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THE INSTITUTE OF MARINE ENGINEERS

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The Development of Air Conditioning in Ships

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A short historical introduction is followed by a breakdown of the spaces in a ship from the point of view of air treatment. One section only, namely living accommodation, is then considered.

The physiological effects of surrounding air conditions are discussed and human comfort related to a scale known as "effective temperature".

A typical air conditioning calculation is given for a ship's dining saloon, both for cooling and heating cycle, and design conditions are suggested for various ship routes. Modern methods of air conditioning and controls are briefly described, and reference is made to developments in refrigeration plant.

The practical problems of the air conditioning engineer are indicated, together with the associated problems of the naval architect and superintendent engineer.

Certain conclusions and further developments are suggested, and the appendix includes a glossary of terms, psychrometric chart and pictures of ship installations, together with references for further study.

HISTORICAL

There seems little doubt that the earlier civilizations were based in climatic conditions of a temperate and pleasant nature, and the discovery of fire and the means of producing it permitted voyages of discovery into less clement lands, where warmth in the form of fires was produced by man for his additional comfort and well being. It would also seem to be an historical fact that these civilizations were aware of one method of cooling, although it is unlikely that the reason for this was understood. This refers, of course, to the porous pot of water, from which some water evaporates and extracts its latent heat of evaporation from the remainder. A more modern form of this is the "butter cooler" and, more recently, the vacuum refrigeration plant.

It was not until 1854, however, that Professor Thompson, later Lord Kelvin, and the father of thermodynamics as the subject is known today, propounded the theory on which modern refrigeration is based. Furthermore, at that time he suggested the possibilities of the application of the heat pump, which over the past decade has been applied on an ever-increasing scale.

W. H. Glass points out in his paper, "Air Conditioning in Ships' Passenger and Cargo Spaces"[1], that probably the first application of so called "comfort cooling" in ships was in 1903 and was fitted in the *Kumono Maru* by the late A. W. Stewart. This, he states, was followed in 1914 by installations in the *Cap Polonio* for the Hamburg South American Steam Ship Company, and the s.s. *Aisie* for Chargeurs Réunis. It was, however, considered at that time that the drain on the ship's refrigeration plant was too heavy to justify its inclusion in later vessels.

Glass points out that the term "air conditioning" seems to have originated in connexion with patents taken out by Stuart W. Cramer in America in 1906. It is essential, therefore, to have a clear understanding of the term "air conditioning". In the broadest sense all heating, cooling, and ventilating systems affect in one way or another the condition of the air in the space for which they are used, but for the purpose of this paper the term "air conditioning" refers to the production and control of temperature, humidity, air purity and movement as it affects human comfort.

It will be obvious that where large numbers of people are congregated together in an enclosed space, the condition of the surrounding air can in a short time become unpleasant, and there is little doubt that a tremendous fillip was given to air conditioning by its application to cinemas and the theatres in America in the 1930's. These advances in the comfort and well being of patrons made demands for similar standards on ships, particularly those used by American travellers.

It is not surprising, therefore, that the first of the more modern applications was made in passenger ship public rooms, principally dining saloons, while the rest of the vessel was mechanically ventilated with atmospheric air. Gradual increases in the standards of comfort demanded by the travelling public called for increased standards of ventilation with diminishing returns, until consideration had to be given to air conditioning the lesser public rooms, then passenger accommodation, and finally crew accommodation. The stage has now been reached where to build a tropical going ship without full air conditioning would mean that she would be out of date before she makes her maiden voyage.

THE PROBLEM

From the point of view of air treatment, a ship divides itself into four separate categories, as follows:

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1) Living accommodation.
2) Machinery spaces.
3) Spaces such as galleys where large heat dissipation is likely to exist.
4) Cargo spaces.

In turn these categories are further broken down as follows:

1) (a) Public rooms.
   (b) Private accommodation.
   (c) Public lavatories, wash places, etc.
2) (a) Boiler rooms.
   (b) Main machinery space or engine room.
   (c) Auxiliary machinery spaces (generator rooms, etc.).
3) (a) Galleys proper.
   (b) Galley dependencies.
4) (a) General cargo spaces.
   (b) Refrigerated cargo spaces.
   (c) Special cargo spaces.

Apart from these categories the general ship subdivision, from the point of view of watertight integrity and fireproofiing, must also be duly considered.

To deal adequately with all three sections is not possible in one paper and it is therefore section (1) only which the authors intend to cover at this time.

PHYSIOLOGICAL CONSIDERATIONS

In order to understand the problem fully, an appreciation of the heat balance system of the human body is necessary, so that it is possible to see how variations in the properties of air have a bearing on the normal body functions.

Quite a good analogy can be made between the human body and the main machinery of a ship. The energy of the body is derived from food by the oxidation and conversion of carbohydrates, etc., into sugars. In breathing and eating oxygen and carbohydrates are provided for this purpose and this roughly corresponds with the combustion air and fuel. The first conversion takes place in the stomach and the useful products, sugars, are circulated from this source *via* the blood stream.

This corresponds with boiler and steam lines on a ship. The energizing material in the blood stream sets brain and muscles in motion in the same way as steam applied to engines, and so the body derives its propellent to brain and muscle.

Like all machines a peak efficiency is reached at definite temperatures, and the body normally functions best at a condition of 98·4 deg. F. This means that under varying conditions of activity and for the most efficient working of the organs of the body, this temperature must be maintained. To preserve the heat balance the body has three methods at work to stabilize this condition.

1) It can radiate or absorb heat.
2) It can lose or gain heat by convection.
3) It can control moisture evaporation by the opening and closing of sweat glands or pores, thus increasing or decreasing loss of heat by evaporation of moisture from the skin.

These facts give the clues straight away as to the properties of air governing the heat balance, and they are listed as follows:

a) Oxygen must be available to initiate the energy cycle from food.
b) Temperature variations will affect loss or gain by radiation and convection.
c) Humidity will affect loss of heat by evaporation.
d) Air movement increases the evaporation and convection effect.

The quantity of heat to be dissipated from the body by these means varies according to the person's activity, but in general ship calculations may be taken as approximately 400 B.t.u. per hr. (Fig. 1).

From the point of view of air purity oxygen must always be available for life to exist, but other ventilation factors associated with air conditioning in ships assure an ample supply of oxygen for life, and this does not normally enter into the problems involved in any significant way, except in special cases such as submarines and other naval vessels.

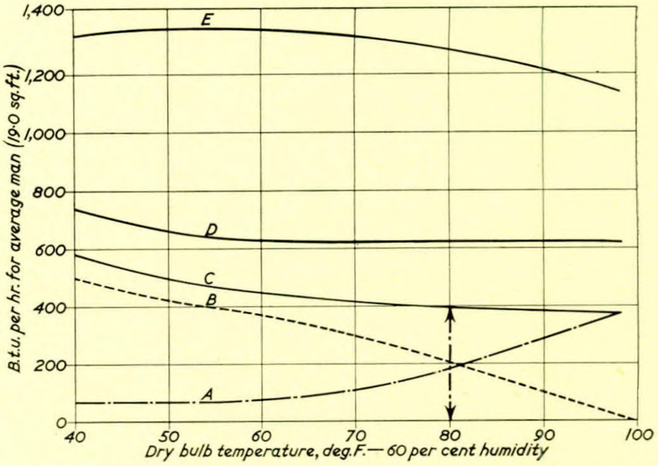
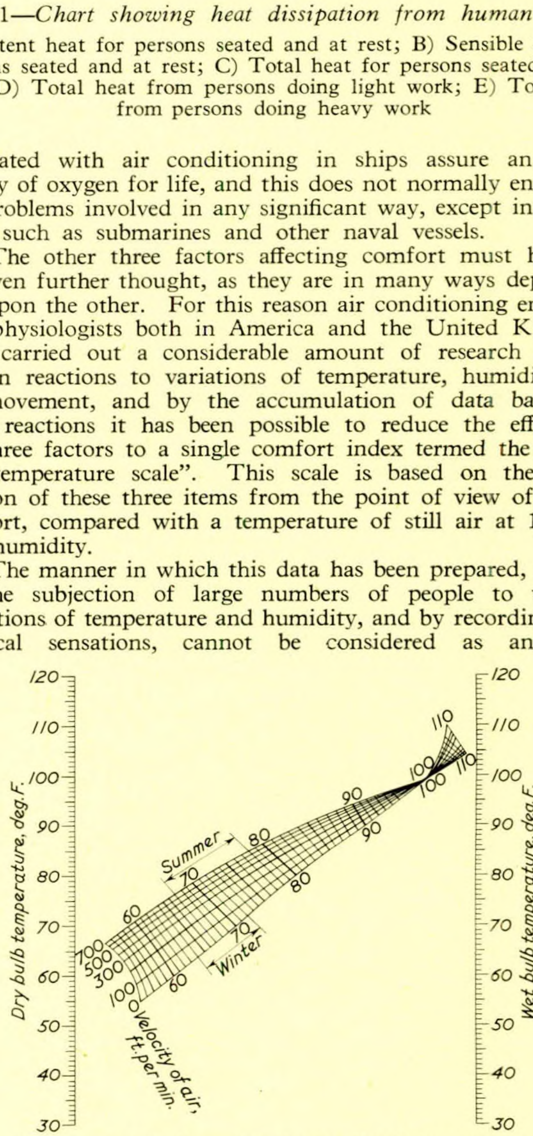


FIG. 1—*Chart showing heat dissipation from human bodies*

A) Latent heat for persons seated and at rest; B) Sensible heat for persons seated and at rest; C) Total heat for persons seated and at rest; D) Total heat from persons doing light work; E) Total heat from persons doing heavy work

The other three factors affecting comfort must however be given further thought, as they are in many ways dependent one upon the other. For this reason air conditioning engineers and physiologists both in America and the United Kingdom have carried out a considerable amount of research on the human reactions to variations of temperature, humidity and air movement, and by the accumulation of data based on these reactions it has been possible to reduce the effects of the three factors to a single comfort index termed the "effective temperature scale". This scale is based on the interrelation of these three items from the point of view of bodily comfort, compared with a temperature of still air at 100 per cent humidity.

