SHIP SERVICE MACHINERY

BY

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The following article gives an account of the work carried out over the past few years in the Ship Service Machinery Section of the Marine Engineering Division of the Ship Department. The Author was from June, 1959, until August, 1962, the Inspector of that Section.

SECTION 1 : INTRODUCTION AND GENERAL REMARKS

Before giving an account of the work of this Section some general comments on the various influences affecting the work of the Specialist Sections as a whole, and Ship Service Machinery in particular, would be appropriate.

Basically we are called upon to provide our ships with the best and most up-to-date machinery, while often, particularly in S.S.M., we are asked to design and develop an item or equipment to perform a new and unusual function, one which is certainly new and possibly peculiar to the Service. (For example : the electrolyser, CO_2 absorption units, missile cooling systems, etc.) Unfortunately, and mainly for reasons beyond our immediate control we sometimes fall short of our objective, namely to provide the best design, and we have to make do with second best equipments which are not up to specification either in performance or design.

It appears that our main problem is the fact that too often are we called upon to take 'fire-brigade action' in order to get new equipments into service quickly and also with equipments whose defects (design or otherwise) have been shown up under service conditions. In this Section it is estimated that 25 per cent of our time is taken up with problems associated with the operation of the Fleet's machinery. After allowing for work on equipment destined for new construction, modernizations and A.s and A.s, very little time and man-power remains for research and development. One thing in our favour would appear to be the fact that we are fast developing into a repository of specialist knowledge, even so there is no doubt that more research and development work should be sponsored by the Specialist Sections than is possible at the moment.

The main problem here is one of time and manpower, the one being complementary to the other. It may well be that some of our R. and D. work, particularly in the design study and development stages, should be apportioned to selected consulting engineering firms. Maybe we should consider staffing the Specialist Sections with an increased number of senior grades, ensuring at the same time that these posts are occupied by personnel with the correct background and flair for this type of work.

And now to the work of the Section. In setting out these details comparisons have been introduced, where applicable, of our present progress with statements and forecasts made by the predecessors of this chair. In particular it is most noticeable how the emphasis on, and change in importance of, the various fields have altered during the past 10 years. This is particularly noticeable in the compressed air, gases and refrigeration fields. Hence, equipments which in the past have been only of secondary importance are now an essential feature of a ship's machinery installation. Thus the work of the Section has increased and is progressively becoming more complex.

Special Aspects of the Section's Work

In further amplification of the previous comments it would be appropriate to mention some special aspects of the work carried out by the Section :

(1) Much of our machinery is fitted outside the main machinery spaces, and often in their own compartments, which is one reason why we used to handle installation as well as design.

(2) Most of our machinery is provided to meet requirements arising outside D.M.E.'s responsibility. For example, refrigeration and air conditioning machinery is designed to meet requirements provided by D.N.C. Missile cooling and charging plants are provided to meet requirements put forward by D.G.W., oxygen plants for D.G.A. and so on. In all these cases we have to wait for specific requirements to be passed to us from other departments, or divisions of D.G.S., before we can get down to detailed design.

(3) Much of our machinery is of a common user nature, and an identical machine may be fitted in several classes of ships. In developing the design, therefore, we must take into account all the requirements and not just the narrow view of what is required in any one particular class of ship.

(4) Nearly all our machinery is motor driven which means we have to work very closely with the appropriate D.E.E. sections.

(5) Because of the diversified nature of the machinery for which we are responsible, we are involved in all ships and most craft in one field or the other.

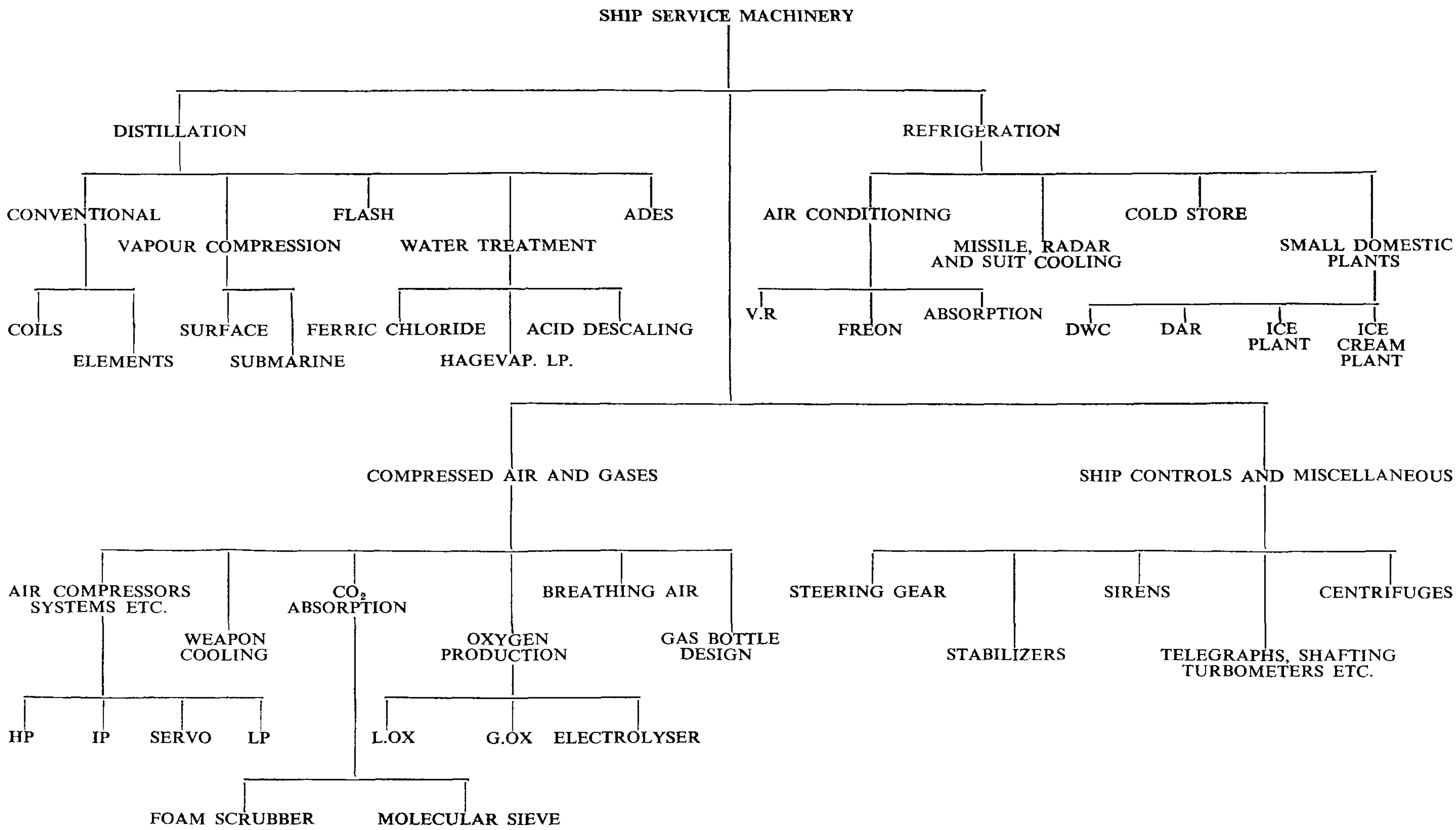

FIG. 1—ORGANIZATION OF SHIP SERVICE MACHINERY SECTION

Staff

We are a large staff for a specialist section, consisting of one Inspector, one Assistant Inspector, one Senior Draghtsman, four Leading Draughtsmen, seven Draughtsmen, and one and a half Clerical Assistants. Despite the size of the Staff we still have barely enough to cope with the diversified equipment for which we are responsible, and for the many queries and problems that arise. As already mentioned, we have dealings with nearly all other Ship Department Sections and many Admiralty Departments, involving considerable correspondence. We are also involved in most modernizations and conversions since there is an ever increasing demand for air conditioning, distilling plants and the like; no modernization or conversion takes place without a substantial increment of some of the machinery for which we are responsible. All this, in addition to new construction and other work provides a heavy work load, and in some cases, shortage of staff and short term delivery requirements have caused us to select existing designs which involve little work in preference to choosing more advanced machines which would require considerable design effort.

The work of the Section falls into four main categories:—

1. Distillation
2. Compressed Air and Gases
3. Refrigeration
4. Ship Controls and Miscellaneous

These subjects cover a multitude of sins and no doubt the machinery associated with the majority of these processes have caused many a sleepless night on the part of the engine-room staffs of Her Majesty's ships of war. Let us now look at these subjects in more detail.

