an easily-operated ship and one that was a constant cause of trouble and expense.

The author had listed the essential features of a good installation under a number of headings to which two further headings might have been added. The first was "Simplicity" and in that connection the duplication of lines and valves and cross connections should only be fitted if thorough investigation and judgment proved them absolutely necessary, for they certainly complicated the system very often needlessly. A great many of the so-called emergency cross connections were themselves a cause of trouble and expense, and their number should be cut down to a minimum.

Another heading should refer to the need for utter cleanliness of the interiors of pipes and valves. Time taken and money spent in thoroughly cleaning out all pipe systems from mill-scale, sand and foreign matter of all sorts was money and time well spent in the initial stages.

Table 1, Velocities and Resistance, made it very clear how in the modern ship with relatively short pipe leads it was the valves that created the greatest pressure drop. If better design of valves and the use of the author's recommended venturi sluice valve cut down pressure losses, then the pipe losses could have been based on higher velocities than those given in the table. In fact, it was often the optimum choice to afford some reasonable pressure drop and thus use smaller pipe sizes, which was most important in high pressure and temperature installations.

It would be interesting to have it made clear why higher steam velocities could be used with the higher pressures. It was understandable why higher velocities were permissible with higher superheats, and it was possible that the author had associated higher superheats with those higher pressures.

With regard to materials and the design of flanges and bolts, there was a lot of experience which proved that stud bolts (type *C* and *D*) recommended in the paper should be used. There had been very many instances of faulty heads dropping off bolts after a short time in service, and it would have been a good thing if the stud bolt had become standard practice.

There was a practice of tightening bolts up to a measurable extension corresponding to a design stress, but the very true observation contained in the paper that the pipe flange rose in temperature more rapidly than the bolts with consequent increase in stress had always to be taken into account.

On the subject of insulation, usually too little thought was given to the choice of material. Very often a combination of two or even three materials which, when combined, gave high insulation value on a minimum thickness with a maximum of mechanical strength,

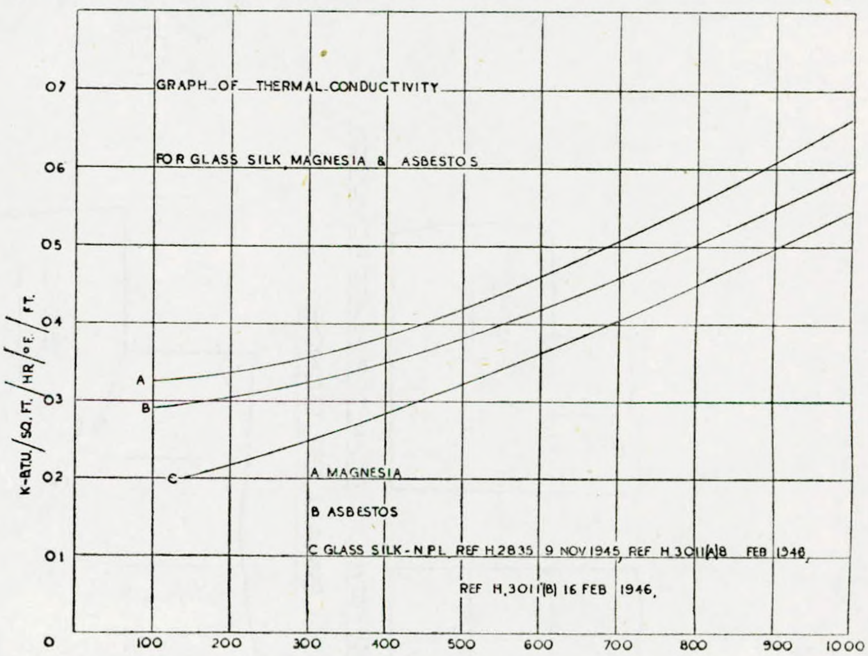

FIG. 23.

was often much better than a single material. Adequate protection against physical damage to insulation was also very important.

With regard to engine-room arrangement of ventilation, particularly in the modern steamer, the forced-draught fans delivered to the boilers an amount of air many times more than the change of air given by the author, and in laying out the arrangement it was often found that the forced-draught fans could be positioned, or have their intakes arranged, so that they served well as an important part of the machinery space ventilation scheme.

There were really very few points in the paper which could be termed controversial. In fact, the paper should be read and kept as a valuable reference for those who were writing specifications and for use in engineering drawing offices.

Mr. R. R. Houston (Visitor) said that, in regard to Table III, when two thermal conductivities were given against one material, it was essential to state the density at which these thermal conductivities had been taken, as this was a determining factor. On the question of mean temperatures, a fact that might not generally be appreciated was that it was essential to state both hot and cold faces, otherwise no true working temperature was given. For example, one might take a mean temperature of 500°, but it was a question as to how it was arrived at—it might be 100° cold and 900° hot; on the other hand, it might be a higher cold face and lower hot face. Therefore one did not get a true picture when only the mean temperature was stated.

Fig. 23 was a graph of thermal conductivities of magnesia, asbestos and glass silk, and it would be seen that the conductivity of magnesia did not approach the figures of glass silk at any temperature on the scale.

The author stated that owing to the delicate structure of glass silk, it was liable to heavier depreciation in service. This had not been the experience of the manufacturers in many years of marine and land engineering work; it was certainly not more liable to depreciation than any other insulating medium.

Mr. R. L. J. Hayden (Visitor) said that the paper could be taken as a very good example of how any design problem should be tackled, that was by setting down clearly the objective to be achieved and the problems that had to be considered in their order of importance. The best design then followed logically.

With regard to the question of tightening of bolts, it would be interesting to have the author's opinion as to whether it was best to tighten bolts on flange joints to their limiting stress for cold strength, or whether the tightening should only be to the stress which bolts would actually withstand under heat. If the flange was at high temperature the bolt would only stand quite a low stress, and it seemed to be the practice to specify that the bolt should be tightened to a very high stress; yet with that high stress it seemed under heat that it would relax and leakage would result.