The manner in which this data has been prepared, namely by the subjection of large numbers of people to varying conditions of temperature and humidity, and by recording their physical sensations, cannot be considered as an exact



By courtesy of the "American Heating, Ventilating, Air Conditioning Guide, 1957"

FIG. 2—*Effective temperature scale*

Use of chart: obtain wet bulb and dry bulb temperatures; draw straight line on chart joining wet and dry bulb temperatures; read off where line intersects curve scientific relation; e.g. 80 deg. F. at 100 per cent humidity cannot be exactly the same as 88 deg. F. and 50 per cent humidity, since some different sensation must be expected with a drier condition at 88 deg. F. However, from the point of view of general comfort, the large majority of subjects considered the one to be as comfortable as the other.

Fig. 2 shows a chart of effective temperatures related to dry bulb temperature, wet bulb temperature and air movement, and a few examples from the chart will soon indicate the effect of variations of these three factors.

It should perhaps be mentioned here that this particular chart of effective temperature does not cater for conditions in spaces such as engine and boiler rooms where the radiant heat factor is of considerable importance. Thanks to the work of Bedford[6] and his colleagues at the British School of Hygiene and Tropical Medicine, however, a "corrected effective temperature chart" is available which incorporates the use of a "globe thermometer" instead of the normal dry bulb instrument, and by this means it is possible to take the radiant heat factor into account where this becomes necessary.

A word must now be added in connexion with the so-called "comfort zones", and it will be obvious that there will be a limited range of conditions within which body comfort will exist. Unfortunately this varies both individually and nationally and again between winter and summer. The two arbitrary zones are indicated on the chart, for Britons, one for summer and one for winter. The reason for this variation is a natural tendency for the individual to become acclimatized physically and also to adapt himself by variation of dress.

When air conditioning is applied, care must be exercised in order to avoid sudden excessive changes, and taking an internal relative humidity condition of say 50 per cent, the temperature drop should be related to the prevailing outside conditions to avoid shock effect, more particularly when the outside humidity is high. Under such conditions, which usually prevail at sea in tropical climates, the inside temperature condition to be maintained can be assessed from Fig. 3.

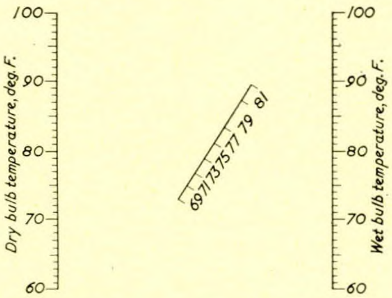


FIG. 3—*Chart giving thermostat settings for various outside conditions*

Use of chart: Obtain outside wet and dry bulb temperatures by sling psychrometer and draw straight line joining readings obtained. Read thermostat setting on mid sloping line; in extreme tropical conditions the setting of the thermostat should be approximately 80 degrees and in more normal conditions down to, but not less than, 70 degrees.

Figs. 4 and 5 are included to show how variations of ambient conditions can be influenced by the proximity of a land mass and were recorded in 1937 in a trip from Suez to Abadan. It should be noted that as the vessel approached Abadan the northerly wind altered dry bulb and wet bulb conditions considerably.

It is further interesting to note that with a thermostat set to give room conditions of say 80 deg. F., Fig. 3 shows there is no need to alter this setting despite the fact that a temperature differential of perhaps 20 degrees to 30 degrees might exist. It should therefore be pointed out that as the ambient dry bulb temperature rises above normal body temperature the wet bulb tends to fall, and thus the humidity of the outside air is considerably reduced. Under these conditions shock effect is less and the body is quite able to cope with such a temperature change. A similar drop in dry bulb temperature under more humid conditions when the ambient dry bulb temperature is say 90 deg. F., might, however, cause collapse.

It can therefore be deduced that the shock effect depends largely on the wet bulb temperature, and with a high wet bulb temperature the dry bulb differential between outside and inside conditions should not exceed say 10 deg. F.

As previously stated, when the dry bulb starts to rise in tropical conditions the wet bulb tends to fall. This is general and fortunate as otherwise people would have difficulty in surviving at all, because the body temperature could not be maintained but would start to rise to fever conditions, i.e. above 98·4 deg. F. It is interesting to note that from recordings of thermostat settings on Transatlantic liners over the past few years and relating these to the nationalities of people travelling, it is clear the Americans prefer a slightly cooler condition in summer and slightly warmer conditions in winter than Britons. A fuller discussion on variations of individual comfort is contained in a short paper[5] by one of the authors.

There is one important figure in the "effective temperature" scale which has a pronounced effect on comfort. It is commonly known as the "threshold of comfort" and is 78 deg. E.T. It has been found that below this figure 90 per cent of people taking part in tests ceased to perspire, and as a result of this the U.S. Naval Bureau and the British Admiralty have adopted this figure as the maximum to which inside conditions shall be permitted to reach when a ship is air conditioned. In passenger and crew accommodation for most British vessels, however, a figure between 77 deg. E.T. and 78 deg. E.T. is usually taken for design purposes, and associated with a reasonable outside ambient peak.

It would be incorrect to assume that such a figure produces full comfort, particularly in extended exposure, but it should be remembered that there is a certain flywheel effect from the ship and furnishings which tends to offset peak extremes, and experience has shown that figures of 74 deg. E.T. or better are normally maintained.

PSYCHROMETRIC CHARTS

The properties of air are easily reproduced in graphical form known as psychrometric charts and by the use of these charts it is possible to demonstrate in visual form the cycle of operations through which the air passes in doing its work through the system. These charts are also valuable in that with two known properties of air all the other properties are read direct from the chart.

Heating and cooling cycle diagrams are fully discussed in reference 1, and no useful purpose would be achieved by repeating the details. A psychrometric chart, however, forms part of the appendix to this paper. To date the authors have given a good deal of space to the fundamentals involved as it is only by a clear understanding of these principles that a full appreciation of the practical application can be achieved.

CALCULATIONS

The object of the initial calculation must be to create a heat balance in such a way that the air coming into the space at a definite predetermined condition, and absorbing heat from the space, will eventually arrive at the internal conditions specified.

The first problem, therefore, is to establish the heat load leaking into the space concerned, and this can be divided into the following component parts.

1) Heat infiltration through the structure, including sun radiation, if any.
2) Body heat, both sensible and latent.

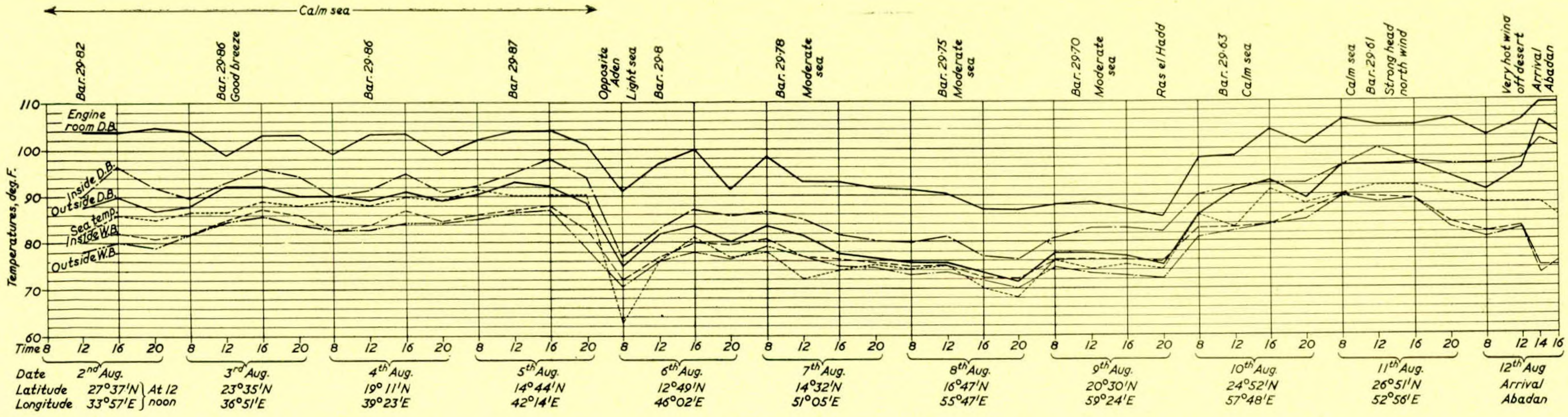


FIG. 4—*Graph of maximum temperatures in ship (accommodation) on voyage between Suez and Abadan, 2nd August 1937-12th August 1937*