The Section is responsible for the research and development, design and maintenance aspects relating to the machinery items fitted in ships as shown in FIG. 1. This responsibility includes recommendation of types and designs to be adopted, tender to be accepted, suitability of firms from the design aspect and keeping abreast with current developments. We are also responsible for attendance at trials of this machinery as may be necessary, preparation of specifications and type test requirements, providing information for and checking handbooks, checking C.P.L.s and recommending 'on-board' spares provisioning. Maintenance of and allocations from 'pools' of drinking water coolers and certain self-contained air conditioning plants. We also act as advisers to other Admiralty Departments, Commonwealth Navies, and also represent the Department on various service and industrial committees.

It is not intended to cover each individual subject in detail but to highlight our achievements, at the same time pointing out our failures, underlining our problems and to indicate what machinery developments we think will occur in these various fields in the future.

General Design Trends

Noise—In all cases where reciprocating moving parts are involved we are aiming at noise level reductions by designing machines which are fully balanced, by considering improved designs for submarine air conditioning and distilling machinery.

Reliability—We are aiming at reducing the maintenance problem by designing machines to run for longer periods between major overhauls, and lengthening the lives of the shorter lived items such as compressor valves, etc. At the same time we are endeavouring to give our machinery a more streamlined appearance to facilitate cleaning, internally and externally.

Standardization—In the refrigeration, steering gear and compressed air fields a standard range of machinery designs is gradually being built up which can be used to meet most of our commitments. However, information from various Ship Sections is still required before we can complete the overall ship compressed air assessment which will obviously affect the range and type of compressors required. We are also building up a standard design range of flash distilling plants modified in the light of experience gained at the Admiralty Distilling Experimental Station ; thus we hope to have in the Section up-to-date designs of distilling plants of varying performance and capacity. However, we must at the same time be prepared for the need to produce ‘ tailor-made ’ designs when required.

Materials—In the interest of weight reductions and freedom from corrosion, suitable plastics are being investigated for the fabrication of heat exchanger end covers and such like. Fibreglass, tufnol and polythene is already well proved in ferric chloride systems.

Space and accessibility—Machines and plants are being designed to the most compact of design compatible with accessibility—internally and externally.

SECTION 2: DISTILLATION

Looking back over the past decade we see the advent of vapour compression plants for surface Diesel ships and submarines, investigations into the problems of evaporator feed treatment, pressure being applied to British manufacturers to produce flexing element designs, and latterly the production of a flash plant design which shows great promise in overcoming many of our distilling plant problems. Running concurrently with these developments has been the invaluable work on plants and components at the A.D.E.S. Portland.

One of our biggest problems has been that of finding manufacturers, not only who can produce these new designs, but who can develop them in the time available. Take for instance, the vapour compression plant. It took five years for Howden to produce the Lysholm displacement type compressor. Because of this there was insufficient time to prove it and it was replaced at a very late stage in the design of the plant by the Reavell centrifugal compressor which was being developed concurrently and put into production for similar plants. This was in spite of the fact that the Admiralty considered the Howden compressor more suitable for this service. Often we have found the end product cannot be guaranteed, even although the basic design was sound.

However, we have now reached a stage of consolidation of the designs of the many and varied types of plants, and one where we must press on with the introduction of the flash design into the Fleet.

Conventional Plants

For many years these plants have been beset with two basic problems : one being the requirement to produce water continuously at the rated output, the other being its inherent instability. These problems have been brought about, or aggravated by the following factors :—

(*a*) The ability of this design to scale up with maddening rapidity.

(*b*) Domestic water allowance increases and actual consumption of water running ahead of the designed outputs of the installation.

(*c*) The instability of this design is unfortunately caused, for reasons of economy in weight and space, by the plants being constructed to very fine design limits. Because of these fine limits, disastrous salinities too often occur.

(*d*) Poor pump design.

(*e*) Installation—cramped, and pipe systems badly arranged.

We have now reached the stage where the majority of these problems have been resolved. Very shortly we may be in a position to forecast a solution to the problem of instability for the following reasons :—

(*a*) Increased water production has been achieved by an improved design of the heating surface in the evaporator, and at the same time decreasing the incidence of scale formation on the heating surfaces. Where the element type of heater has not replaced the steam coils the use of chemical feed treatment has achieved the same objective.
(*b*) Stability has been improved by the use of ebullition level controllers and as a consequence better outputs have resulted.
(*c*) The replacement of the present design vane type baffle by a wire-mesh separator may further improve stability.
(*d*) Distilling plants of capacities more realistically related to water demands are now being fitted in ships. Never again will we see a ship with only one distilling plant.
(*e*) More attention is being paid to the pumps and other ancillaries of the plant.

Flexing Elements

' Maxims ' of America were the first to re-introduce flexing elements after the war. In 1953 the efficiency of this heating element was appreciated by Admiralty, and British firms were encouraged to develop similar designs of their own. The elements now in use in the Fleet are :—

(*a*) The Weir's Thermoflex
(*b*) Caird and Rayner Vaflex

both being manufactured in monel metal. In general they both show self-scale shedding properties, even without shocking, although scale-shedding is enhanced by routine shocking every 48 hours. Eventually, however, after approximately 1,500 hours they require chemical descaling treatment.

Needless to say, they have their problems, namely, a limited life, and by the very nature of their design they are not sufficiently robust to withstand ill-treatment in the form of internal pressures in excess of 50 lb/sq in. in the case of the Thermoflex element, and in excess of 25/30 lb/sq in. in the case of the Vaflex element.

There is, therefore, room for improvement in both designs before the ideal is attained. To date it is not possible to state what the life of these elements should be, although reports from sea indicate a shorter life than was originally hoped.

Element Failures

We have reports of three types of failures :—

(*a*) Distortion and eventual bursting by maloperation
(*b*) Fatigue cracking, mainly in way of the welding—(Weir's Thermoflex)
(*c*) Failure of the Thermoflex element steam distributor.

Ebullition Level Controllers

These controllers are fitted on all new plants and consist of a pot secured to the side of the evaporator shell, preferably in the fore and aft line, at about ebullition level. A sill, or weir, whose height is so arranged to suit the level required is fitted between the pot and the evaporator shell to control the actual level of ebullition. The pot is connected to the brine pump and the boiling brine passes over the sill and is pumped away by the brine pump. The fitting of these controllers has eliminated the need for a brine valve and the frequent adjustments that were necessary. These controllers have done much to simplify the operation of this type of distilling plant.

Pumps

The use of combined pumps has been discontinued, and arrangements are now in hand for each pump associated with the plant to have its individual electric motor and control gear. As will be seen later, this is necessary for ensuring that correct shocking and blowing down procedure is observed. In order to ensure prolonged maintenance of designed performance, pump glands will in future be fitted with mechanical seals.

Blowing Down and Shocking Procedure

The introduction of flexing elements, and the use of ebullition level controllers has resulted in a blowing down problem, especially in carriers—H.M.S. *Victorious* has recently reported that because of the pressure differential involved being in excess of the working pressure of the element it is not possible to raise sufficient pressure in the evaporator shell to blow the plant down to sea. This is further aggravated by the fact that as there is no brine suction valve the shell is at sea pressure unless the brine pump is running. Consideration is being given to a revised blowing down procedure.

Heat Exchanger Failures

This defect has come to light during the past 2½ years in certain ships fitted with the Weir's Y.100 design plant where the distillers and other heat exchangers are of soldered and riveted construction. Because of their construction they are prone to distortion and eventual failure of the riveted seams when overheated, or suddenly cooled. This means that whenever steam is on this type of plant the circulating water pump must always be kept running. A new design distiller of all welded construction is available and will be used when replacement becomes necessary.

Vapour Compression Plants

General

This type of distilling plant was first brought into Service use in 1943, when small plants of some 2 gallons/hour, manufactured by Caird and Rayner based on a captured German design (Siemen ex ' U ' Boat), were fitted in submarines. After the war, when larger plants were required for fitting in the A.A. and A.D. frigates, Messrs. Weir's, Buckley and Taylor and Caird and Rayner produced designs of a 25 ton/day plant ; the design by Caird and Rayner was eventually selected for this service.

Most of the problems associated with these plants have been related to the compressor, and the scaling of the steam heating coils and electric immersion heaters. Some of these problems were foreseen in 1948 and later were referred to as being ' of unsophisticated design ' when serious scaling of the steam coils was being experienced.

Today we have not completely succeeded in overcoming all these problems but we would like to think that we are well on the way to having the right solutions ; in the meantime we hope we may be overtaken by events in the form of a flash plant, using waste gases as a possible heat source.