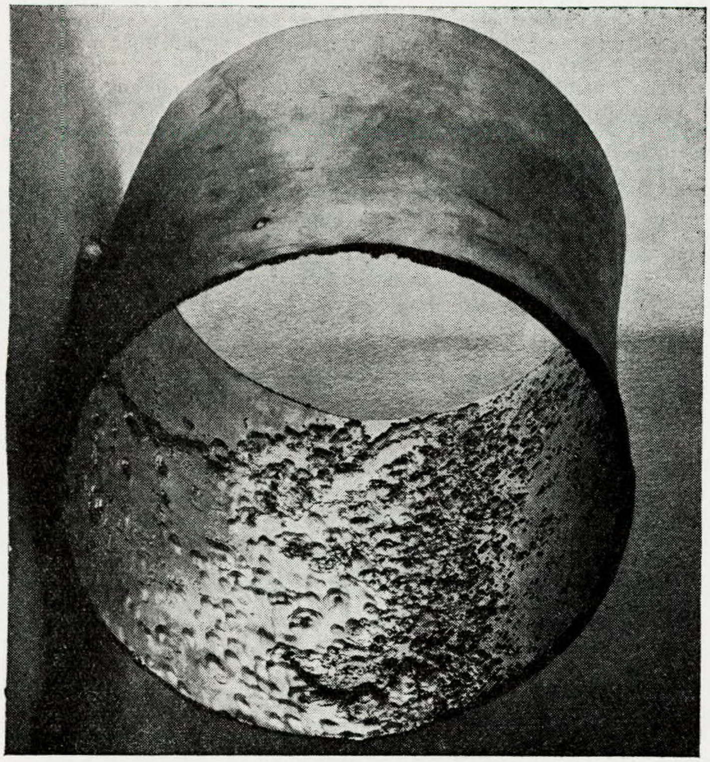

Fig. 24.

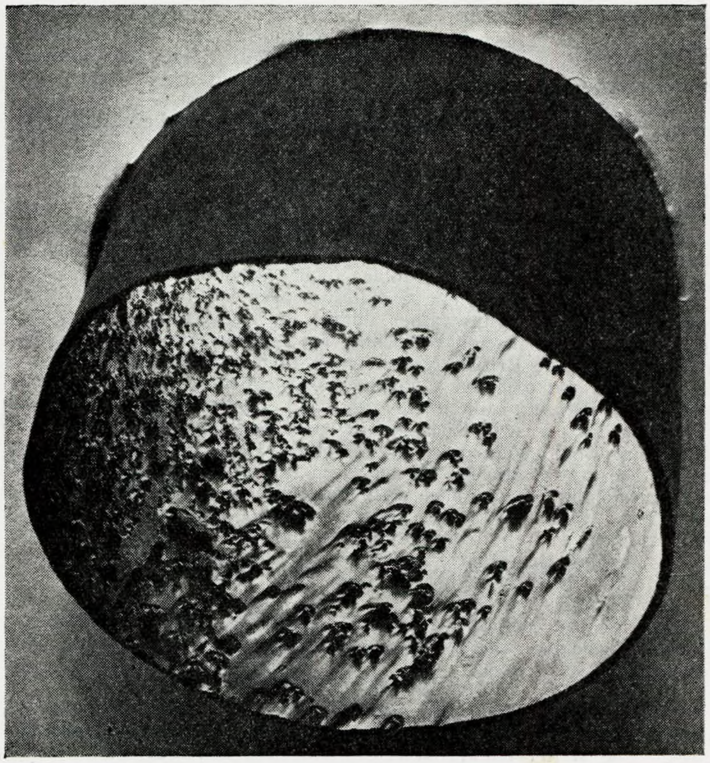

Fig. 25.

There was a need for flange standards. There was no doubt that there were an unlimited number of sizes of flanges which were used and something could be done in that direction. American standards tended to large pitch circle diameters which caused a corresponding increase in flange size which was not always desirable.

With regard to gas-filled joint rings, it was not often one heard of these being used with high-pressure steam and it would be interesting to hear if the author had had any experience of this type of joint.

Although no mention was made of the details of piping expansion calculations in the paper, amplification was desired as to the method of determining the rigidity of the fixed points. There seemed to be some doubt as to whether any movement of those fixed points occurred.

With regard to the shape of welds connecting flanges to pipes, the conclusion had been reached by the speaker's firm that a rounded weld was not the right thing. The electrode could not get to the bottom of the weld and one got a shorting between the tip of the rod and the sides of the flange with consequent slag inclusions.

Mr. H. F. Sherborne, M.C., M.A. (Associate) said that it was gratifying to note the painstaking care which had been taken in looking into the structure of the details of the German destroyers. If the same amount of care as was taken on that part of the job was given to the remainder, a lot of useful information should be available.

On the subject of materials, the speaker was engaged in trying to discover the extent to which copper pipes were suitable for conveying salt-water in merchant ships. Nothing the author had said would indicate that they were anything other than satisfactory, but as it was quite impossible to deal with all aspects of the subject it might well be that that had been left out. On the metallurgical side it would not do to build far into the future, but one prediction which it might be possible to make was that in a few years time, on naval vessels at any rate, there would not be any salt-water conveyed through copper pipes. There was no question whatever that where salt-water was sent at high speed through copper pipes, and under conditions which made for turbulent flow, exactly the same type of corrosion occurred as used to take place in condensers when brass tubes were used. That was now ancient history, because metallurgists had produced tubes which would not corrode under those conditions.

Figs. 24 and 25 illustrated the effects of horseshoe corrosion, more accurately described as air infringement attack.