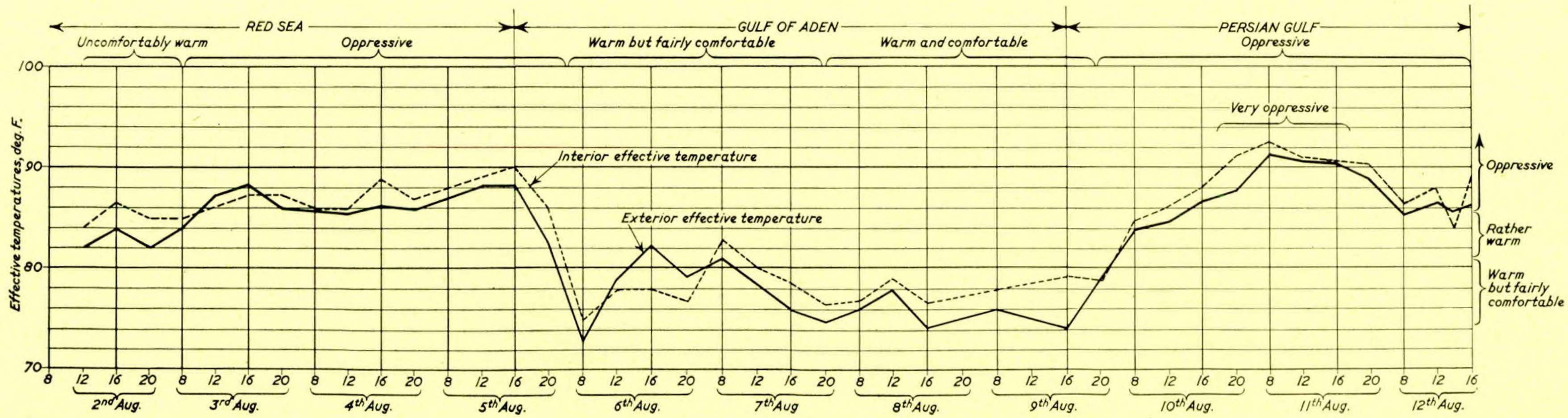


FIG. 5—*Comparison of interior and exterior effective temperatures on board a tanker vessel on voyage between Suez and Abadan*

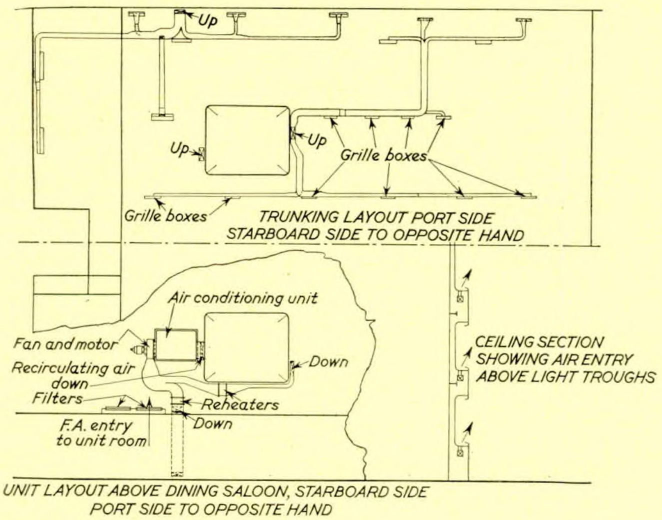


FIG. 6—*Layout of unit and ducting associated with air conditioning of a dining room*

3) Lighting or other electric apparatus, etc., giving off heat.
4) Fan heat (caused by work done on the air at the fan).

Consider the case of a dining saloon shown in Fig. 6. Tables I and II give design calculation sheets for the cooling cycle and heating cycle respectively. As the cooling cycle is the more important calculation this is dealt with first. The full sensible heat load (Table I) from the various sources amounts to 254,480 B.t.u. per hr., and this must be balanced by a quantity of incoming air at the right condition so that as this heat is absorbed the air arrives at the condition required within the space.

If H = sensible heat load, B.t.u. per hr.
W = weight of air in lb. per hr.
Sp = specific heat of air at constant pressure.
t_1 = temperature of incoming air, deg. F.
t_2 = room temperature required, deg. F.

Then the following equation must apply:

$$W \times Sp\ (t_2 - t_1) = H$$

The object of this equation is to find the quantity of air which, when introduced into the space at a definite dew point, will then arrive at the room condition required in absorbing the sensible heat. The room condition to be maintained from the table is 82 deg. F. D.B., 66½ deg. F. W.B., which is a dew point of 58 deg. F.

The first trial temperature rise, therefore, is from 58 deg. F. to 82 deg. F. (i.e. 24 deg. F.).

This establishes the first $(t_2 - t_1)$ value in the equation.

Sp can be taken as a constant over the range of conditions normally used for air conditioning and its value as 0·241 B.t.u. per lb. of air.

Solving the equation we have

$$W \times 0{\cdot}241 \times 24 = 254{,}480$$

$$\therefore\ W = \frac{254{,}480}{0{\cdot}241 \times 24}$$

Converting to cu. ft. per min.

$$Q = \frac{254{,}480 \times 13{\cdot}5}{0{\cdot}241 \times 24 \times 60}$$

where 13·5 is the number of cu. ft. per lb. of air at this condition.

$\therefore\ Q$ = 10,000 cu. ft. per min. approximately.

From a study of the figures again it will be seen that 100,000 B.t.u. per hr. in the form of moisture from bodies is coming into the space. This means that approximately 100 lb. of water has to be absorbed by the air every hour and this in turn means a moisture content increase of 1/6 lb. of water added to every 1,000 cu. ft. of air circulated.

If, therefore, the air is introduced to the space at 58 deg. F. dew point, the final room condition will be 82 deg. F. and 69½ deg. F. D.B., which is not quite the

TABLE I

Date

CALCULATION OF ~~HEATING OR~~ COOLING LOAD

CONTRACT
per

SPACE TOURIST DINING SALOON VOLUME 72,724 AIR CHANGES/HOUR 8·5
OUTSIDE CONDITIONS 90°F.D.B. 78°F.W.B. No. OF OCCUPANTS SAY 500
CONDITION MAINTAINED 82°F.D.B. 66½°F.W.B. 45% R.H. FRESH AIR PER PERSON C.F.M.

SURFACE	AREA SQ. FT.	TEMP. DIFF. °F.	B.Th.Us./Sq. Ft. /1 °F. DIFF.	TOTAL B. Th. Us.
ROOF [UNDER ENGINE HATCH]	225	50	0·11	1240
SIDES.	1980	8	0·13	2060
BULKHEAD [AGAINST GALLEY SPACES]	730	27	0·13	2570
BULKHEAD [" HATCHES]	1020	18	0·40	5300
FLOOR [OVER ENGINE CASING]	1530	50	0·11	8420
GLASS.	50	8	1·10	440
BULKHEAD [AGAINST ENGINE CASING]	1020	50	0·11	5620

SUN RADIATION		
DUPLICATED SIDES :- 1980 □' @ 7 B.T.U's/□'		13880
GLASS :- 50 □' @ 150 " / "		7500
	TOTAL	47,030
SENSIBLE HEAT		
OCCUPANTS 500 @ 200 B.T.U's		100,000
FANS 10 H.P.		25450
LIGHTING 24 K.W's		82000
FRESH AIR		
PUMPS		
	TOTAL	254480
LATENT HEAT		
OCCUPANTS 500 @ 200 B.T.U's		100,000
FRESH AIR $\frac{500 \times 15 \times 60 \times 9{\cdot}6}{13{\cdot}5}$		319000
	TOTAL	673480

FAN OUTPUT $\frac{254{,}480}{24 \times 60 \times 0{\cdot}241}$ = 740 Lbs./Min. = 10,000 Cu. Ft./Min.

TABLE II

Date

CALCULATION OF HEATING ~~OR COOLING~~ LOAD

CONTRACT
per

SPACE TOURIST DINING SALOON VOLUME AIR CHANGES/HOUR
OUTSIDE CONDITIONS 0°F No. OF OCCUPANTS
CONDITION MAINTAINED 70°F FRESH AIR PER PERSON C.F.M.

SURFACE	AREA SQ. FT.	TEMP. DIFF. °F.	B.Th.Us./Sq. Ft. /1 °F. DIFF.	TOTAL B. Th. Us.
SIDES [EXPOSED]	1980	70	0·16	22,200
BULKHEADS [NEXT TO HATCHES]	1020	40	0·40	16,300
GLASS [EXPOSED]	50	70	1·47	5,140
				43,640

SUN RADIATION		
	TOTAL	
SENSIBLE HEAT		
OCCUPANTS		
FANS		
LIGHTING		
FRESH AIR $\frac{7500 \times 60 \times 70 \times 0{\cdot}241}{12{\cdot}5}$		605,000
PUMPS		
	TOTAL	
LATENT HEAT		
OCCUPANTS		
FRESH AIR		
	TOTAL	648,640

FAN OUTPUT Lbs./Min. = Cu. Ft./Min.

condition required. An adjustment in the entry air is necessary therefore and the dew point must be reduced to cater for the moisture pick-up. As there are disadvantages in having large temperature differentials between incoming air and the normal room condition some reheat may be necessary in this particular case.