Performance

The performance ratio of this plant is higher than either the equivalent conventional or flash design. However, it is influenced by the size of the heat exchanger transfer surface and the method of driving the compressor and the means of supplying heat to make good losses. Even so it has two major disadvantages when compared with the other types of plant :

(*a*) Difficulty of manufacture, particularly the compressor

(*b*) Heavy and expensive maintenance load.

A.A. and A.D. Frigate Design

(*a*) In the earlier plants ferric chloride was used to prevent the formation of scale on the coils, in the heater-cooler, and on the electric immersion heaters. Later plants are fitted with ' Vaflex ' elements and the immersion heaters are now situated in the made water circuit, so that ferric chloride is now only required in the brine/fresh water cooler/heaters. Stability of these plants should be considerably improved with the fitting of the ' Vaflex ' elements which should reduce the surge effects and improve the compressor reliability. These improvements are comparatively new and have only just been fitted in seagoing ships (*Beas, Betwa* and *Vidal*) ; results are awaited with interest.

(*b*) Compressor problems and failures.—The compressors in these plants are driven by an A.C. motor through a double train epicyclic step-up gear box made by Allens and a number of these gear boxes have failed in service:

- (*i*) Compressor gearbox sunwheel—stripping of the output high speed sunwheel, splitting of the muff coupling on the output shaft. These faults were eventually overcome by the fitting of a ' lighthouse ' type pinion.
- (*ii*) In order to reduce high starting torques ' Twiflex ' couplings are now fitted. This has resulted in a considerable reduction of gear box failures.
- (*iii*) Oil pump drive.—Two modifications have been carried out, the latest has not yet been fully proved consisting of the use of a fine toothed coupling at the lower end and a Mollart Hookes joint at the upper. An oil supply has also been arranged for the upper joint.
- (*iv*) High speed coupling nut failures, of the split nut type, now replaced by a nut with a grub screw locking the nut to the shaft.
- (*v*) Compressor rotors.—Due to corrosion the stainless steel rotors have been replaced by ' K ' monel ; at the same time fine clearance bearings have been fitted to reduce the wear on the carbon glands and hence reduce vapour leakage. Results are awaited with interest.
- (*vi*) Water contamination of the lubricating oil.—Since their introduction these plants have been seriously affected by water contamination of the lub. oil. Much has been said of this contamination and many failures of the gears attributed to it. Blanking of the gearbox vent, and the provision of a ' Fram ' type water/oil separator has been tried out in H.M.S. *Lynx* with encouraging results but it is too early yet to draw any lasting conclusions.

Submarine Plants—Vapour Compression type

(*a*) The ' D ' type design by Caird and Rayner now being fitted into the *Oberon* Class of submarine of some 15/20 g.p.h. capacity is the logical development of the earlier models based on the original captured German plant. This model incorporates a number of modifications to its forerunners, designed to overcome faults and weaknesses which have been shown up in service. By the use of modification kits, earlier models of the ' C ' type can be brought up to the standard of the ' D ' type performance. The majority of these modifications affect the controls of the plant and are as follows :—

- (*i*) Fitting of a brine level weir
- (*ii*) Fitting of feed stabilizing control valve
- (*iii*) Fitting of thermostatic control of immersion heaters

(*iv*) Fitting of compressor discharge thermostat and ' cut-out '. This is a safety device to prevent overheating and eventual seizure of the compressor.

(*b*) Compressor problems and failures.—The compressors used on these plants are of the Rootes type and although they have the right characteristics for this duty they are larger for an equivalent capacity than the centrifugal compressor and have the added disadvantage that fine clearances are used between the lobes which makes them susceptible to temperature variations and also they impart a degree of superheat to the steam.

The earlier compressors failed due to seizure of the rotors and consequent stripping of the ' Tufnol ' gear. All compressors are now fitted with one C.I. gear wheel and one bronze gear wheel. Seizure of the rotors is caused solely by maloperation of the plant in so far as a reduction in vapour quantity to the compressor will cause the compressor to overheat, expand and due to its fine clearance—seize. The remedy for this is to increase the number of immersion heaters in use ; this operation is done automatically in the latest design, and ' handraulically ' in the earlier designs. The other problem associated with this compressor is :—

Gears are ' mated' for each compressor and are not interchangeable.

(*c*) Wellworthy Ricardo Compressor.—Based on a supercharger design for Diesel lorries this compressor employs a wobble-plate to operate 14 pistons, arranged symmetrically with seven cylinders each side. The cylinders are arranged around a central rotary valve. A prototype compressor is now being built by Wellworthy as a possible replacement for the present Rootes type compressor. Advantages claimed are reduced power consumption (two-thirds that of the Rootes) and lower noise level.

Flash Plants

Most of our attention in the distillation field has been directed to the proving of a flash plant suitable for use at sea. A plant, already proved at the A.D.E.S., will be going to sea in H.M.S. *Manxman* and the design and construction of two flash plants for the Assault Ship is now in hand. Even so we are ten years behind the United States Navy and, even worse, two to five years astern of our own Merchant Navy.

Although the principle of ' flash distillation ' has been well known for many years, and was being investigated before the war by Admiralty, it wasn't until 1958 that we were able to persuade a British manufacturer to consider the design of a marine plant. Recently every distilling plant manufacturer in the country, and others aspiring to this distinction, are offering flash plant designs for marine use. To date we have completed the evaluation of three plant designs at the A.D.E.S., one of 2 ton/hr capacity by Buckley and Taylors for use with a steam installation ; one by Aitons of 1 ton/hr capacity for use with a Diesel installation and the other by Marshalls (Cleaver Brook) of 1.5 ton/hr. Details of these trials, others in progress and those scheduled will be dealt with later. (See A.D.E.S.)

The Principle of Flash

Feed water is passed through successive heat exchangers to condense the steam made in each stage of the evaporator, thus regaining the latent heat of evaporation. On exit from the 1st stage heat exchanger the feed is led to an external heat exchanger where it is further heated, either by steam or some other form of heat such as Diesel jacket cooling water or waste gases. This hot feed is then passed into the flash chambers in each of which steam is flashed off under vacuum and the temperature of the feed successively reduced. Eventually the brine is pumped away overboard. The top temperature of the feed is limited to 170/175 degrees F; low pressure, sub-atmospheric steam is used in the external heat exchanger and a ' once through ' pass of brine ensures that the plant operates at a low density—1.2 of sea water.

The Case for Flash

(*a*) Scale formation has been, to all intents and purposes, eliminated. This is the most advantageous feature, achieved in part by the use of low temperatures and low density. A further contributory factor is that the feed supply is under pressure in the heat exchangers, which means that not only is boiling eliminated but also that the pressure prevents the release of CO_2. With the exception of sulphate scale, all scale formed in sea water distilling plants is caused by the break-down of bicarbonates which is accompanied by the release of CO_2. By inhibiting the release of CO_2 the break-down of the bicarbonates is restricted.

(*b*) Flash plants are more stable and operate at better purities, probably due to the greater ' fly-wheel ' effect of the large quantity of water being used and to the more stable method of vapour release, i.e. the elimination of boiling and the expansion of the surface from which comes the vapour. The improved purity is certainly due, in part, to the better baffling and to the extension of the surface referred to above.

(*c*) Flash plants lend themselves very readily to automatic controls. The output is directly proportional to the flow through and temperature drop. The flow and final brine temperature are reasonably fixed by design, and the top temperature can be simply controlled. Other variables generally follow this control.

(*d*) Performance—In gain ratio (water made/1,000 B.T.U.s) flash plants can be designed to give better results than conventional plants of approximately the same space requirement ; but unlike conventional plants, the number of stages has no bearing on this, apart from the limit on the flashing range that can be accepted in a chamber of fixed dimensions. The various designs use interstage transfer arrangements to suit the design temperature drop and the quantity of water handled.

Results of Tests at A.D.E.S.

On the designs tested, results in general indicate that the claimed advantages are justified. With regard to stability, two plants have been left running for periods up to several weeks during which time no adjustments were made to the plants despite fluctuations in steam supply, feed temperature, etc. Deliberate mishandling trials showed also that these plants are not prone to instability and very severe action had to be taken to produce bad water which cleared in a very short time after corrective action was taken.

Flash Plant Problems

(*i*) The unit being under vacuum must have sound joints, and as few as possible.

(*ii*) Because of the high vacuum (28 in.) in the last stage, brine pumps in particular must be very good.