On page 113, column 1, it was stated: "In Diesel vessels it is now universally accepted that fresh-water cooling for jackets and fresh-water or oil cooling for piston are a prerequisite for satisfactory operation of the vessel. It is also becoming standard practice to work the fresh-water cooling systems on a closed circuit . . ." The Anglo-Saxon Petroleum Co. had various jobs done on the Clyde and Tyne and at Belfast with tubes up to 7½ to 8in. in aluminium brass, the same as the alloy which had been so successful for condenser tubes. The apprehended trouble about aluminium-brass in some quarters was that it was not so readily copper-smithable. That would appear to be displaying rather undue apprehension of the copper-smith who, after all, could probably be led quietly along if he were not bustled. The British Non-Ferrous Metals Research Association had evolved and patented a copper-nickel-iron alloy with 5 per cent. nickel, 1 per cent. iron and 94 per cent. copper, which they were trying out in at least three classes of naval vessels at the present time. How that would compare with the other would remain to be seen. If the Mercantile Marine had not been troubled in the same way as the Navy had been troubled with that type of attack, perhaps those new alloys would not be so general as otherwise would have been the case, but to repeat the prediction that had already been made, it was thought that in five years' time there would not be any salt-water taken through copper pipes on naval vessels.

On the proposal of **Mr. A. F. C. Timpson, M.B.E.** (Member of Council) a hearty vote of thanks was accorded to the author with acclamation.

BY CORRESPONDENCE:

Wing Commander J. M. Aiton: The author stated that for high temperature work over 750° F., it was necessary to use a molybdenum steel. The writer could not agree with this statement as it stood. A normal 0·18 per cent. carbon steel was perfectly satisfactory for use up to 850° F. and even in certain cases up to 875° F.

Low-alloy pipe steels did not show any appreciable advantage over carbon steels except in their ability to resist creep strain. Up to 850° F. the allowable working stress was fixed by allowing a factor of safety on the limit of proportionality of the steel to be used, because this stress was lower than the stress which was allowable if creep was used as the basis of design.

The writer felt also that to describe the alloy steel to be used merely as a "molybdenum steel" was far too vague, and considered that if the author had said "a steel which contains among other elements molybdenum", this statement would have been more valuable. The writer agreed that molybdenum should be used, but up to 975° F. preferred to use a chrome-molybdenum steel. Such a steel had important advantages over a carbon-molybdenum steel as the chromium helped to impart a better surface to the pipe, had valuable corrosion-resisting properties, and tended to resist graphitization while it did not cause any difficulties in manipulation, under which heading he included welding. Alloy steel pipes should be normalized and not annealed.

All steels to some extent were liable to inter-granular penetration by certain non-ferrous metals, and the author mentioned certain precautions to be taken to avoid this, but he did not mention that serious damage could be caused by using unsuitable paints for protecting or identifying pipes. Suitable paints were titanium-oxide or heat-resistant aluminium paints.

The analysis best fitted for pipes and flanges at working temperatures from 850° F. up to 975° F. was as follows:—

Carbon	0·15% max.
Silicon	0·3% max.
Manganese	0·3% to 0·6%
Sulphur	0·04% max.
Phosphorus	0·04% max.
Chromium	0·7% to 1·2%
Molybdenum	0·45% to 0·6%

Aluminium if used at all for killing was not to be used in quantities greater than ½lb. of aluminium per ton of steel.

The writer considered that all the materials listed in Table II which contained nickel should be deleted, as nickel-bearing steels were all particularly susceptible to embrittlement after service at high temperature, and in no case was the hardness imparted by nickel useful or even desirable in pipework practice.

Fig. 2 (*1*) showed a joint which was unsatisfactory because distortion took place on the jointing face due to welding. This joint soon gave way to the American "Sarlun" joint shown in Fig. 26. This joint had as its characteristic feature a very light and fragile welding lip. The best seal weld joint was the "Corwel" joint

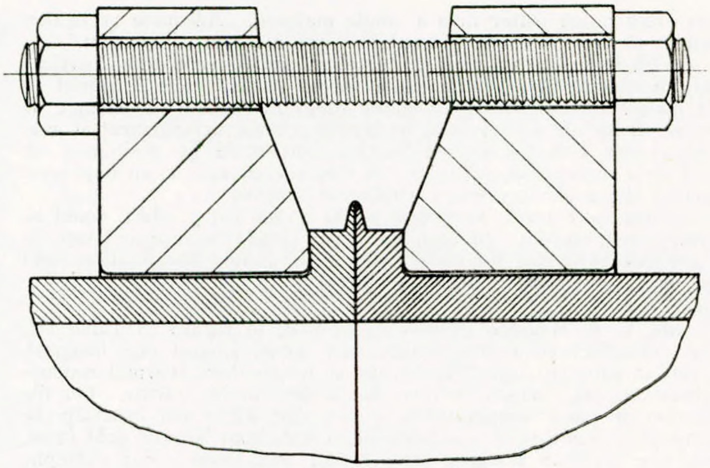

FIG. 26.—*Sarlun joint.*

illustrated in Fig. 27. This joint was made by joining a corrugation on the tube end, which corrugation was afterwards rolled and pressed flat. This joint was robust, allowed of a substantial seal weld and had a good grain structure with a thickness at the root somewhat greater than the tube from which it was formed. The weld could be broken and re-welded many times and breaking the weld was not a difficult operation to perform.

Receiver pipes were very frequently and successfully made of corrugated pipe. Such pipes fulfilled all requirements of adequate flexibility, ease of fitting and low head-room. The pressure drop through such a pipe was small as the steam velocity in them was very low. It might well be that the low pressure drop through the pipe illustrated in Fig. 11 was also attributable to low steam velocity rather than to the design of the venturi.

Fig. 28 showed a typical corrugated receiver pipe.

Under the heading "Main Steam and Auxiliary Steam", the author referred to corrugated and creased pipes for providing adequate flexibility. The writer did not agree with the use of creased bends for this purpose, as they were no more flexible than plain bends.

The advantage of a creased bend was that it ensured that the back wall of a bend was not thinned at all. As a consequence, it was unnecessary to use specially thick tubes to form bends. Corrugated pipes were undoubtedly of very great advantage when properly used, but he did criticize the tendency of designers to lay down a steam arrangement for plain pipes and then to fit into that arrangement such corrugated pipes as might be necessary to reduce the stresses. He considered that if it was established that in any particular range it was necessary to use corrugated pipes, then the whole range should be re-designed *ab initio* so as to obtain the best layout, and including in it such corrugated pipes as were necessary.

He agreed most heartily with the author in his pleasure at seeing sliding expansion joints eliminated.