The heating cycle will be based on the transmission figures shown in Table II, which have been calculated in a similar fashion to the cooling loads but based of course on winter temperature conditions.

If the same air quantity be kept in circulation as for cooling, it is possible to calculate the temperature of the incoming air to satisfy the new equation.

$$\frac{10{,}000}{13 \cdot 5} \times 60 \times 0 \cdot 241\,(t_1 - t_2) = 43{,}640$$

$$t_1 - 70 = \frac{43{,}640 \times 13 \cdot 5}{10{,}000 \times 60 \times 0 \cdot 241}$$

$$= 4 \cdot 1 \text{ deg. F.}$$

$$\therefore\ t_1 = 74 \cdot 1 \text{ deg. F.}$$

When the outside air is particularly cold it may be necessary to add moisture to increase the humidity within the space. This is done by the direct introduction of water vapour in the form of steam and is controlled by a humidistat within the space. It will be noted that the temperature of air entering the space is not very high in view of the small sensible heat losses through the boundaries.

Naturally, however, the fresh air has to be heated from 0 deg F. to 70 deg. F. under peak winter conditions, and the heater must therefore be designed to cater for this load as well. Similarly, reverting to Table I, it will be obvious that the refrigerating plant and cooling coils must be capable of extracting both sensible and latent heat loads.

Requests are often made to assess cooling loads by volume and occupancy of the space concerned and it must be appreciated that no accurate assessment can be made in this way. Fig. 7 does, however, give rough figures for spaces where self-contained units have been fitted in the past on existing ships, and are included to show average loads in graphical form which may be of some value. It is necessary to check this carefully in any particular application by calculations, as demonstrated above.

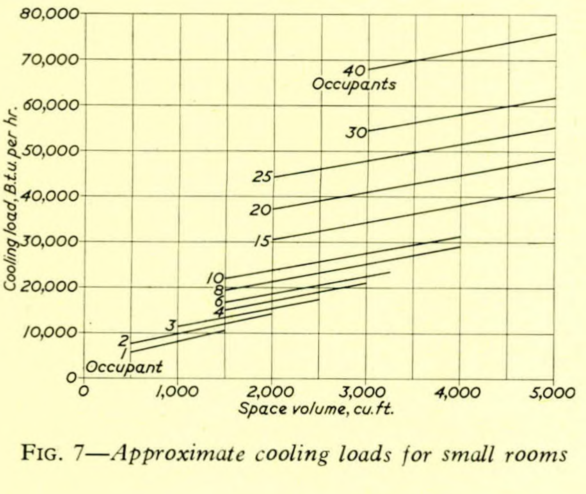


FIG. 7—*Approximate cooling loads for small rooms*

DESIGN CONDITIONS

Before the application of air conditioning can be considered, a basis of design must be decided upon, bearing in mind the ambient conditions likely to be experienced by the vessel concerned.

The United States Naval Bureau and British Admiralty have decided that ships not normally sailing in the Red Sea or Persian Gulf routes can be covered by allowing for an outside ambient of 88 deg. F. D.B. and 80 deg. F. W.B. and under these conditions the inside effective temperatures should not exceed 78 deg. E.T. It can be seen from an effective temperature chart that this allows for a drop in effective temperature of 5 degrees. It is the authors' opinion that this is the minimum range one should consider, and if the vessel is likely to travel through the Red Sea or in the Persian Gulf an effective temperature drop of 8 degrees to 10 degrees should apply. A reference to the chart will show that even this is not necessarily ideal under certain peak Red Sea conditions. Results in service, however, based on these figures, have proved adequate and they do give a reasonable economic basis, allow for a certain amount of body acclimatization, and the fly wheel effect of the ship's structure and furnishings.

Design conditions suggested therefore are as follows:—

TABLE III.

Type of ship	Outside temperatures		Inside temperatures	
	Dry bulb, deg. F.	Wet bulb, deg. F.	Dry bulb, deg. F.	Wet bulb, deg. F.
Red Sea passenger vessels	90	86	84	70
Other passenger vessels	88	80	84	70
Persian Gulf cargo vessels and tankers	90	84	84	70

It should be noted that reference is often made to "partial air conditioning", and for this reason ambient conditions have been reduced in some cases, it being clearly understood that when outside temperature peaks occur, the inside condition may rise above 78 deg. E.T., and will be considered as a heat wave condition. The authors feel that any reduction below the standards given above tends to destroy the value of the air conditioning when it is most needed.

Having decided the conditions to be catered for, the actual design of plant to give the inside conditions required must be considered.

METHODS OF APPLICATION

It is not proposed to discuss in detail the various types of air conditioning systems, as these have already been covered in detail by MacVicar and Fairweather[3]. A brief résumé of the various methods of application is however given herewith and Figs. 8 to 11 inclusive show the general diagrammatic arrangements.

1) *Central Station Plant (Fig. 8)*

This plant is normally best applied to public rooms and other accommodation where a zone form of control is satisfactory.

With this type of unit it is common practice to use the same heat exchanger for heating or cooling, the medium in each case being the chilled water or brine circulated from the refrigerating plant; this avoids duplication of piping.

When heating, a calorifier is brought into circuit, and the refrigeration plant is of course out of action, and *vice versa*.

It will be obvious that care has to be taken to ensure that the spaces which are served by such a plant all require to be heated or cooled at the same time and it must therefore not be applied to divergent zones where it is possible in the in-between seasons that one space may require cooling while another may require to be heated.

2) *Reheat Plant (Fig. 9)*

This plant also has a central station main system with

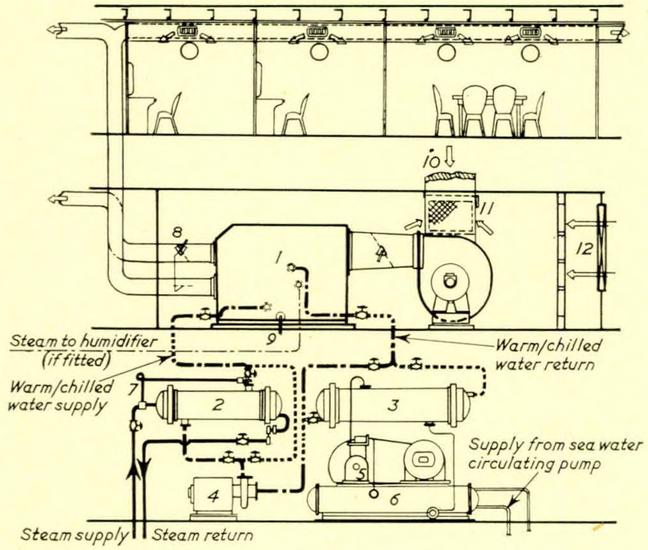


FIG. 8

1) Air conditioning unit; 2) Warm water calorifier; 3) Evaporator/ water cooler; 4) Warm/chilled water circulating pump; 5) Refrigerator compressor; 6) Refrigerator condenser; 7) Automatic warm water temperature controller; 8) Temperature regulating valves (manual or automatic); 9) Drain connexion; 10) Recirculated air duct; 11) Recirculating/fresh air regulating valve; 12) Air filtering equipment and fresh air inlet

ducts led away to the various spaces dealt with. In the branch duct systems serving the different spaces a reheater is introduced and is operated either manually or thermostatically from the space it serves.

This enables each space to be controlled independently, and because of this it will be obvious that it is ideal for cabin accommodation and living spaces generally.

It should also be noted that with this arrangement the in-between periods between summer and winter can be readily controlled.

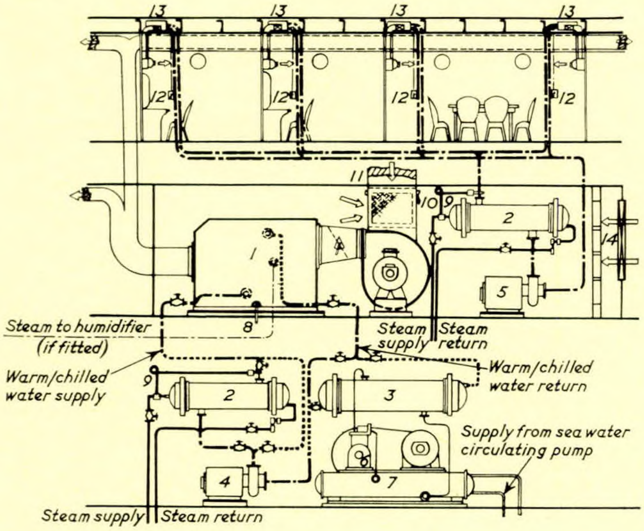


FIG. 9

1) Air conditioning unit; 2) Warm water calorifier; 3) Evaporator/ water cooler; 4) Warm/chilled water circulating pump; 5) Warm water circulating pump; 6) Refrigerator compressor; 7) Refrigerator condenser; 8) Drain connexion; 9) Automatic warm water temperature controller; 10) Recirculating/fresh air regulating valve; 11) Recirculated air duct; 12) Space temperature regulators (manual or automatic); 13) Individual space reheaters; 14) Air filtering equipment and fresh air inlet