(*iii*) The plant depends entirely on its pumps and all must be reliable and glands tight. In addition a very necessary margin of 10 per cent must be allowed on pump performance to allow for general fouling of surfaces, wear and emergency overload conditions.

(*iv*) Under Arctic sea-water conditions the amount of steam or heat required to maintain output increases rapidly, unless some form of brine recirculation is used to compensate for low sea temperatures. This introduces an additional possibility of scale by increasing the density of the feed ; but this is still very low in comparison with conventional designs.

The Admiralty Distilling Experimental Station (A.D.E.S.)

The A.D.E.S. was commissioned in 1952. It would appear that the proposal had a stormy passage before it was finally approved. We should be thankful now that our predecessors persevered since the value of the A.D.E.S. cannot now be measured in terms of money. There is no doubt that the station has, and still is achieving the objectives for which it was set up. Its value is shown up in the general improvements in distilling plants which have been achieved since 1952. The station is sited in Portland Naval Base at the shore end of the outer breakwater, and as a matter of interest, the sea water obtained at this point was found to be more representative of ocean sea water than could be found in any convenient place anywhere else around the shores of Britain. It is the only testing place in the United Kingdom which has the facilities for endurance testing of distilling plants and where they can be proved on shore before installation in ships. All plant manufacturers are keen to make use of these facilities ; unfortunately we are limited in the number of plants tested by the space available and the financial limit.

Modernization

The time has now come where once again we must prepare for the future to ensure that the station will be as useful to our successors in 1970 as it is to us at the present time. For this reason a scheme of modernization is now being prepared, which at the same time will increase its available facilities. The biggest change will be the conversion from 220-volt D.C. to 440-volt A.C. supplies. This will ensure that pump motors, etc., will be operated under conditions similar to those of a ship-borne installation.

The following is a summary of the trials carried out to date :—

Prototype trials and development of:

(*a*) Feed treatments (1952-1956, and periodically since as new compounds become available)
(*b*) Injection equipment associated with (*a*)
(*c*) Flexing elements
(*d*) First element type conventional plant for *Blackwood* II and subsequent Weir designs
(*e*) Flash plants—design testing and development
(*f*) Vapour compression plant for submarines
(*g*) Cleaning processes including acid de-scaling.

Future trials will consist of the combination of (a), (e) and (f).

Instrumentation

One of the major problems encountered in plant evaluation is the necessity for high accuracy in readings without which many border line situations can pass unnoticed, and faults in design are not determined without a lot of time-wasting cross checking.

Chemical Descaling

The recent introduction of chemical descaling of evaporators was the direct result of trials carried out at the A.D.E.S. A.F.O.s 2426/59 and 104/60 were published after the results achieved at the A.D.E.S. were confirmed by practical experience in the dockyards. This procedure reduces the manual effort in cleaning coils or elements to a minimum.

Salinity/Purity

In order to clarify the purity requirement of distilled water and to ensure that loopholes in distilling plant specification are closed it has been decided to specify the *total* conductivity of the made water rather than its salinity. The salinometer indicates conductivity due to all causes and not merely chlorine, therefore the actual chlorine content is now specified as well as the total conductivity. By this means a limit is imposed on the amount of CO_2, NH_3, etc., that will be accepted. All impurities are therefore taken into account and no longer will the manufacturer be able to force the acceptance of a plant with the time worn phrase ' but it is only CO_2 '.

Salinometer/Conductivity Meter

An advance has recently been made in meter design and it is now possible to record the purity of the water actually in the pipe rather than from a sample by-passed through the instrument. This eases the installation problems as the meter can be sited remotely from the sensing point in the most convenient watchkeeping position. It is also possible to use the same instrument to sense a number of points.

SECTION 3 : COMPRESSED AIR AND GASES

We have come a long way in this field since the Section assumed responsibility for H.P. air compressors and systems in 1951. Gradually additional projects were taken on until we have now reached a position where we embrace a host of subjects associated with the compression of air, and the manufacture and compression of oxygen. The call for various forms of compressed air has increased tremendously, especially during the past ten years. In particular L.P. oil-free air for servo systems, and air of far greater purity than could have been imagined ten years ago is now required for special cooling services associated with missiles. Gone are the days of the compressor whose sole function was the periodic topping up of gun recuperators and the weekly charging of torpedo air bottles. Associated with this increased demand for air is the requirement to produce compressors capable of these new and often arduous duties, at the same time the design of valves, systems, separators, bottles, and filters has had to be progressed. This, together with the design of special equipments, such as the electrolyser and CO_2 absorption plant, has transformed a comparatively straightforward subject into one where a deal of gas problems have to be resolved and an understanding of chemical processes is essential.

Air Compressors, Systems, Valves and Fittings

H.P. Air Compressors

During the past five years we have introduced a range of H.P. air compressors which are now proving themselves in service. They are manufactured by Reavell and Co. Ltd., based on their commercial design, of capacities of 40, 80 and 120 c.f.m. compressing to 4,000 lb/sq in., in four stages arranged in the conventional manner of two stages per crank. Compressors of this design are being matched to liquid oxygen plants as well as being used for the more usual H.P. air services. With an eye to the future we are currently engaged in the design of a new range which in many ways is the logical development of the present one, special emphasis being paid to long life, silent running and ease of maintenance. One such compressor by Reavell is a six-cylinder in-line machine whose motion work is dynamically balanced with four stages (two first, two second, a third and a fourth stage) compressing to 4,000 lb/sq in.

Its construction is on general lines already approved by the Admiralty for high pressure work ; but an unusual feature will be the packingless plunger used for the high pressure stage. This plunger is ground to a very close fit in the cylinder liner and is operated entirely without rings or other packing. According to the manufacturer this design has been used successfully for some years up to pressures of 6,000 lb/sq in., but has not previously been used for Admiralty construction. We anticipate that the prototype will be ready for trials during 1963. Another compressor development is being carried out by Williams and James, but unfortunately this is running astern of station because of other important Admiralty work in hand by that firm. However, the basic design has been approved and the compressor will be in the form of an ' L ', i.e. with two vertical and two horizontal stages. The compressor will run at some 500/550 r.p.m., compressing to 4,000 lb/sq in., with a capacity of 80 c.f.m. We are also investigating the possibility of an uprating to 120 c.f.m. at 650/700 r.p.m.

I.P. Air Compressors

(*a*) Weirs. This compressor is of 10 c.f.m. compressing to 1,200 lb/sq in. and was introduced as a standard Diesel air start compressor. It is driven by a Diesel Enfield HO2 engine and fitted in the present G.P. frigates and G.M. ships. Unfortunately we have not been very successful in this design. The compressor started off with two stages and had to be changed to a three stage design very much too late in its life ; consequently the third stage has a fixed piston and reciprocating cylinder.

(*b*) Dunlop. This compressor is being designed as an alternative to the Weirs. It is of 10 c.f.m. compressing to 1,200 lb/sq in. in four compression stages. The design of this compressor follows a type produced by Dunlop with an output of 5 c.f.m. at 4,000 lb/sq in. used for charging S.A.B.A. sets. The compressor, therefore, follows proved basic design parameters and we confidently expect tests will prove it to be very reliable. The first of these will be fitted in the Assault ship and H.M.S. *Triumph.*

L.P. Air Compressors

In this field we are now concentrating on the oil-free type, the designed principle being to divide the compressor into two parts, i.e. the crankcase and guide section, which is oil lubricated, and above this the compression cylinders. Freedom from oil is obtained by the use of ' self-lubricating ' carbon piston rings. To date we have such a compressor which, by ' ringing the changes ' on motors, can supply 20, 33 or 55 c.f.m. at 120 lb/sq in. Development of a similar type which will supply 400/500 c.f.m. at 120 lb/sq in. is in hand, scheduled to complete by mid 1963.

In the light of existing information it would appear that a third design, capable of 100/200 c.f.m. at 120 lb/sq in. is also required in order to cover the entire general service L.P. air range.

Servo Air Compressors

The automatic servo controls now installed in the G.P. frigates, G.M. ships, *Tiger* Class, etc., require air which is completely free from oil to ensure that the small-bore orifices and passages do not become choked. This requirement has been satisfied by the use of the Williams and James oil-free type compressor, similar to the low output type mentioned in the previous paragraph. In fact, these compressors were developed for servo air systems and have since been incorporated into the General Service range. A considerable amount of work has been done on this compressor since its introduction into service. Problems which have arisen are :—

(*a*) Corrosion of cylinder liner base material beneath the hard chrome deposit resulting in the peeling of the chrome
(*b*) Overheating, resulting in complete failure in *Tiger*, due to restriction of circulating water flow by air locking, the air coming out of solution from the firemain circulating water
(*c*) Short life (300 hrs) of 2nd stage air delivery valves.