He did not agree that drainage should ever be arranged with a flow of water in the opposite direction to the flow of steam, because water would not drain back in these circumstances. He considered that drainage ought to be from boiler to manœuvring valve and from manœuvring valve to turbine.

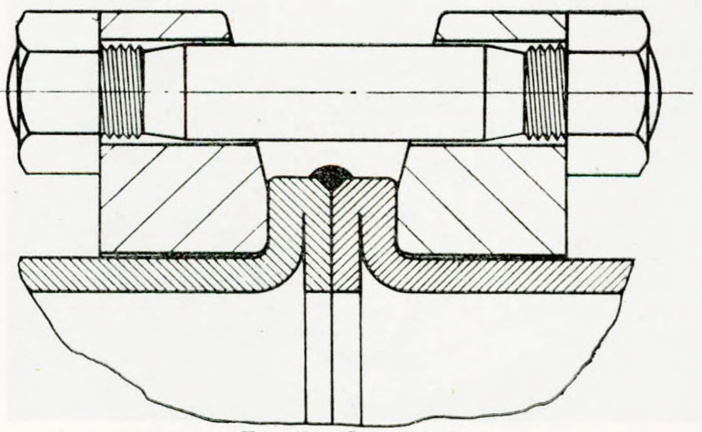

FIG. 27.—*Corwel joint.*

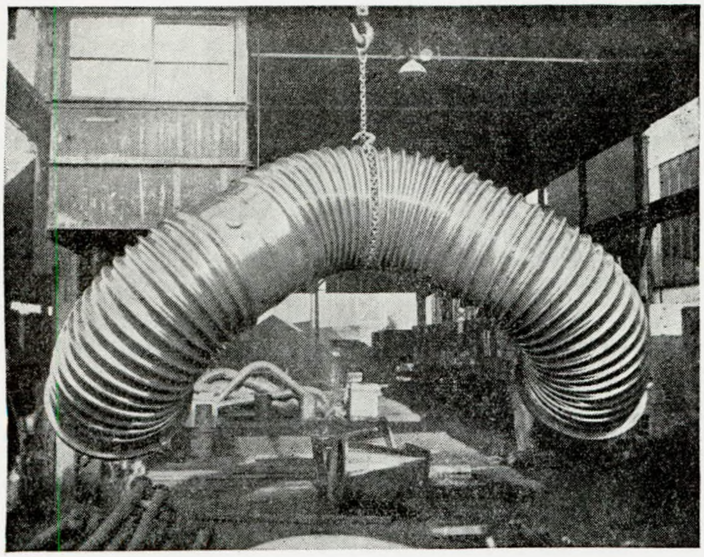

FIG. 28.—*Typical corrugated receiver pipe.*

Mr. E. Rothwell (Member): Under the heading "Material", the author referred to the use of molybdenum steel for high temperature pipe work. Would such piping be readily available in these days of supply difficulties, and would the cost of such material not be prohibitive?

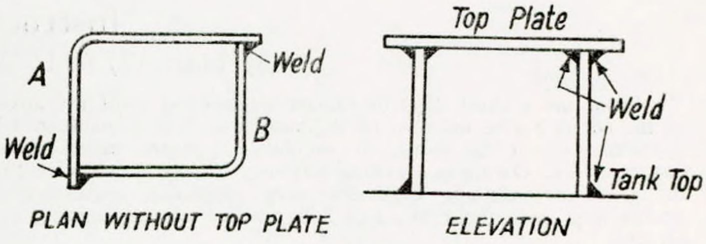

FIG. 29.

Regarding the use of bellows joints for steam piping, would the author regard this practice as suitable for high-pressure work, as it appeared to the writer that under such conditions, welding would not be satisfactory?

The insulated bulkhead valve illustrated in Fig. 15 was an interesting example of what could be done to minimize heat transference to passengers' quarters. The fins on the bulkhead appeared to the writer to be an excellent idea, but surely to cast fins on the valve itself was not good design, as the heat in the steam flaming through the valve would tend to be dissipated instead of conserved.

The seat illustrated in Fig. 18 was certainly much more rigid than the more orthodox type, but would not the cost of manufacture outweigh the extra strength gained? After all, what type of seat could be simpler than that widely used by the writer's firm, involving no rolling mill or special skill in building? This seat was illustrated in Fig. 29. *A* and *B* were flat plates bent at right angles and welded as shown in the plan view. The cover was then welded in place both inside and outside, and finally the seat was lowered on to the tank top and welded in position.

The Author's Reply to the Discussion.

The author was grateful to Mr. Sampson for adding the features of simplicity and cleanliness to the essentials of a good pipe arrangement, and was in full agreement with him that too many alternative cross connections were most undesirable.

As regards cleanliness, the author's firm had experienced so much difficulty in ensuring that a ship started off with clean pipe systems, that they had recently installed a large pickle bath in which all steel castings (including turbine casings) and all steel pipes were pickled. All steel plates used for structures such as bedplates, which would consequently come into contact with lubricating oil, were also pickled to remove mill scale, and a large sandblast house had also been installed to deal with iron castings, such as bedplates, to get rid of the moulding sand and plumbago on the surfaces exposed to oil.

The suggestion that higher steam velocities should be used with high pressures assumed that high temperatures would also be involved and was frequently the best way of reducing the pipe stresses to acceptable figures without introducing too many expansion bends; in other words, by increasing the speed and reducing the pipe diameter, the total pressure drop might be less than if a larger pipe was used with more expansion bends.

Mr. Sampson emphasized the importance of locating forced-draught fans in such a position that they would play their part in the ventilation of machinery spaces, and the same care should be taken that the scavenge pump suction of Diesel engines was also used for ventilation purposes as far as possible.

The author agreed with Mr. Houston that densities should be taken into account in comparing conductivity of different materials. Table III was based on ordinary commercial materials. The author also agreed with Mr. Houston regarding his statement on hot and cold faces. As regards depreciation of glass silk in service, experience had shown that it was necessary to protect this form of covering from any form of loading, such as would be occasioned by traffic on top of boilers or planks resting on covered pipes, as the glass silk tended to crush under pressure, and the fine glass dust formed blew out.