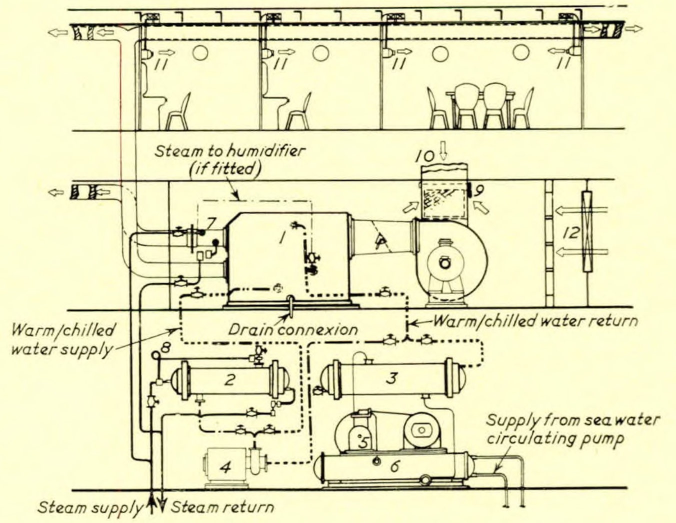


FIG. 10

1) Air conditioning unit; 2) Warm water calorifier; 3) Evaporator/ water cooler; 4) Warm/chilled water circulating pump; 5) Refrigerator compressor; 6) Refrigerator condenser; 7) Reheater; 8) Automatic warm water temperature controller; 9) Recirculating/ fresh air regulating valve; 10) Recirculated air duct; 11) Louvre giving air temperature and direction control; 12) Air filtering equipment and fresh air inlet

3) *Twin Duct System (Fig. 10)*

This arrangement again has a central station conditioner but two main ducts come from it and in the one duct a heater is inserted.

These two ducts and branch systems are then led to the various spaces concerned, and by a suitable mixing arrangement within the various spaces, either at the air terminal itself or in the duct system, a suitable mixture can be maintained thermostatically or by manual control.

Pressure controllers in the system ensure steady duct pressures.

4) *Unit Systems*

This section has to be subdivided into several parts.

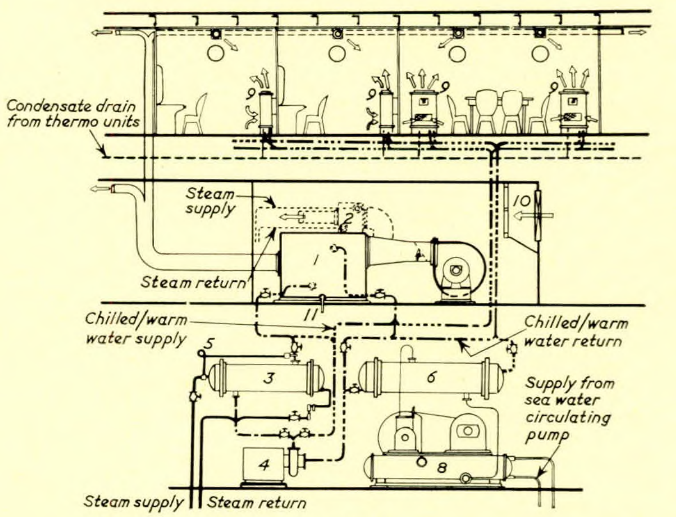


FIG. 11

1) Central fresh air conditioning unit; 2) Heater for non-conditioned spaces (if required); 3) Warm water calorifier; 4) Warm/chilled water circulating pump; 5) Automatic warm water temperature control; 6) Evaporator/water cooler; 7) Refrigerator compressor; 8) Refrigerator condenser; 9) Room conditioners; 10) Air filtering equipment and fresh air inlet; 11) Drain connexion

a) This arrangement (Fig. 11) has a central station plant dealing with the fresh air supply in the zone concerned. Air heating/cooling units recirculate air from the room and discharge it to the room after it has passed over a suitable heater/cooler coil. While the central station unit deals with the fresh air cooling, the room unit deals with local internal sources of heating in the room itself, such as transmission lighting, body heat, etc.

b) This system is like (a) except that the room conditioners deal with the total cooling or heating and are arranged to draw some fresh air from outside or through a supply system already fitted in the ship.

c) Next comes the self-contained unit in which both refrigerating plant and air circulating unit are incorporated in the same casing. As these are housed within the spaces to be treated they are limited in capacity because of their bulk.

With the advent of the hermetic type refrigeration unit, however, a considerable advance has been made in the reduction of the bulk size and cost of this equipment, but since only an alternating current can be used with the hermetic units, rotary converters are required for d.c. ships and this detracts somewhat from their use in these cases.

d) In some cases it is convenient to use direct expansion units with the condensing section outside the room treated. For practical reasons, however, it is not desirable to separate the two sections by too great a distance and a run up to 40ft. or so of refrigeration piping between the compressor unit and evaporator in the air cooler is normal.

HIGH VELOCITY OR HIGH PRESSURE SYSTEMS

High velocity can readily be applied to systems 1, 2, 3 and 4(a) but a full appreciation of all the factors involved is essential. It will be obvious that to force a quantity of air through a system at 4,000 to 6,000ft. per min. will require considerably more power than at the conventional ship velocities. This power goes into the air as heat and must be extracted by the refrigeration plant, and sound attenuation and pressure converters must be fitted to allow the air into the spaces at normal discharge velocities.

A full appraisal of this question is contained in the paper by MacVicar and Fairweather[3] and has been given public airing in an article by W. H. Glass printed in the technical press in 1956[2].

To summarize the general application of air conditioning in ships it can be said that no one method can necessarily be applied to the best advantage in all cases, and a careful study of the various aspects of each case has to be made both from the point of view of technical design, first cost and running costs.

METHODS OF CONTROL

It will be appreciated that the original design is based on the likely maximum demand for heating or cooling and arrangements are made through control apparatus to deal with varying heat loads.

The systems in a modern liner are naturally of an extensive and complicated nature and in fact a paper could be written on this matter alone. However the following brief descriptions will show how the main problems are resolved.

On the cooling side, in large installations brine is circulated from a central refrigeration machinery space and the watchkeeper must ensure an adequate supply of brine at the right temperature to the system as a whole.

At the air treatment units a thermostat is fitted in the air stream directly after the cooler and this controls the flow of brine through the cooler to maintain a steady dew point temperature.

As the cooling requirement in the space decreases, a thermostat in the recirculating duct, exhaust air duct or other convenient place senses a drop in temperature and the following can be arranged.

a) The thermostat can be made to modulate a cooler bypass; or

b) A reheater can be brought into operation; or

c) A direct restriction of the air quantity can be arranged.

It should be noted here that the fresh air must always pass through the cooler so that the humidity may be kept at the correct figure, but any recirculated air which is already at the correct temperature and humidity can be bypassed, thus reducing the quantity of air being cooled to a figure capable of maintaining the correct conditions on the reduced load.

With the reheat method no variation in air quantity through the cooler is arranged.

Where bypass or air quantity regulation can effectively be applied it is obviously more economical on the cooling cycle. There are advantages with the reheat method, however, as the air conditioning unit is more simple and the careful maintenance of face and bypass dampers with their bearings and linkage gear is eradicated.

While bypass damper mechanisms can also be cut out with the restricted air method, pressure balancing devices must be incorporated so that other parts of the system do not get increased quantities of air when one section starts to close.

Furthermore, there are hygienic limits below which air quantities should not be reduced and care must be exercised therefore in the use of this method.

In cases where individual control is required to a number of spaces served by the same unit, then the reheat or twin duct systems really show considerable advantages.

Turning to the heating cycle, a direct thermostatic control of the quantity of hot brine or water to the heat exchanger can be arranged or a bypass equally well applied as for the cooling cycle. Care must be exercised with the restricted air quantity method if used to ensure effective control of the heating medium, as otherwise excessive air temperatures in ducts and at outlet can cause damage to panelling, etc., through shrinkage, etc.

Naturally, with very cold conditions, outside humidity can be very low on the heating cycle and a *humidistat* is normally introduced which modulates a valve on a steam spray in the air stream after the heat exchanger.

On the small, self-contained cooling units a thermostat in the return air stream or within the room normally shuts off the refrigeration plant which restarts again through an automatic contactor starter on rise of temperature over a few degrees.

REFRIGERATION PLANT

It will be appreciated that space does not permit a comprehensive discussion on this portion of the cooling equipment. A few comments, however, must be made on this very important part of the plant.

The advance in design of refrigeration plant over the last thirty years has been considerable, due to the discovery of new and effective refrigerants and advances in manufacturing techniques.

There are certain obvious differences between refrigeration for air conditioning compared with its well known application to cold storage. The refrigerant can evaporate at a higher temperature and is normally about 35 deg. F. for a brine system and 40 deg. F. to 45 deg. F. for a direct expansion application.

The condenser is normally cooled by sea water and as such has to be of ample capacity to deal with sea water temperatures of 90 deg. F., and also possible fouling by marine growth and dirty port water conditions.

The majority of compressor plants in service today for air conditioning use Arcton 6 (difluor-dichloro methane $C.Cl_2F_2$) and this has proved effective over a considerable range of capacity. This refrigerant is very "searching" and care must be taken to ensure a "tight" system so that leakage of the refrigerant does not occur.