A compressor of this type was installed at the A.D.E.S. in April 1961, and has been run continually with periodic examination. The results of this trial to date have been instrumental in :—

(*i*) The introduction of a new design second stage valve with a life of more than 3,000 hours
(*ii*) Showing that liner corrosion may be overcome by the use of a thicker (0.010 in.) hard chrome deposit.

The overheating problem has been cured by fitting air vent cocks in the cylinder head, and a circulating water thermal cut-out to switch off the compressor when the water temperature reaches a dangerously high level.

*Servo Air Compressor for Dounreay and S.S.N.*02

A motor driven, two stage, oil-free rotary compressor having an output of 25 c.f.m. at 45 lb/sq in. was developed for this duty. The first stage being driven by the motor and the second stage by gear wheels from the first. During prototype trials the compressor proved to be extremely noisy, due to badly machined gear wheels which rapidly became worn. After an abortive attempt to produce satisfactory gearing, it was decided to accept this design for Dounreay. For S.S.N.02 a new design is in hand, taking the form of a 2-stage in-line machine. Type tests of this design are scheduled for September 1962, with delivery in November 1962.

Valves and Systems

The cupro-nickel pipework, together with its O-ring sealed couplings and capillary brazed joints and fittings has proved reliable and to have a low maintenance requirement.

The original nylon stop valve design is still giving satisfactory service; however, a balanced valve has recently been developed which because of its ease of operation, especially in the larger bore sizes, will become the natural successor of the present design. Other advantages claimed for this balanced valve are :—

(*a*) Virtual freedom from wear
(*b*) On-board spares need only to consist of the renewable plastic seat and O-ring replacements.

Solenoid valve—This design will be spring loaded arranged to 'fail safe' in either the open or closed position depending upon the application, and operated by a pilot piston which will be solenoid operated.

The pilot valve will supply air to an operating plunger on the main valve at a controlled rate against the back pressure of the spring, and so producing a slow or regulated main pressure build up.

Explosions in H.P. Air Systems

This phenomenon has been reported from time to time by the U.S. Navy, but to date it has not caused any undue concern in H.M. ships. However, we have recently completed a number of experiments in this field on two test rigs at Reavells, one to determine the behaviour of an air flow in an air system which is suddenly opened up to an empty tank. This is based on conditions that will pertain in S.S.N.02. The other to determine the purity of H.P. air after it had passed through the Admiralty Duplex separator and carbon filter.

The pressure drop experiment showed that the main pressure drop is at the outlet from the system and that there should be no difficulty in passing large quantities of air in a short time from storage to buoyancy tanks. The air purity experiment has proved conclusively that :—

(*a*) Activated carbon is the best known filter material for the removal of oil vapour from an air system.

(*b*) The duplex separator will ‘ mechanically ’ dry high pressure air to a dewpoint of minus 30 degrees C (at 760 mm Hg) when the air temperature is 32 degrees C. The dryness attainable will depend on the temperature of the compressed air at the separator, the higher the temperature the more moisture will pass through as vapour; this is dependent upon the sea circulating water temperature in the after cooler. The duplex separator will also retain oil to such an extent that less than one part per million by weight is carried through by the compressed air.

(*c*) It has been found that $\frac{1}{4}$ lb of activated carbon will clean oil, from 40 cu ft. of free air/min., to one part in 20 million by weight for 120 hours.

With these safeguards built into an H.P. air system the possibility of explosions caused by ‘ dieseling ’ and shock waves in the system should be extremely remote. However, as an even further precaution in nuclear submarines, controlled opening of solenoid operated air valves will be employed. Valves by I.V. Pressure Controllers and Seetru will shortly be subjected to a series of exhaustive trials on the test rig at Reavells.

Weapon Cooling

This is one of the most recent developments in the compressed air field where we are required to provide air of almost virgin purity to cool certain parts of a missile while it is undergoing test, or actually on the launcher ready for firing. At the present moment we are associated with two developments, and have as a result to undertake a deal of basic research in the realms of air flows and chemical processes. In this work we maintain very close liaison both with D.G.A. and D.G.W.

CO_2 Absorption

As well as the need for pure air in certain missile systems, a chemical method of removing CO_2 from atmospheric air in both conventional and nuclear submarines is being developed. Two processes are possible :—

(*a*) Foam absorbers
(*b*) Molecular sieves.

The former development is well in hand, and plants for both types of submarines are being built. The use of molecular sieves as an alternative to the foam absorber is being investigated and developments in this field are possible within the next two years.

Foam Absorbers

CO_2 is absorbed by monoethanolamine acid (MEA). The air is ‘ scrubbed ’ of CO_2 by passing it through a bed of foaming MEA. With this system the MEA can be reactivated for further use, but pumps are required to circulate the MEA and the plant must be constructed of acid resisting materials. The application of this type of absorber varies from one of continuous reactivation in nuclear submarines to intermittent reactivation in conventional submarines.

The major problem met to date is one of producing a unit that will meet the specified extraction rate (45 cubic ft CO_2/hour when concentration is 0.75 per cent and 90 cubic ft CO_2/hour when concentration is 1.5 per cent) and at the same time fit into the space allowed.

Molecular Sieve

The molecular sieve has two major advantages over the foam absorber :

(*a*) Freedom from acid

(*b*) Pumps not required.

A.M.L. has been experimenting with a test rig built by ' Birlec ' incorporating specifications and recommendations of A.M.L. Basically it consists of a refrigeration unit (hermetic gas system) to ' freeze out ' the moisture content of the air, and a system of molecular sieves which are designed to remove CO_2 and also any residual moisture.

The system looks promising for application in nuclear submarines and possibly for air purification for missiles, where a continuously operated plant is acceptable and where the power required for regeneration of the sieves is readily available—regeneration will be a problem in conventional submarines where power is limited.

The molecular sieve (sodium aluminium silicate), is described as ' selective absorption by controlled pore size '—or in every day language sodium aluminium silicate has the property of having a greater or lesser affinity for a particular gas, depending upon its pore size.

Oxygen Production

Oxygen plants are fitted in carriers to produce breathing oxygen which must be dry and of a purity of not less than 99.5 per cent for air crews. Originally gaseous oxygen plants, manufactured by the British Oxygen Company were fitted, but in order to meet recent aircraft developments where liquid oxygen is required, liquid oxygen plants by Messrs. Air Products are being fitted, and in due course the gaseous plants will be replaced. Oxygen production is also necessary in nuclear submarines and to this end we are developing, in conjunction with D.M.R. and Constructors John Brown, an electrolyser plant for the production of oxygen from seawater. This will eliminate the need for oxygen candles.

Liquid Oxygen Plants

Two such plants will always be fitted, each with their own matched H.P. air compressor and with a separate metered stand-by supply of air from the H.P. air ring main. The compressed air is first dried in alumina driers and then expanded through an expansion valve. At this stage of the cycle the cold semi-liquid air passes through CO_2 filters arranged in parallel to allow reactivation, and then through a further expansion valve to reduce its temperature to the liquefaction temperature of air.

In order to assist the cooling of this air, the cold effluent waste nitrogen is discharged through a heat exchanger through which the incoming air is passed and where it gives up some of its heat.

Liquid oxygen is then separated from liquid air in a pair of separation columns and collects in a small sump within the plant. When this sump is filled up, it is shut off from the plant and its temperature allowed to rise slightly, thus raising its pressure which discharges the liquid oxygen into the storage tank, and the process is repeated. This plant can also produce gaseous oxygen.

A great deal of the problems associated with this plant has been due to the failure of brazed connections within the separator. The plant is based on a U.S. Navy design, and in order to keep it compact, the separator column has been split into three parts which necessitates extra pipe joints. Simplification and reduction in maintenance could be achieved if the plant were to be designed with a single separator column as is the case with industrial plants.

The Electrolyser

The use of the long range nuclear submarine will call for some reliable means of providing breathing gases and the electrolyser, at present being developed at the Leatherhead Research Station of Constructors John Brown, will be used for the production of oxygen.

In this plant oxygen is produced by the electrolysis of demineralized water, with the addition of potassium hydroxide in a 30 per cent solution to assist the electrolytic process. Hydrogen and oxygen are led from the electrolyser cells, which are contained within a pressure vessel, to the separator in which a sea water coil condenses any vapour in the oxygen and hydrogen streams.