In reply to Mr. Hayden, the author's opinion was that bolts for high-pressure steam should only be tightened to a stress which under steam they could withstand without undue creep. The time when bolts were overstressed was during warming up, as the flange heated up quicker than the bolt. As regards gas-filled joint rings, the author's firm had had limited experience of these rings with 500lb. per sq. in. steam pressure on valves for low-level alarms, and the results were completely satisfactory. As regards the rigidity of fixed points in pipe systems, in making calculations these points were treated as completely rigid and any deformation which might occur would reduce the stresses on the remainder of the system.

The author was indebted to Mr. Sherborne for calling attention to the nickel-iron-copper alloy pipes now being tried out for salt-water services by the Admiralty, and agreed that copper pipes frequently showed heavy attack. One of the three types of vessels mentioned as being used for experiments with this alloy was being built by the author's firm.

The author was grateful to Wing Commander Aiton for his remarks, which in view of the high reputation of his firm for pipework formed a valuable contribution. The figure of 750° F. mentioned as the limit for carbon-steel pipes took into account the fact that in a marine installation with no controlled superheat, the steam temperature during starting up and manœuvring conditions would frequently exceed this figure. The author was in agreement with the writer as regards the effects of nickel on bolts, and as regards the normalizing of pipes after welding. Recent experiments on flash-welded pipes showed that a temperature of about 910° was necessary to obtain a good Izod figure.

As regards the drainage of steam, while it was appreciated that under steaming conditions water would not drain back to the boilers, it was not always possible in a marine installation to arrange for drainage towards the turbine, and it was quite possible with a proper slope of pipe for water to run back to the boiler when starting up and before the turbine stop valve was opened.

In reply to Mr. Rothwell, the price of molybdenum steel pipes suitable for high-temperature steam was about 33 per cent. higher than for mild steel of similar quality, and these pipes were obtainable in this country.

As regards bellows joints for high pressure, the highest pressure of which the author had experience was 220lb. per sq. in., but there appeared to be no reason why this type of joint should not be used at higher pressures. The type of fabricated seat in Mr. Rothwell's communication was a good design and where facilities for rolling conical plates were not available was probably the cheapest design possible, but the curved surfaces of the conical type enabled lighter plate to be used, and in practice it had proved to be the cheapest design.

Instruction Books.

By Lieut. (E) P. L. Woodall, R.N.R. (Member).

From the earliest days of marine engineering until the advent of the Diesel engine the flow of engineers was largely maintained by apprentices from the works of shipbuilders, engine manufacturers and repairers. Owing to a natural tendency for travel and adventure, the ranks of seagoing engineers were plentifully augmented by youths who were eager to adopt both the sea and engineering as a career.

Very few radical changes took place during this period and the youth well grounded in the use of tools and the fundamentals of steam engines found no difficulty in accommodating himself to any new departure in established practice. Improvements in the design of main and auxiliary machinery based on familiar principles were easily assimilated, especially where sketches and a few notes were supplied. The patent governor, shuttle valve feed pump and boiler safety valves were typical problems to be mastered by the candidate for Board of Trade certificates.

As the Diesel tonnage grew it became apparent that a new educational viewpoint would be necessary. The old and well-tried practices were to be jettisoned, a knowledge of lap and lead in "D" valves and the merits of patent piston rings and the mysteries of eccentrics were all things of a different world, the steam world. A pride in craftsmanship manifested by the scraping of flat surfaces and bearings was looked upon in horror; ground surfaces, machining to $\pm$·001in. and a multitude of new mechanical devices appeared, all to add confusion to the young engineer.

The same sudden impact was felt in the power houses and shore installations and, coupled with various economic factors, resulted in a definite shortage of trained personnel suitable to take charge of Diesel plant.

It then became apparent that the engine builder for his own preservation would have to take a hand in the training of the men responsible for the running and maintenance of the plant. Where a big contract is concerned it is obviously to the advantage of both the owner and the builder that an owners' representative should be present during the erection and testing, but this system is not feasible in the case of smaller orders. Therefore a large majority of the engines are placed in the charge of men who have had no previous experience with the particular type of plant now under their care.

In many cases a semi-skilled or partly-trained man who lacks the advantages of an apprenticeship will, having only one type of engine in his care, to a great degree overcome this disability by keenness and enthusiasm. The obvious answer is an efficient servicing department, so that engines may be visited periodically for routine check or overhaul, but for financial reasons this arrangement is not always acceptable, particularly in the case of exported engines where the service unit may have journeys of 500 to 1,000 miles between two calls. Therefore the most satisfactory method for the manufacturer to educate the operator in the care of the engine is by means of a handbook showing the unusual points of design and the particular brand of "cussedness", if any, of his wares.

America took a leading part in the development of the handbook, due in part to the low ratio of skilled men to the large number of engines in operation and the wide area over which the engines are distributed. In the home market requests for suitable literature have not been so urgent, as local branches or agencies have been in a position to supply either advice or a repair unit at short notice.

Furthermore, the present system of mass production does not lend itself to the training of suitable servicing personnel. The actual running and testing of engines on the test lines is often left to a handful of men specially picked for this type of work, and the only other opportunity of gaining suitable running experience is on the installation where the engine trial is sometimes run under adverse conditions. However, though experience is of the greatest importance, the service engineer has to show resource, ingenuity and a flair for diagnosing symptoms.

The prospective buyers, after ascertaining that the engine meets their requirements, ask for two things only—reliability and low maintenance charges. A mythical saving of ·000X pints of fuel per hour is seldom a selling point, especially in cases where an untoward breakdown of an hour's duration will cause loss of production costing the equivalent of a month's total fuel bill.

Maintenance costs are to a large extent influenced by the ability and knowledge of the person responsible for the upkeep, whether he be the local garage odd-job man or the manager of a large maintenance unit. Therefore the instruction book, as an insurance against breakdown, is a good selling point. Moreover, if the book is well edited and bound the additional value as an advertising medium is out of all proportion to the extra cost.