On modern liners where very large loads are now involved, centrifugal compressors driven by steam turbines are being installed. The refrigerant used in this case is Arcton 9 (trichlor-fluoromethane $C.Cl_3F$). This, of course, makes a flexible arrangement which will work efficiently over a considerable range of conditions, particularly with a group of similar machines fitted with speed control.

In large installations it is normal to circulate brine from one or two main sources to the various air treatment units. This involves two heat exchangers, one between the refrigerant and the brine and one between the brine and the air. Some loss of overall efficiency will be expected, therefore, and under these conditions approximately 8,000 B.t.u. per hr. may be extracted for every h.p. applied to the compressor. This loss of efficiency in large installations is however compensated by the ease of control of the brine system circulating to large numbers of air treatment units.

It is common practice, however, on smaller plants (e.g. tankers) to use the refrigerant evaporator directly applied in the air stream and about 10,000 B.t.u. per hr. per h.p. may be obtained. The control of such equipment, however, is not as flexible as the brine method and accurate control of temperatures and humidities is more complicated.

It is known, however, that considerable research has been and is being carried out in America in an effort to obtain a suitable and easily controlled application of direct expansion to series of units over a wide area, and naturally if this can be achieved effectively a considerable gain in thermal efficiency seems possible. Perhaps those members who are intimately concerned with refrigeration may like to comment on this aspect.

Vacuum refrigeration has also been used with some success but would appear to require rather more careful maintenance than the modern Arcton 6 reciprocating machine. This type of plant is better suited to the larger loads, say, over 1,000,000 B.t.u. per hr., although smaller plants have been fitted.

THE AIR CONDITIONING ENGINEER'S PRACTICAL DESIGN PROBLEMS

It is suggested that the following are matters of importance: —

1) The designs must be very robust and capable of giving reliable service throughout the life of the ship, with no major overhaul involving replacement of central air conditioning units, ducting systems, or large component parts.
2) They must be flexible and in the great majority of cases "tailor made".
3) Once installed they must be capable of being serviced easily by a ship's engineering staff on the high seas.
4) With rapidly changing weather conditions during voyages, they must be largely automatically controlled.
5) In view of the confined spaces served in accommodation in particular, and restricted heights, the air must be introduced correctly and without draughts, but at a sufficiently high speed to ensure adequate mixing with room air.
6) The volume and deck area taken up by the equipment must be as small as possible to give maximum space for paying passengers or cargoes, therefore the whole scheme must be worked in at a very early stage in the design to give the maximum advantage to owner, builder and air conditioning engineer.
7) They must be operated as economically as possible.

Enlarging on these points, certain main items are considered desirable to maintain the proper standards.

Units, etc.

Central type air conditioning units should be of the double casing construction with a robust inner casing galvanized after manufacture and separated thermally by suitable hardwood frames and insulated panels from the outer casing of galvanized plate. Access doors should be of the hinged plug type with robust fixing attachments, and capable of complete removal in restricted positions.

The internal components should be sized and positioned so that they can be removed by manhandling, with ample access doors as required.

Extended surface heat exchangers should be made of tinned copper tubes and fins in the case of chilled water circulation and may be of cupro-nickel where brine circulation is used.

It is also considered essential to fit good strainers on the brine inlets to the cooling coils to prevent fouling inside the coil tubes by jointing materials, undissolved calcium salt and other debris.

The air side coils should be protected from dirt and debris by filters, and after many years of experiment tinned brass wool filling suitably treated with viscous oil gives excellent results. Plastic ferrules covered with viscous oil have also given good service and are fitted on many vessels. These filters are readily cleaned with the modern detergents and service cleaning facilities are available at the large ports in the United Kingdom if required.

The base of the air conditioning unit should be made of fairly heavy plate and suitably stiffened and then galvanized after manufacture and acts as a deep sump arranged with ample drainage connexions to cope with roll, list or pitching of the ship.

Flexibility

The question of flexibility applies not only to the arrangement of plant in plant rooms of varying shapes, but also, because of the subdivision of the ship and heat producing areas, it is often likely that one space may require cooling while another requires heating, and careful consideration must be given to these points in the design stage. Plant rooms should as far as possible be centrally disposed in the spaces they serve, so that main ducts can be broken down quickly into reasonable sizes to enable the maximum head room to be obtained. Full use is made of positions between beams and stiffeners for housing ducts as near the deck head as possible, and as the main branch ducts often have to run longitudinally under beams the sooner they can be broken down to smaller sizes the better.

Since frictional resistance in a duct system is proportional to duct perimeter divided by area, wide ducts of little depth are not desirable and normally ratios of more than 4 to 1 on breadth and depth are bad practice; furthermore, trunk depths of less than 4in. have serious manufacturing snags and require special machinery.

Servicing

It cannot be emphasized too much that good servicing by a ship's personnel is only achieved when it is possible to service properly. Oiling points and damper mechanism, etc., must therefore be placed in easily accessible positions and access doors must be readily removed.

It must be stressed that even though this fact may be fully appreciated, it is nevertheless extremely difficult to achieve in the congested spaces in which plant often has to be fitted.

Unit Rooms

It is a point well worth considering when space is being allocated for plant, that too much pressure should not be brought to bear on the air conditioning engineer by limiting too severely the space allocated for plant.

It is fully appreciated that space is money in all vessels, but when one considers the cost of the plant put in and the running costs associated with difficult and costly maintenance, it behoves both naval architects and air conditioning engineers to work in close liaison from the earliest design stage so that these points can be given the fullest consideration.

Controls

It has been said that an air conditioning plant is as good as its controls and it is most desirable to have robust control equipment.

Modulating controls of the potentiometric, electronic and pneumatic types have already proved to be both sensitive and reliable, although it is probably true to say that the potentiometric and electronic types are more frequently used.

Air Distribution Ducting

It is a well known fact that the fitting of duct systems into ships is always a difficulty to owners and builders and the advent of air conditioning will ease this problem as compared with the mechanical ventilation systems.

With mechanical ventilation schemes, air quantities, and therefore duct sizes, rose steeply in an effort to give comfortable conditions. Now with cooling applied, the quantities of air in circulation can usually be considerably reduced. Nevertheless it will always be a problem to house ducts in such a way as to give the maximum head room in all cases and because of these difficulties a priority of services should be established and duct systems should be well in the lead of priorities, if not no. 1 priority in this respect.

Air Distribution Fittings

While reference has been made to the intention that an air conditioning system is only as good as its controls, this might be said to be equally true in relation to air distribution and the type of air terminal used.

Frequently the designs of the decorative architect preclude the introduction of the best form of air terminal and compromise has to be made in order to fit in with the accepted decorative design. While it is not suggested that continuous air slots, etc., cannot be arranged in most cases to give first class distribution and at the same time maintain the decorative architect's general design, it cannot be too strongly pointed out that æsthetic requirements alone should not be allowed to overrule the requirements of complete comfort. Surely it could not be suggested that a passenger seated in a room, no matter how tastefully decorated or to however high a standard, would be so overcome by its æsthetic appeal that he would fail to notice an uncomfortable draught caused by a badly sited grille or inconveniently placed air terminal.

Space and Power Economies

Naturally, as the vessel is to run as economically as possible, the space occupied by plant should be reduced to a minimum, subject to comments already made about accessibility for servicing. Therefore the air conditioning engineer must be prepared to use all his ingenuity in design to make the best possible use of the space available and on most occasions will have to "tailor make" the plants to fit the ship.

If the calculation figures are studied again it will be seen that the fresh air heating and cooling loads are a large proportion of the total. It is for this reason that recirculation of air is introduced, with the object of reducing the refrigeration load. The amount of recirculation which can be achieved, however, is governed largely by the satisfactory extraction of air from and through toilet spaces, etc. Obviously these must be kept free from smells and furthermore it is necessary to have the ship as a whole under slight pressure. For these reasons it is rarely possible to recirculate more than about 50 per cent of the air in circulation. Many authorities feel that in cabin accommodation, for instance, a full fresh air system is desirable so that perfumes and tobacco smells, etc., are not transmitted through the system to other surrounding spaces.

The use of all fresh air is not so serious as it might appear on first thought since in cabin accommodation from six to eight air changes only are required (depending on the position in the ship) to carry the necessary heat load, as compared with twelve to twenty changes arbitrarily arranged in an ordinary mechanical ventilation system previously fitted. Naturally, however, maximum advantage must be taken of all possible savings which can be achieved without upsetting the overall balance of the design.

Insulation

At this stage it would be as well to consider the general effect of insulation.

Generally speaking, when ships are fitted with ceilings and lining, little value is obtained by fitting insulation to any surfaces except those subject to extreme conditions, e.g. outer skin of ship and bulkheads, etc., surrounding main machinery spaces, etc. Internal bulkheads otherwise have little or no temperature difference between them and are therefore not transmitting heat.