Because it is safer and the plant is more compact, hydrogen and oxygen are generated under pressure ; this also ensures that the gases can be discharged at diving depth and into the submarine atmosphere. Oxygen and hydrogen are, therefore, generated at a pressure of 2,000 lb/sq in., and production at full power (35 kW) achieves 100 standard cubic feet of oxygen and 200 standard cubic feet of hydrogen per hour.

An elaborate system of controls will be provided to ensure safe operation. An oxygen detector will be fitted in the hydrogen system and a hydrogen detector in the oxygen line. Differences of pressure in the oxygen and hydrogen systems will be sensed and an automatic control of electrolyte level fitted. On shutting down, the system is flushed with nitrogen.

A first design of this model took the form of co-axial cells ; space considerations have now enabled us to use the more conventional type of flat plate electrolyser such as is used extensively in industry.

This model is aimed at S.S.N.02 which will eventually be fitted with two. Development has so far been largely the responsibility of D.M.R. (Director of Materials Research) but arrangements are now in hand for the project to be transferred to D.G.S. (D.M.E.).

Oxygen Valve Design

Improvements in valve design have been brought about as a result of a number of fires and minor explosions in the valves of oxygen systems fitted in aircraft carriers. The earliest design was the Admiralty standard H.P. air valve, degreased. This proved unsuccessful and the first oxygen valve was developed. The valve was fitted with a removable seat of stainless steel, a stainless steel spindle and ' cage ' to hold the nylon valve.

Fire occurred with this design and so the stainless steel seat was replaced in aluminium bronze. This design also proved to be a fire hazard, and even more important, it was demonstrated that under certain conditions stainless steel was incompatible with oxygen.

A new design of valve containing no stainless steel but fitted with a nylon valve pad was then tried ; unfortunately this was also unsuccessful, the nylon having caused the fire. The next modification was to replace the nylon with hostaflon. So far we have one report of a fire with this valve and it would appear that there is no known plastic that is really safe with oxygen in this application.

A safe valve must, therefore, be found, and to this end we have developed a non-ferrous valve assembly, with an all metal closure and where copper has replaced the hostaflan valve pad. This design has been proved gas-tight and suitable for service use. It is important to state here that the experts in this field are most reluctant to lay down specific conditions which would cause oxygen fires in valves. In fact they were at pains to point out that a valve could be tested for a year and prove perfectly safe and the next day a condition could be reached where an explosion would result. We hope the latest design will be the solution to this problem.

Breathing Apparatus, Compressors and Systems

A deal of useful work has recently been accomplished by the Section on problems and designs associated with breathing sets and emergency breathing systems in submarines. Some of this work has been carried out in conjunction with the Experimental Diving Establishment at H.M.S. *Vernon.*

Oxygen/Nitrogen Booster Pump

This is a portable compressor design, used for charging the oxygen bottles of breathing apparatus from the larger storage bottles. A Diesel driven compressor by Hamworthy's was designed for this purpose but unfortunately has not proved very successful and a design by Siebe Gorman is now being investigated by this Section and the Experimental Diving Establishment.

Portable Air Compressors

These are Diesel driven compressors by Dunlop (Aviation) Ltd. and used for re-charging the breathing set air bottles, especially when diving is in progress from an open boat and away from the ship or base—and for ships in which there is no H.P. air system.

Built-In Breathing System for Submarines (B.I.B.S.)

The H.P. air supply bottles and emergency reducing panel associated with the B.I.B.S. has now reached a satisfactory and reliable form. Recent replacement of the diaphragm type pressure gauge valve and the back seating bulkhead valve with modern nylon seated valves, together with the use of static O-ring seals in place of sweated seals has improved the air retaining efficiency and eased installation work.

Swimmers Assisted Breathing Apparatus (S.A.B.A.)

A panel for charging the S.A.B.A. equipment is currently being fitted into all surface ships. Criticism that the system could be maloperated by inexperienced personnel has been levelled at this design and an operating instruction sheet will, therefore, be issued to guard against the possibility of mishandling.

Gas Bottles

The Section is responsible for approving the design of all gas and air bottles fitted or used in H.M. ships. Where this involves Naval Store bottles, such as containers for oxygen, refrigerants, etc., these bottles which are transportable and liable to transportation around the country must also conform to the Home Office specifications which are generally more stringent than our own regulations. Thus any design that meets Home Office specification is generally considered to be suitable for Service use.

We are not responsible for any bottles used in conjunction with aircraft and which generally conform to R.A.F. standards ; these are the responsibility of D.G.A.

We are also represented on the Inter-Services Standardization Committee for gas bottles, and although we are not greatly concerned in standardizing fixed bottles with the other Services, representation on this committee does mean we keep in touch with current standards, problems and design trends.

Types

Numbers of bottle of various types and sizes are used and efforts have been made to standardize to some extent in this field. We now fit only 3.75 and 9.1 cu ft air bottles for main storage, and they are now Naval Store items. D.M.E. is responsible only for design and carrying out inspections during manufacture.

We endeavour, as far as possible, to use these bottles also for oxygen and other storage commitments. Where non-standard bottles are required, even by other authorities such as D.G.W. we are responsible for approving the design.

Another feature of this work is the increasing demand of aluminium alloy bottles for diving equipment and services where non-magnetic and light-weight bottles are required.

SECTION 4 : AIR CONDITIONING AND REFRIGERATION

General

The emphasis in improvements in habitability in all classes of vessesl has led to a vast increase in the need for air conditioning equipment and a big increase in the capacity of the plant required. A few years ago a frigate would need 180,000 B.T.U./hr., today's requirement is $1\frac{1}{2}$ million. At the other end of the scale capacities of up to 12 million B.T.U./hr. are being considered for aircraft carriers. Plants are also required to cool electronics, ventilated suits and weapons. Since 1959 we have been associated with the design of 75×10^6 B.T.U.s worth of air conditioning machinery.

Stand-by Capacity

Policy is to provide 100 per cent capacity only for habitability air conditioning, but to make provision for stand-by capacity for electronic and weapon cooling. For cold store plants 100 per cent stand-by is provided.

Reliability in service is being achieved by thorough prototype testing of new designs of equipment, attention to balance in moving parts and design for long working life. The tendency to design for hermetic circuits helps in maintenance reduction by ensuring clean gas systems and correct gas charges.

The Vacuum Refrigeration Plant

In view of the larger plants now required, the steam jet (VR) plant is unlikely to be used much in the future because of its high power consumption. Consideration has been given to the absorption plant, but there is insufficient advantage in the use of this type to justify a change, except perhaps for nuclear submarines where its quietness and lack of potential Arcton leakage would be an advantage.

Development work is leading towards the use of hermetic circuits wherever possible, smaller high speed compressors with Arcton lubricated bearings, more compact assemblies, because the oil-free compressors help in reducing contamination of heat exchanger surfaces, and complete automatic control.

Air Conditioning

General

It has been the aim of this Section, together with the responsible D.N.C. Sections, to fit a small number of centralized plants into ships rather than a large number of small self-contained plants. By adopting this policy we hope to reduce the plant maintenance load in the ship. However, where for some reason such as time, money or space, it is impracticable to install centralized plants, small self-contained units are becoming available. Wherever possible those of the hermetic circuit type should be used in preference to any other.

The use of the small self-contained units is not encouraged ; but as is usual in this life we are often overtaken by events, ships request additional air conditioning capacity, or to have selected compartments air conditioned while stationed in tropical/equatorial waters. ' Fire-brigade ' action is then taken which results in the use of these self-contained units. It is the old story : once an amenity is introduced into selected ships, all the others ask for and expect the same treatment. Unfortunately we still have no clear mandate in this matter, it takes time and money to completely air condition a ship, while there is no Section or composite body in the Ship Department solely responsible for air conditioning. It would seem that until we have a single Section responsible for all the facets of air conditioning, efforts to produce an overall policy and really effective systems will be extremely difficult.

Air conditioning is also used for the cooling of certain electronic equipment; this sometimes leads to complications with the type of plant fitted, especially in ships where only steam driven plants are installed, and where the electronic equipment requires cooling, even when steam is down.

Types of Plant

There is no doubt that the most suitable plant known to date is the Arcton vapour compressor. Other forms of refrigeration such as absorption and thermo-electric have been considered, weighed and found wanting. This is also true of industry; other types of refrigeration cycles are used only where the particular application suits, (i.e. VR plant where waste steam is available).

The lithium bromide absorption plant has been considered for the nuclear submarine application, mainly on the noise aspect ; however, this is basically a static plant and doesn't take kindly to prolonged angles of heel and trim. The U.S. Navy has some of these plants at sea, accepting a reduction in capacity of up to 60 per cent at 45 degrees prolonged heel although sea experience to date has shown that changes in heel and trim are too rapid and too short-lived to have any noticeable effect on capacity.