Instruction books can be broadly divided into three groups. The first one, essential to all engines, is a pamphlet or better still a glazed wall chart, giving information regarding lubrication, minor adjustments and other details likely to be of assistance to the operator. The second is a booklet giving notes on installation, clearances, starting and stopping routine, periods of overhaul, and details and drawings of unusual features, all very useful to the trained mechanic. Thirdly, the more comprehensive volume detailing, with illustrations, every operation in dismantling and reassembling, so that the veriest tyro in the most isolated part of the world can, when confronted with even a major breakdown, carry out the work with confidence.

The book itself is not designed to spend its active life on the student's desk, but rather in the workshop propped open with an oil-can. Therefore it should have good board or pliable covers and binding which will permit any page to be opened and left open.

The print should be large and legible, the text well paragraphed and indexed, and the paper of good quality and durable. The illustrations showing methods of handling and operation should be actual photographs and sketches showing details of design simplified, the ordinary drawing being quite unsuitable for this purpose. All sketches must be placed adjacent to the relevant text. Nothing can be more annoying than to have to turn back a page to find out what a certain letter indicates. Larger drawings can be placed at the end of the section or inside the back cover and arranged to open out clear of the pages to assist direct reference. The more complicated drawings, especially fuel and lubricating circuits, are improved by colouring.

The importance of all these points cannot be too highly stressed, but the book ultimately stands or falls by the quality of its text; this should be concise but readable. A dry and formal style precludes to a great extent the possibility of it ever being read in its entirety and limits its use to that of a book of reference. This does not induce the operator to study the engine as a number of integral parts each interdependent on the rest. To this end a number of smaller handbooks printed for the instruction of the U.S. Navy are written and illustrated in a distinctly humorous vein.

Here again the difficulty of obtaining trained personnel to produce a suitable book is manifest, the difficulty being in finding a technician capable of committing to paper the operations he carries out in the workshop. Therefore the key man will be the trained engineer with journalistic ability, able to collate reports and assume responsibility for the editing of the book. His assistant will act as liaison between the shops and the drawing office, writing up the various operations carried out on the assembly lines and collecting data. The service department will prove of considerable value in preparing lists of maximum clearances for wear and renewal tables, and also for details of failures which may be avoided.

The layout and covers should be in the hands of a draughtsman-cum-artist who will work in conjunction with the advertising department and be responsible for preparing the drawings and sketches.

The photographs can best be produced by an outside agency specialising in this type of work. The greater portion of the work, however, will be carried out by those responsible for cross references, indexing and checking that no descrepancy exists between figures and statements given in various parts of the book.

Details of propriety articles supplied are always readily obtainable from the makers, who are only too pleased to give permission for their reproduction.

Finally, the question of printing. Quantities should be based on the anticipated sales over a definite period, as shown by the order book. At the end of the period a further edition can be put in hand embodying all the improvements and alterations, and amplifying details as required.

In circumstances where the original unit may be used for a number of purposes all requiring different auxiliaries, such as air or electric starting, or in any cases where the driven unit may vary within limits, the binding can be of the loose-leaf variety allowing sections covering various additions to be bound together, so incorporating the whole contract.

The spares list requires entirely different technique and should be published as a separate handbook; the text requires no elaboration being a transcription of the assembly lists prepared by the drawing office for the production lines.

These lists often follow a set form, divided into sections each of which covers one assembly group. The items in each group should be numbered starting with the complete unit and followed by the various items comprising that group. For example:—

(*1*) Piston assembly group complete.
(*2*) Piston bare.
(*3*) Piston rings, pressure.
(*4*) Piston rings, scraper.
(*5*) Gudgeon pin.
(*6*) Circlip.

In this manner any portion of the engine may be referred to without delay, it also assists the client in assessing the number of parts required and in ordering ready for the next overhaul.

Further columns should be added giving (*a*) the quantity of each item in the assembly, (*b*) the code or part number and (*c*) the illustration number.

The code number is one of great importance and for preference should be similar to the assembly list number, but in many cases it is too unwieldy for practical use, being a combination of letters, figures and strokes unsuitable for transmission by cable. In this case a four- or six-figure system may be evolved; as for example three pairs of figures, the first pair denoting the assembly number, the second pair the item of that assembly and finally a code figure for the type, size or model of engine concerned. In the case above, assuming a gudgeon pin required and the piston assembly being the twelfth in the book, the code number would be 120546. Where a part or assembly has been modified this should be clearly stated and a new number allocated, using errata slips if required.

Errata slips covering both the maintenance section and spares lists should be promulgated every six or twelve months in the form of an "after sales" service. Propriety articles should be subject to the same breakdown, the necessary information being obtained from the makers.

Standard fittings such as nuts and bolts, split pins, etc., should have full particulars so that they may be obtained locally or through the general stores. A list of special tools should be appended; in this respect every workshop devises various gadgets to facilitate operations, and these could be developed and sold.

Lists of supplementary spares can be added covering a period of six or 12 months, worked out in collaboration with the service department; these will be invaluable to overseas customers. This feature will save friction with clients in cases where experience has shown a part to have a doubtful life of twelve months. This is particularly true of components bought from outside sources and naturally glossed over by the sales department. The client carrying a spare is saved a prolonged stoppage, and praises his own foresight to everyone's advantage.

In the case of a complete overhaul the number of new joints required is always a debatable point. Also by their nature of coming between two assemblies their location in the parts list is often in doubt. Therefore it is advantageous to add two extra assemblies, one a copy of all the joints and the second a list of all the ball and roller bearings, giving their original part numbers. As before, item one will cover the complete list so that a full set can be ordered in the case of an overhaul by using one code number.

The costs of the book for sale will be based on the cost of editing the data obtained from the various departments plus the cost of illustrations, photographs, production and printing. The book may be passed to the customer of each engine free of charge, the costs being carried in the overheads and advertising, extra copies being sold at a reasonable profit.

It is not suggested that the book be issued in the three forms mentioned earlier, though this method is favoured by some government departments.