The insulation of air ducts, however, is most important from the following points of view:

a) Heat or cold conservation
b) Heat radiation
c) Condensation

a) *Heat or Cold Conservation.* Duct systems from the central plants often have a considerable length to travel before arriving at their destination. Normally, with careful design and with the full co-operation of builders and owners, architects and engineers, this can be limited to reasonable figures. Nevertheless, the correct air quantities must be delivered at the correct condition, so that heat loss from the large duct areas must be kept to a minimum.

b) *Heat Radiation.* If hot air ducts pass through cabins they can radiate quite a considerable amount of heat where it is not required so that overall effective insulation of the ducting system is an important matter.

c) *Condensation.* Condensation on air ducts will only occur when the dew point of the surrounding air is greater than the duct temperature and as a ship becomes fully air conditioned the likelihood of condensation becomes less except in the case where an air conditioning duct passes through a normally ventilated space or a space where water vapour is being diffused into the atmosphere. Furthermore, in such cases insulation must have an effective vapour seal.

Item (a) and (b) above, however, are normally the main factors.

PRACTICAL PROBLEMS OF NAVAL ARCHITECTS AND SUPERINTENDENT ENGINEERS

It may be profitable to give some consideration to the effect that air conditioning has within the province of the naval architect and the superintendent engineer.

In the early days of air conditioning on board ship the system was invariably confined to one or two public rooms and a few suite rooms, and the naval architect's problem under these circumstances was that of a relatively minor allocation of space to house the air conditioning units. It is not suggested, of course, that even in those days the space required by the units did not present some difficulty, since space is always at a premium on board ship. However, as only two or possibly three air conditioning units were usually involved, it was always possible to house them in some location reasonably convenient to the spaces served. It might be said, in fact, that the introduction of air conditioning to dining saloons caused the disappearance of the familiar dome within such spaces since the luxury of space given up to air conditioning plant plus the space required to house the dome could not be tolerated and the dome space invariably became the air conditioning unit room.

The naval architect's problem on the fully air conditioned ship, however, is a major consideration and has added seriously to the many complex problems which continue to face him on modern vessels.

The possibility of designing a vessel with particular requirements and then searching for spaces to house the equipment no longer exists, and the naval architect is therefore faced with the problem of designing his vessel to meet all the requirements and all the amenities of modern passenger travel and at the same time to design very largely around the air conditioning plant rooms.

It must be acknowledged that ship designers at home have faced up to these difficulties in a remarkably efficient fashion and, in many instances, have been quite prepared to vary normal construction methods and arrangements in order to achieve the best possible compromise.

It has been said that the building of a ship is largely a matter of compromise, in that not only has the naval architect to design a ship which will carry the necessary complement of passengers and give them all the amenities which owners now consider indispensable in a modern ship, but he has to cope with the æsthetic requirements of the decorative architect, whilst being saddled at the same time with the further encumbrances of air conditioning units, associated duct work and the inevitable air terminals.

Nowadays it is clearly recognized by all ship designers that even at the earliest stages of basic design, it is not only advisable but economically essential to give the earliest possible consideration to the requirements of the air conditioning engineer and thus avoid subsequent confusion and additional expense which must occur if the considerations of air conditioning are left to a later stage.

Similarly, the superintendent engineer, when considering boiler requirements, generator sizes, etc., must be given early intimation of the refrigerating capacity necessary to deal with the air conditioning.

On some modern liners the load associated with air conditioning may be upwards of 20 million B.t.u. per hr. and this represents a large refrigeration load with extensive demands on generating capacity, or, if steam driven, directly on the boilers.

Unfortunately, loading requirements must vary extensively depending on climate and time of year so that the engineer designer may find difficulty in fitting in this large additional load in attempting to get the best overall thermal efficiency.

In addition, space must be found to house the large refrigerating machinery involved, and ultimately, of course, the question of watchkeeping has its repercussions on the additional engineers to be carried, together with their accommodation requirements.

While, from the point of view of distribution of the cooling medium, it might be argued that the refrigerating plant should be split into a number of smaller machines suitably located in spaces throughout the length of the passenger accommodation, this merely complicates the problem of staffing, and ultimately the marine engineer may have to be content with all the refrigerating plant situated in one engine room, and placed in the most convenient position relative to the ship as a whole, and to the availability of the source of power.

Where one main refrigerating machinery room is decided upon, then both the marine engineer and the naval architect are faced with the housing of very large diameter brine leads, sometimes in the order of 18in. to 20in. diameter, not including the necessary insulation. Naturally, every effort will be made to split up the main brine leads as early as possible and, naturally also, every effort will be made to have the main distribution of the cooling medium arranged vertically so as to avoid horizontal leads within passenger accommodation, which are not only difficult to house but, no matter how well insulated, may be a potential source of troublesome condensation under certain circumstances.

When it is appreciated that on larger installations upwards of 100 tons of condensate per day in the tropics have to be drained from the air conditioning units, this condensate coming of course from the air and being more or less pure distilled water, the design engineer may also feel compelled to consider utilizing this water for other purposes rather than let it drain to waste. In some cases the condensate from the air conditioning plants has been used for boiler make-up feed after single distilling.

The foregoing points have been dealt with in a very general fashion but no doubt in the near future it will be possible to persuade a naval architect and a superintendent engineer to present a paper dealing in detail with these aspects of air conditioning.

The paper, so far, has touched upon problems of design, the choice of the most suitable system, and the difficulties encountered in the conception and installation of an air conditioning system, but ultimately the point arises as to how the system should be operated by the seagoing engineer, and some comments on this aspect may be appreciated.

The tendency, up to the present, has been to place considerable onus on the engineer delegated to this duty. He has been asked to determine when ventilation at low speed is all that is necessary. At a later stage, in a tropical going vessel, it is assumed he will be able to decide the exact moment at which fans should be arranged to run at top speed to give maximum ventilation, and then ultimately when the refrigerating plant should be made available and cooling applied to such spaces as are air conditioned. Having decided—successfully or otherwise—on the foregoing sequence he should then adjust thermostat settings to suit variations in climatic conditions. If, for example, the thermostat in a dining saloon were set at a figure much lower than would be generally acceptable from a comfort point of view, then when the space is unoccupied the tendency will be for the air conditioning to cool the space to a condition appropriate to this setting, since in an empty space the loading due to body heat and light, etc., is absent and the full capacity of the plant is available to reduce the temperature. The immediate effect of this method of working is that on the passengers entering the saloon, a feeling of cold shock is experienced and during the course of the meal, when the space is fully occupied, the plant merely continues to operate at its maximum capacity against an inevitable rise in temperature. Under such circumstances it might be stated that the correct conditions are only achieved immediately prior to the saloon emptying at the end of the meal, after which a further effort is made by the plant to reduce the temperature once more under the dictates of the low thermostat setting.

It has been known for thermostats in public rooms to be set at a constant temperature of 70 deg. F., which may be quite satisfactory during the more temperate parts of the voyage, but no effort made to adjust the thermostats when the ambient temperature rose to, say, 90 deg. F., under which circumstances the thermostat settings should have been progressively raised to 78 deg. F. or 80 deg. F.

In addition to the general routine which the operating engineer must endeavour to work to, he is frequently of rather junior rank and may be dictated to by senior officers who have their own ideas as to the best conditions to maintain, and irrespective of how conscientiously the operating engineer may endeavour to adhere to his instruction book, he may not be permitted to do so.

Again, where passenger cabins are concerned and where the control is based on a simple group system, individual passengers may make demands through the appropriate authority for variations in conditions which the junior engineer or electrician may be able to meet, but only at the expense of incurring complaints from other passengers who were previously perfectly satisfied. Knowing these difficulties as encountered at sea, the superintendent engineer responsible for the efficient operation of a large and complex system on a modern passenger vessel may be considerably concerned when faced with the requirement of making a suitable appointment on a ship fully air conditioned, bearing in mind the troubles already encountered in previous vessels where air conditioning may have been applied to a relatively small proportion of public rooms and passenger accommodation.

It is not part of the authors' province to suggest the rank or standing of the officer in charge of a complete air conditioning installation on a large passenger liner but one or two pointers indicating the general trend in controls, etc., may serve as guidance.

In a completely air conditioned vessel it should be accepted at the outset that cooling should be available at a very early stage and in relatively temperate climates. The modern system is designed to handle the correct quantity of air for air conditioning purposes and since this is usually considerably less within the main body of the ship than the quantity associated with straightforward ventilation, very little advantage is obtained from straight ventilation when the outside temperature of the air to the fan room exceeds 60 deg. F. Incidentally, the latter temperature is of greater importance since the air in fan shafts frequently picks up heat between the actual inlet on deck and the unit room below. These fan shafts are, in many cases, adjacent to the machinery bulkheads and, while insulated to a certain degree, some heat is bound to be transmitted to the incoming air.

To return to the question of air quantities delivered to the living accommodation, as already stated these are determined by air conditioning requirements, and consequently it is customary to arrange for single speed motors driving the fans so that the only regulation that is available is that of air quality and not air quantity. This, of course, relieves the operating engineer of some of his quandary in that there is no need for him to make any decisions with regard to fan speeds. In addition, if the refrigerating plant is started up in accordance with warning signals which are based on inlet air conditions, then the decision as to whether or not cooling should be introduced is no longer his responsibility.

From the point of view of passenger requirements, the trend in first class accommodation at any rate is to give individual control within each room. This may be accomplished on a central system either by reheat control or by the provision of twin ducts as already described.