A study of FIG. 2 will reveal our present practice, our hopes and aims for the future in the design of refrigeration plants and units for air conditioning purposes.

Two projects worthy of mention, being of a rather revolutionary nature, are the direct expansion test rig at West and Beynons and the Napier development of an oil free, freon lubricated compressor, Both applications are aimed at submarine use, but the latter, if successful, could also be used in surface ships.

Controls

Large capacity plants of 250,000—4 x 10^6 B.T.U./hr using distilled water to circulate the air treatment batteries in the ventilation trunking are controlled by a thermostat ' feeler ' bulb positioned in the freon evaporator chilled water outlet.

This sensing element is the medium for operating the following methods of control :—

(*a*) Where the compressor is cut ' in ' and ' out ' in direct proportion to the chilled water temperature

(*b*) Where banks of cylinders, on multi-cylinder compressors are off-loaded by electrical switch gear on 3-step load capacities :—
- (*i*) 75 per cent
- (*ii*) 50 per cent } of full load
- (*iii*) 25 per cent

(*c*) Infinitely variable, hot gas by-pass control from full load to no load with continuous running compressor. This method has the advantage of simplicity of equipment and reduction in wear caused by compressor stopping and starting.

Of the three, method (*a*) will not be used in future installations since experience has shown a high incidence of overheated motors and burnt out contactors due to a too frequent on/off cycle.

Weapon Cooling

The Arcton recovery plant was designed to cool missile sub-assemblies and complete missiles during servicing and testing. These plants have been in service for 4-5 years and most of the teething troubles have been overcome.

Type of Plant and Compressor			Application
Self Contained Plant (See Note 1)	Hermetically sealed refrigeration units (*a*) 9,000 BTU/hr (*b*) 12,000 BTU/hr (*c*) 24,000 BTU/hr		Ships with A.C. electrical supplies
	Semi-hermetically sealed refrigeration units (*d*) 15,000 BTU/hr.		Ships with D.C. electrical supplies
Centralized Plants		(*e*) Chilled water main to air treatment units	Surface ships
	Conventional Compressors 20,000—3 x 10^6 BTU.s per hour	(*f*) Direct expansion to one air treatment unit	Submarines
		(*g*) Direct expansion to multiple air treatment units	' A ' Class Submarines
	Balanced Reciprocating Compressor	(*h*) Direct expansion to one air treatment unit	Submarines
	Rotary Compressor	(*j*) Direct expansion to one air treatment unit	Submarines
	Oil free Centrifugal Compressor	(*k*) Direct expansion to one air treatment unit	Submarines
		(*l*) Direct expansion	Submarines and selected ships
		(*m*) Chilled water main to air treatment units	Surface ships

Notes : 1. It is Admiralty policy only to fit self-contained plants in ships where space and/or They are intended as temporary expedients only.

2. Should the oil free centrifugal compressor prove successful, it is likely that all f in reduced size, noise, and maintenance problems.

Fig. 2—Air Conditioning Machine

Manufacturer	*Remarks*
ermotank ›rris-Warming	(*a*) 9,000 BTU/hr unit by Thermotank based on commercial marine practice, modified to Admiralty requirements (*b*) and (*c*) 12,000 and 24,000 BTU/hr units by Norris-Warming, designed and built to Admiralty requirements Delivery of first units November/December, 1961
›rris-Warming	(*d*) Designed and built to meet Admiralty requirements. Delivery of first of units April, 1962
;htfoot rk Shipley lls	(*e*) and (*f*) Compressor design based on commercial practice
›st and Beynon	(*g*) This system has been proposed so that the A/C machinery can be sited away from the Asdic compartment and multiple air cooling units installed in lieu of the single cooler now employed Vote 8 development—Test rig successful : design of air cooling units being investigated
lls	(*h*) If successful, intended as replacement for conventional compressor in ' SS01 ' Class submarines in order to achieve more silent operation of A/C Plant Vote 6 development—compressor due for installation 1962
Paul Duclos Marseilles	(*j*) (*i*) Purchase of French designed and manufactured rotary compressor for evaluation in 'A' Class submarines. Vote 8 purchase. At sea in *Acheron*, reported to be noisy
West and Beynon	(*ii*) Designs in hand—if proved successful intended to replace reciprocating compressors in ' A ' and ' T ' Classes. This project may be combined with (*g*) Vote 6 development. Compressor assembled and being bench tested
Napiers	(*k*) Proposed to reduce size and weight of present plants—Vote 8 development, preliminary designs approved.
	(*l*) As for (*k*) above. No development until (*k*) and (*g*) satisfactorily completed
	(*m*) As for (*k*). No development until (*k*) satisfactorily completed.

ıot allow the installation of centralized plants.

ıditioning plants will be fitted with compressors of this type, thereby showing an advantage

›N COMPRESSORS

The main complaint from sea has been the plants are unable to cope with the increased number of missiles now required to be tested by D.G.A. Larger capacity plants now on order will shortly be fitted.

Radar and Aircrew Ventilated Suit Cooling

The static and mobile cooling units, manufactured by Sir George Godfrey and Partners, have not been entirely satisfactory mainly due to an appreciable number of gearbox and compressor defects.

The main pattern of these defects was the failure of the compressor gearbox drive shafts, caused by fatigue after a series of starts at high torque. These shafts have been modified and to date no further failures have been reported.

The noise level of the mobile unit has also come in for a deal of criticism and so a new design silencer has been fitted to one plant for trials. Although the noise level was reduced it was still considered too noisy for comfort and action is now in hand to build an acoustic shed around the unit.

Cold Store Refrigeration

General

All new refrigeration plants for cold store refrigeration use freon 12 as the refrigerant and employ the principle of direct expansion which simplifies the plant and eliminates the need for brine systems. The use of direct expansion enables smaller plants to be fitted, with a consequent saving in weight and space.

The plants are automatically controlled and arranged to cut in and out either by the electrical control gear or by ' off loading ' the compressor, as necessary to maintain the correct room temperatures.

In recent years we have adopted the practice of cooling rooms by recirculation of the air within the room over a cooling coil or grid. The advantage of this system is that it enables cold to penetrate more readily to all parts of the rooms and it also enables the size of the cooling coils to be made smaller than the conventional grids because of the rate of circulation over them. The advantages of this method apply only in the main to large rooms; for rooms of 150 cu ft or less, normal grids or coils are used.

Standard Automatic Controls

At present the various refrigerator manufacturers use their own particular methods of auto controls. Investigations are now under way to establish a standard form of control ; this is proving rather more difficult than was originally thought.

Domestic Automatic Refrigerators, Drinking Water Coolers, Ice Cream Machines and Ice Making Machines

Domestic Automatic Refrigerators

The majority of DARs now in service are of the ' Electrolux ' absorption type, but in certain applications, such as submarines and boom defence vessels, i.e. where a ' permanent list ' might develop, vapour compression plants by West and Baynon are used. Both types are giving good refrigeration service, but certain of the door fittings of the Electrolux models come in for a deal of criticism.

Whilst the West and Beynon unit has been designed especially for naval service the Electrolux model is taken straight off the normal commercial production line. It is not easy, therefore, to modify the Electrolux units in any way without developing a special range which, because of the comparatively small number ordered for naval service, would be uneconomical, and in any case it is doubtful whether the firm would even consider such an interference of the production line.

Both the West and Beynon and the Electrolux models have been patternized within the past 18 months and are now supplied by the Director of Stores Department.

Drinking Water Coolers

The new water cooler of some 8 gall/hr capacity by West and Beynon based on the design fitted in H.M.S/M. *Dreadnought* will shortly be available for issue to the Fleet. This unit is for use with an A.C. electrical supply and contains a hermetic refrigeration system. It is hoped that it will be an improvement of the present Sterne design. By suitable modification to a ship's ventilation arrangements in way of the unit it is expected that this design could be used in ships' machinery spaces. One such water cooler is currently being fitted into the engine room of H.M.S. *Hermes* for trial.

Water cooler designs for use with D.C. electrical supplies of 4 gallons per hour capacity are also available and are manufactured by West and Beynon.

Once these designs are proved they will be patternized and supplied to the Fleet by the Director of Stores Department.

Ice Cream Machines

Although these machines are at present supplied by the NAAFI, it is intended tha this Section will shortly assume iesponsibility for their design and provisioning.