The importance of the form of the book cannot be too highly stressed from a sales angle, and it is felt that if any advance is to be made in the export field, competition in this sphere must be boldly met. An engine on show is an inanimate object not likely to rouse the enthusiasm of a buyer, and only the most exacting will be influenced by the mythical stories of fuel saving compared with the competitors' engine.

Stories of reliability and low maintenance are received with cynicism, and it is only on rare occasions that an engine actually running under favourable conditions can be exhibited in the locality. Therefore, the only sales points that one can make after the more obvious one of low initial cost and suitability, are good workmanship, design, attention to detail and low maintenance costs.

A most cursory glance through the handbook will drive these points home and what better insurance against stoppage can be had than a good handbook in the hands of an intelligent man?

ADDITIONS TO THE LIBRARY.

Presented by the Publishers.

The Institution of Mechanical Engineers Journal and Proceedings (Journal, June 1946; and Proceedings, 1946, Vol. 154, No. 1).

B.S. 1306, Part 1 : 1946—Non-ferrous Pipes and Piping Installations for and in Connection with Land Boilers, 14pp., illus., price 2s. net, post free.

PD. 514. Amendment No. 1 to B.S. 649 : 1935—Internal Combustion Engines. (Excluding Carburettor Type Engines).

—British Standards Institution.

Journal of the American Society of Naval Engineers, Vol. 58, No. 2, May, 1946.

The Journal of the Institution of Electrical Engineers.

Vol. 93. Part I. No. 64. April, 1946.—General.
Vol. 93. Part II. No. 32. April, 1946.—Power Engineering.
Vol. 93. Part I. No. 65. May, 1946—General.
Vol. 93. Part III. No. 23. May, 1946—Radio and Communication Engineering.
Vol. 93. Part I. No. 66. June, 1946.—General.
Vol. 93. Part II. No. 33. June, 1946.—Power Engineering.

The British Shipbuilding Research Association Journal.

Vol. 1, No. 1, April, 1946.
Vol. 1, No. 2, May, 1946.
Vol. 1, No. 3, June, 1946.

The Motor Ship. Bound Volume XXVI. April 1945 to March 1946.

A Primer of the Internal Combustion Engine. By H. E. Wimperis, C.B., C.B.E., M.A.(Cantab.). Constable & Co., Ltd., 1944, 141pp., 60 illus., 5s. net.

This well known little book, first published over thirty years ago, has recently been revised throughout by Mr. W. J. Stern, A.R.C.S., D.I.C., B.Sc. It now includes additional matter on mechanism, carburation, ignition systems, and electrical indicators, and two paragraphs on gas turbines and jet propulsion. Rather less than half of the book deals with theoretical principles, the remainder with the practical side—fuels, engine details, and engine tests.

The treatment everywhere is brief, the intention being to provide a general elementary course preliminary to a more thorough study of the subject, such for example as that followed by engineering apprentices studying for National Certificates. The book serves its purpose very well.

Some slight criticism may be made. In an elementary book concerned with first ideas, fundamental principles need to be presented with particular care, if confusion and discouragement later on are to be avoided. For example, in the book under review (and in most elementary books on this subject) adiabatic expansion is defined as one during which no heat is given to or taken from the gas, and then the statement is made that in such a case P and V are related by the law $PV^{\gamma}=\text{constant}$. This, however, is not generally true; it is not true when a gas at high pressure flows from one heat-insulated vessel into another, although this would be an adiabatic expansion according to the definition. Even if in the interests of brevity it is not possible to treat the gas laws rigorously, some warning qualification should be included where necessary.

There is a printer's error on page 31 (line 27), and another on page 95 (line 16).

The Elements of Machine Design. By Wilfred Collins, B.Sc. (Hons.) A.C.G.I., A.M.I.Mech.E., Lecturer in Engineering Design and Applied Mechanics, City and Guilds (Engineering) College, London. Oxford University Press, London: Humphrey Milford, 1931, 248pp., illus., 15s. net.

The object of this book is to indicate to engineering students the scope and limitations of the elementary principles of science when, combined with the experience of the workshop, they are applied to the design of machine parts. The author suggests that the book may be considered as a series of notes which should be amplified by the student's own efforts at analysis. The average student, studying this problem of design, has little or no idea of the manufacturing difficulties involved in the workshop before the final article is produced. The author has obviously had a great deal of experience of this lack of knowledge and presents the subject in a logical sequence beginning with a description of materials in common use with their distinctive features and properties, followed by workshop processes necessary to produce the requisite form. A full chapter complete with numerical examples, gives a mathematical analysis of probable internal stresses, with an excellent note on rearranging relative positions of parts to eliminate avoidable stresses.

A section is devoted to the importance of studying all possible conditions under which the design may have to operate. Such problems as corrosion, erosion and wear, effects of temperature, racking and distortion in use, vibration, the human factor and the general appearance of the final design are fully discussed. The author then proceeds on general design giving chapters on riveted joints and screws, keys and couplings, bearings, shafting belts and friction gear, and a particularly generous treatment of toothed gearing.

Finally, the designs of some eight well-selected examples are fully calculated and drawn out, and the last chapter is devoted to the design of more complex machine parts including the cylindrical portion of the shell and the stays of a double-ended Scotch marine boiler.

An elementary knowledge of mechanics and the strength and elasticity of materials has been assumed and the text has been generously illustrated throughout with excellent diagrams and drawings.

Purchased.

Operation Neptune. By Commander Kenneth Edwards, R.N. Collins, 14, St. James's Place, London, 1946, 312pp.. illus., 12s. 6d. net.

The invasion of Hitler's "European Fortress", which laid the firm foundation of victory, was known by the code name of "Operation Overlord". "Neptune" was the code name for the naval component of "Overlord", which His Majesty the King described as "The greatest combined operation the world has ever seen—perhaps the greatest it will ever see". Success in "Neptune" was the first essential to success in "Overlord" and to victory. The fighting navies of the United Nations had to land the assault forces in the right places and at the right times after the air bombing and the naval bombardments had dazed the defenders, and the Allied navies and merchant navies had to see to it that the armies of liberation were increased in strength rapidly and continuously to ensure their ability to repulse the strongest of the enemy's armoured counter attacks. This they had to ensure in the face of the worst that the enemy and the weather could do.

" 'Neptune' deserves a book". Those words were said to Commander Kenneth Edwards by Admiral Sir Bertram Ramsay, who had planned the operation and carried it out in his capacity as Allied Naval Commander, Expeditionary Force. That was how this book came to be written.

Commander Edwards has divided his book into three parts. The first deals with the planning and preparation of the Olympian conception upon which depended nothing less than the fate of the free world. This he traces through all its vicissitudes from the faith of a few devoted and unconquerable spirits, through the vital decisions taken by Mr. Churchill and President Roosevelt at their historic meetings, to the great D-Day.

In the second part of the book Commander Edwards gives a detailed and vivid account of the execution of the operation. He describes the tasks and problems of the minesweepers; the preliminary naval bombardment and the subsequent supporting fire given to the armies by the guns of the ships; the assault from the landing craft; the work of the Royal Marine Commandos; the enemy's reactions and "secret weapons" and how they were overcome; and the gigantic problem of the build up of the strength of the armies and the effect of the worst summer gale the Channel has seen in forty years.

Part Three of the book deals with the consolidation of the successful invasion and the capture of the ports of northern France and the low countries, and the great and dangerous tasks of clearing them of mines and booby traps and repairing the damage done by the Germans so that the ports could serve the Allies and shorten the line of land communications which ran from the Normandy beachhead to the German frontier. Commander Edwards describes in detail the epic of Walcheren which opened the Scheldt and the great undamaged port of Antwerp. This must be classed as one of the decisive battles of history, for the use of Antwerp enabled the strength of the armies to be rapidly built up for the final assault upon Germany. There is also a description of the German efforts to interrupt the Antwerp supply line by the use of midget submarines and other weapons.

The book ends with a first-hand account of the surrender of Germany, at which Admiral Sir Harold Burrough as Allied Naval Commander-in-Chief signed the naval clauses on behalf of the navies of the United Nations.

Admiral Sir Bertram Ramsay had promised to write a foreword to this book, but was prevented from doing so by his untimely death. Admiral Sir Harold Burrough, his successor, has written one.

Jane's Fighting Ships, 1944-5. (Corrected to April, 1946), edited by Francis E. McMurtrie, A.I.N.A. Sampson Low, Marston & Co., Ltd., London, 636pp., profusely illus., £3 3s. 0d. net.

PERSONAL.

The Birthday Honours List published on 13th June includes the names of the following:—

K.B.E.—Sir Maurice E. Denny, Bt. (Past-President); *C.B.E.*—D. H. Nairne (Member); *O.B.E.*—J. L. Hagan (Member); *M.B.E.*—J. R. Ward (Member).

Sir Amos L. Ayre, K.B.E. (President) has had the honorary degree of Doctor of Science conferred on him by Durham University for the outstanding services he rendered to the country as Director of Merchant Shipbuilding and Repairs Division of the Ministry of Shipping from 1939-40, and as Deputy Controller of Merchant Shipbuilding and Repairs and Director of Merchant Shipbuilding, Admiralty, 1940-44.

Sir Amos L. Ayre, K.B.E. (President) and Captain W. H. Coombs (Companion) have been appointed members of the Shipbuilding Advisory Committee recently formed by the Government. Sir Amos Ayre, with Sir A. Murray Stephen, will represent the Shipbuilding Conference, while Captain Coombs will represent the Officers (Merchant Navy) Federation.

F. V. Bennett (Member) has been appointed as an engineering assistant to the Ministry of Works at Birmingham.

H. D. Beverton (Member) is taking up an appointment as engineer with The British Borneo Timber Co., Sandakan, B.N.B.

G. Broadbent (Associate) has been released from the Royal Navy and has joined the staff of Messrs. W. H. Brady & Co., Ltd., Bombay.

J. W. Chase (Associate) has obtained an appointment with the Vulcan Boiler & General Insurance Co., Ltd., as an engineer surveyor.

D. J. Collins (Associate) has accepted an appointment with the General & Accident Assurance Corporation, Ltd.

J. C. Herriot (Member) has been released from the Merchant Service and has been re-appointed as engineer surveyor to Lloyd's Register of Shipping.

John Houstoun (Member) has resigned from the service of Messrs. Tyne Plywood Works, Ltd., to take up an appointment as maintenance engineer of all departments of Messrs. John Readhead & Sons, Ltd., of South Shields.

L. J. Humphrys (Member) is now serving as an engineer assistant at the Ministry of Works.

E. A. Legg (Member) has been promoted to the rank of Lt.-Cdr.(E.), R.N.R., with effect from 31st March, 1946.

Alexander MacIntyre (Member) is returning to duty at the Chinese Maritime Customs, Hong Kong, after recovering from the effects of three years internment by the Japanese.

A. J. Paszyc (Member), on the completion of his research on heat transmission at the City and Guilds Engineering College, has had the degree of Ph.D.(Eng.) conferred upon him, and the governing body of the Imperial College of Science and Technology have awarded him the diploma of membership of the college.

G. G. Patterson (Member) returned to this country in March after several years internment by the Japanese. He is retiring in this country and will not be returning to Shanghai.

H. E. Pinches (Member) has been appointed an engineer surveyor by The British Engine, Boiler & Electrical Insurance Co., Ltd., of Manchester.

Alfred Robertson, C.C. (Honorary Member and Treasurer) and T. A. Crompton (Past Chairman of Council) have been elected President and Vice-President respectively of the City Livery Club.

J. J. Scanes (Member) has been appointed to the Bournemouth Office of the Ministry of Works.

W. Smith (Associate) has secured an appointment with Messrs. Ellams of Watford.

A. Taylor (Member) has been appointed an assistant engineer to the Ministry of Works at Newcastle.

G. Thomas (Associate) has been appointed to the supervision staff of Messrs. German & Milne, naval architects and marine surveyors of Montreal.

H. S. Youd (Member) has been appointed to the technical staff of Inspector of Technical Education to the London County Council.

C. W. Tonkin, B.Sc. (Associate Member) has been appointed the Ministry of Works.