Ice Making Machines

Action is being taken to introduce ice-making machines for the production of ' domestic ice ' in H.M. ships. Ice is at present provided only in satisfaction of M.D.G.'s requirements.

Various designs have been investigated and Board approval is now being sought to install a machine, manufactured by Auto Ice Ltd., and capable of producing 100 lb of ice per day, in a ship for trials and evaluation.

SECTION 5 : SHIP CONTROLS AND MISCELLANEOUS

Steering Gear

Current Designs

(*a*) *Frigates.* The Mark I design which was developed for the Type 12, 14, 46 and 61 frigates has proved to be extremely reliable in service. Modified to Mark II (i.e. incorporating unified threads) this design has been extended to *Rothesay* and *Leander* Classes and the G.P. frigates.

(*b*) *G.M. Ship.* Here we were presented with a problem in that the ship was of cruiser size with corresponding rudder torque, whereas the space and weight requirements had to be reduced to destroyer standards. A four-ram arrangement was impossible and we were forced to go for a two-ram arrangement with direct linkage to the wing tillers. Flexible hoses are provided in the tiller flat as a safeguard against loss of hydraulic leads by action damage.

Following successful trials of a commercial type electric steering control in H.M.S. *Cumberland*, D.E.E. produced an Admiralty version for the G.M. ship. This is, in effect, a duplex ' electrical telemotor system '. Movement of the wheel at the steering console causes a motor to run in the ' after power unit ' in the tiller flat. The motor output in each after power unit (two fitted per ship) is geared down to drive a rack on the output arm. The output arms are married together to operate the floating lever controlling the main pumps in the usual way. A feed back from the output arm stops the motor when the rack has moved an amount proportional to the wheel applied. Automatic steering facilities are also provided.

(*c*) *The Assault ship.* It was found possible to use the G.M. ship design of main rams and hydraulic gear to advantage between the widely placed rudder stocks in the Assault ship, saving considerable cost and design work. As automatic steering was included in the Staff Requirements, the control gear will be electric and similar to that in the G.M. ship, but somewhat simpler.

(*d*) *Fast Fleet Replenishment Ship.* This design was largely influenced by D. of S. The gear will be a conventional four-ram arrangement similar to that fitted in existing replenishment tankers. The gear will be controlled by a ' duplex telemotor system ' with transmitters in the wheelhouse *and* the command shelter position. Automatic steering will be by a separate unit (similar to the auto-steering portion of the G.M. ship gear) a prototype of which has already been fitted in H.M.S. *Vidal.*

Problems

In recent years there has been some complaint with regard to the steering gear in aircraft carriers. Complaints have been on two bases :—

(*a*) General reliability
(*b*) Ability to steer a course.

These complaints have been sparked off by the high speed of landing-on of modern aircraft which leaves little margin for error in alignment of aircraft and flight deck.

It is undoubtedly true that the complexity built into big ship steering gear, to enhance the chances of retaining rudder control under action damage contions, has resulted in some loss of reliability. We feel, therefore, that the time has come when we must review the requirements which led to these complications to see whether they are still valid.

It is also necessary to determine whether the directional stability required to make landing-on a safer operation can be achieved with conventional steering methods, and if so, whether we need to change the form of actuating and control gear to give more rapid and accurate response of the rudder.

The G.M. ship design, requiring as it did a departure from accepted practice, highlighted the rather vague terms on which the steering gear design was based. ' Good manoeuvrability ' was the criterion usually expressed in staff requirements. It became evident that some re-thinking should be done on torques, rudder rates and stand-by requirements, etc., to ensure that we are not blindly following practices which were implemented to meet requirements which no longer exist.

A working party has been set up to examine these problems and recommend steering practice to be adopted for various classes of ships.

Future Practice

Future practice will depend very largely on the outcome of the Working Party's deliberations. It may be that the existing forms of rudder actuating gear in carriers, i.e. electro-hydraulic, cannot meet the speed and positional accuracy required for course keeping. This seems to be unlikely, but more rapid response, possibly with some improved form of auto-control may be required.

The Staff has expressed a desire for a light steering wheel and a seated helmsman, with a possible requirement for automatic steering in some ships. The conventional wheel can be abandoned and the P.S.P. resited, anywhere within reason, excepting only the tiller flat, M.C.R. and the bridge.

The most likely change in the future, therefore, is the control gear.

The electrical control system as fitted in the G.M. ship eliminates many of the troubles associated with the telemotors, such as creeping of the rudder(s), pumping round, messiness in the steering position, etc. The console is neat and ' clean ' in appearance, incorporating all the information required by the helmsman. This form of control has some draw-backs, however. Although electrically it has been called a simple circuit it is not so straightforward to the 'common or garden steam plumber'. It has not been easy to provide a truly 'duplex' system and much of the resulting complication is sited in the tiller flat where it is subjected to bad environmental conditions and vulnerable to action damage.

With the idea of avoiding complication in the tiller flat, we have evolved, in conjunction with Messrs. Hastie, a form of power assisted telemotor, the power assistance being at the transmitter end. A unit of this type will be fitted in H.M.S. *Eagle* in conjunction with modifications to the steering gear control system being carried out during the ship's current refit. We are also investigating a form of direct powered telemotor which would not suffer from creep.

Vane Type Steering Gears

Recently introduced to this country from Germany, this design is claimed to have great advantages particularly in weight and space requirements over conventional ram gears.

In essence the vane gear consists of a stator with vanes fixed to the hull and a rotor having corresponding vanes fixed to the rudder stock. Pressure fluid introduced between the rotor and stator vanes causes the roller stock to rotate. The idea is not new, in fact we tried to develop the design in the early '50s, but it is claimed that an improved method of sealing the vanes overcomes earlier objections to this type of gear.

For certain applications, and particularly in small ships, and ships with single pintle type rudders, the vane gear has some advantages, although fluid losses past the vanes must result in reduced efficiencies at higher pressure, but we are not yet convinced that there is any material gain in the context of our usual twin spade rudder practice in frigates and above.

Stabilizers

Stabilizers are now becoming a more frequent Staff Requirement giving advantages in weapon control, facilitating maintenance and habitability.

The G.P. Frigate

This class is fitted with retractable type fins similar to those in the type 41 frigates. The hydraulic gear is also very similar with capacity controlled main V.S.G. pumps actuated by a servo-system with a separate pump which also serves to extend and retract the fins.

The G.M. Ship

It was impossible to provide the space for retractable fins in this class, and so a multi-fixed-fin arrangement was designed. Each power and fin unit (a total of eight per ship) is a self-contained hydraulic unit linked only by the control gear. A new design V.S.G. pump, Mk. IV, is used. This has its own vane type servo pump on the tail of the main pump, and the swash is actuated by a control cylinder mounted at the rear which is supplied with pressure fluid from a rotary control valve mounted on the swash trunnion. The rams actuating the fins through a crosshead, are oscillating (to avoid having to fit guides) the pressure fluid being fed to the rams through the trunnion.

The control gear has been improved recently to give a measure of anticipation of roll correction required. In the G.M. ship the gear is capable of correcting heel on turning.

Telegraphs and Turbometers

Electric telegraphs are now being fitted in all new construction and large scale modernizations of frigate size and above.

Shaft operated turbometers are being retained on the starting platforms as a last-ditch measure.

Centrifuges

Types

Sharples centrifuges are being tried in the G.M. ship on the recommendation of Y-A.R.D. However, we favour the Alfa Laval machine which has a slightly better performance, is considerably lighter, smaller and cheaper. Hopkinson purifiers, which were introduced into service use during the war mainly to offset supply difficulties, have not proved very satisfactory and are being replaced as opportunity offers.

Policy

The fitting of lubricating oil renovating systems offers the opportunity to fit two identical machines so that a stand-by for the main lubricating oil centrifuge can be provided.

Modifications to Alfa Laval Centrifuges

Investigation of reports from sea has led to some minor design changes to the Alfa Laval machines. These include the introduction of stainless steel bowls, discs and fixed suspension, i.e. the bowl is secured to the spindle instead of being loose.

Sirens

Policy

Wherever possible, air blown sirens in preference to steam ones are now being fitted. Progress has been made in fitting ships with sirens which accord with the Staff Requirements as laid down in 'Agreed Characteristics for Sirens'.

The siren ranges quoted by the manufacturers, however, are not being achieved in practice and it looks as if it will be necessary to carry out ranging tests to determine the true range of the various makes.

Siren control

Siren control to give an automatic signal in fog conditions has been fitted in some new construction ships but, in accordance with a recent Staff decision, this has now been discontinued. It was considered to be an unwarrantable complication.