The condition of the air in the cooling duct is thermostatically controlled and, where the reheat system of control is utilized, then the temperature of the water supply to the reheater in each cabin is adjusted automatically to suit climatic conditions, so that the water is merely at a tempering condition in the tropics and at a full reheat condition in colder climates. The introduction of such compensating controls again relieves the operating engineer of making a decision to suit climatic variations.

In the twin duct system the temperature of the reheating air or mixing air is again thermostatically controlled and compensated to suit the climatic conditions and no adjustments on the part of the operator are called for.

In public rooms or in areas where group control of temperature is arranged, climate compensation of thermostat settings are achieved automatically so that in a vessel leaving, say, London or Australia, the original setting may be at 70 deg. F., but as the climate becomes more extreme as the vessel voyages towards and through the tropics, the actual thermostat setting is varied to suit by means of the compensating devices installed, and the defects associated with purely manual adjustment are thereby overcome.

It is not suggested, of course, that the duties of the operating engineer have become a complete sinecure on a fully air conditioned vessel but many of the difficult decisions have been removed, and the need arises simply for a maintenance engineer, preferably one fully conversant with the functioning of modern thermostatic equipment.

Apart from the control aspect, ordinary work associated with the maintenance of pumps, fans, etc., is already normal.

FUTURE DEVELOPMENTS AND CONCLUSIONS

1) It can be expected that air conditioning will be applied to all passenger liners on an ever-increasing scale and that, except for cargo vessels operating in temperate climates only, the full treatment with refrigeration cooling equipment is to be expected.

2) In larger vessels with larger cooling loads electrically driven refrigeration plant is likely to be superseded by turbine driven centrifugal compressors.

3) Direct expansion refrigeration plant may perhaps supersede the present brine circulation system, providing satisfactory distribution of refrigerant together with means of local control can be obtained; this will give an overall improvement in efficiency from the point of view of B.t.u./h.p. extracted.

4) Active development in the early designs between naval architects, superintendent engineers and air conditioning engineers is already well developed here, but considerably more liaison is to be expected.

5) The use of plastic ducting on the branch duct systems, without the necessity for duct insulation, may well develop considerably and is already receiving considerable attention.

6) Reverse cycle or heat pump application may well spread further on certain vessels, depending on the main propulsion methods adopted.

7) Large quantities of condensate from a.c. units may well be put to use in the form of boiler feed or even cooled drinking water services after suitable treatment.

8) High duct velocities with sound and pressure converters, etc., may be used more frequently when the demand on space makes this worth while.

9) Considerable reductions in the size and number of natural exhaust duct systems will result from full application of air conditioning.

10) The provision of opening ports and windows will largely disappear.

11) The development and improvement in air terminals will largely cut out the need for quantity control, *i.e. variation* in the quantity of air delivered to cater for load variation.

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Appendix

Terminology

Dry bulb temperature. The temperature as measured by a thermometer not affected by moisture or radiant heat.

Wet bulb temperature. The temperature as measured by a thermometer, the bulb of which is covered with a wetted cotton fabric and exposed to a current of rapidly moving air.

Relative humidity. The ratio of the quantity of water vapour actually contained in the air to the maximum quantity of water vapour that the same air can carry when saturated at the same temperature and barometric pressure.

Dew point. When any air/water vapour mixture is cooled a temperature is reached when moisture starts to separate out. This is the dew point.

Effective temperature. An arbitrary index which combines the effect of temperature, humidity and air movement on the sensation of warmth or cold felt by the human body. The numerical value is that of the temperature of still saturated air which induces a similar sensation of comfort.

Comfort zone. An area shown on a psychrometric chart showing a range of temperature and humidity conditions which give bodily comfort to the majority of human beings.

Ambient conditions. Normally applied to dry and wet bulb shade temperatures existing in the surrounding outside atmosphere.

Sensible heat. That proportion of the heat which changes only the temperature of the substance involved.

Latent heat. The heat involved in a change of state (moisture absorption or condensation).

Total heat. The sum of the sensible and latent heats at a particular condition.

Globe thermometer. Normally a mercury in glass thermometer with its bulb at the centre of a hollow metal sphere of $3\frac{1}{2}$in. diameter. The outside surface of the sphere is matt black finish.

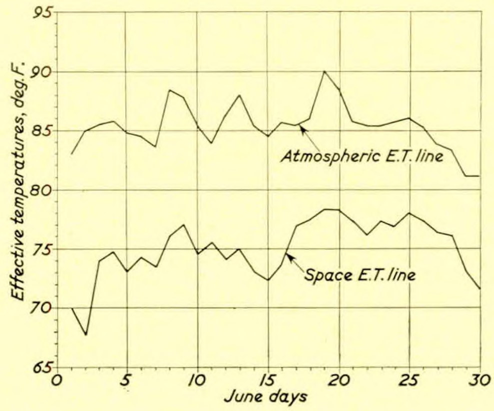


FIG. 12—*Comparative effective temperatures outside and inside air conditioned space, compiled from a ship's log*

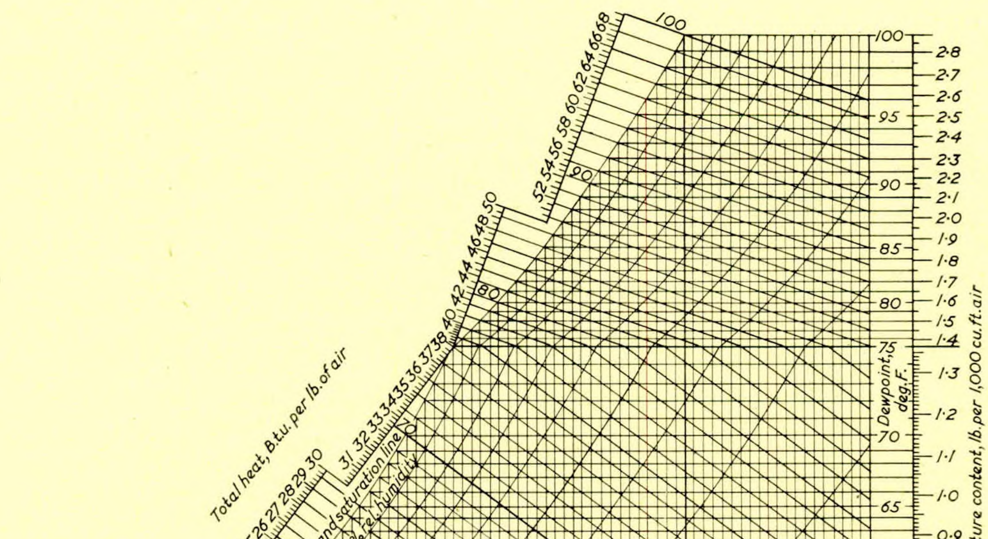


FIG. 13—*Psychrometric chart*

TABLE IV.—SHIP'S AIR CONDITIONING LOG

Date	Time	Temperatures, deg. F. Atmosphere		Thermostat settings		Air into space		Space Temperature		% R.H.	Fan speed	Brine or chilled water temperature inside	Sea water temperature	Remarks
		Dry bulb	Wet bulb	Dry bulb	Dew point	Dry bulb	Wet bulb	Dry bulb	Wet bulb					
1st June	1300	88	80			72	65	73	65	65	800		90	
2nd ,,	1300	91	82			74	67	71	62	65	800		89	
3rd ,,	1300	92	82			76	68	78	69	64	800		88	
4th ,,	1100	92	83			78	69	79	70	63	800		88	
5th ,,	1100	90	82			76	67	77	68	63	800		88	
6th ,,	1130	89	82			76	68	78	70	65	800		90	
7th ,,	1130	88	81			75	68	77	69	65	800		90	
8th ,,	1300	93	87			76	70	81	72	65	800		93	
9th ,,	1300	93	86			78	71	82	73	65	800		92	
10th ,,	1300	90	83			76	69	78	70	65	800		90	
11th ,,	1130	88	82			77	71	80	71	65	800		89	
12th ,,	1130	91	84			76	70	78	69	65	800		92	
13th ,,	1130	96	85			77	70	79	71	65	800		92	
14th ,,	1130	90	83			74	67	77	68	63	800		89	
15th ,,	1300	96	78			74	66	77	67	60	800		90	
16th ,,	1300	102	77			73	62	79	67	55	800		91	
17th ,,	1230	105	75			75	63	84	69	49	800		93	
18th ,,	1300	90	84			78	70	82	73	65	800		90	
19th ,,	1300	95	88			80	74	83	74	65	900		90	
20th ,,	1300	93	87			80	74	83	74	65	900		92	
21st ,,	1300	89	84			79	73	82	73	65	900		91	
22nd ,,	1300	90	83			78	71	81	72	65	900		93	
23rd ,,	1300	88	84			80	72	82	73	65	900		92	
24th ,,	1300	89	84			79	72	81	72	65	900		93	
25th ,,	1300	88	85			80	73	82	73	65	900		92	
26th ,,	1300	88	84			79	73	82	73	65	900		92	
27th ,,	1130	87	82			78	72	81	72	65	900		90	
28th ,,	1130	86	82			78	72	81	72	65	900		88	
29th ,,	1300	84	79			74	66	77	68	63	700		89	
30th ,,	1300	84	79			73	66	75	67	65	700		88	

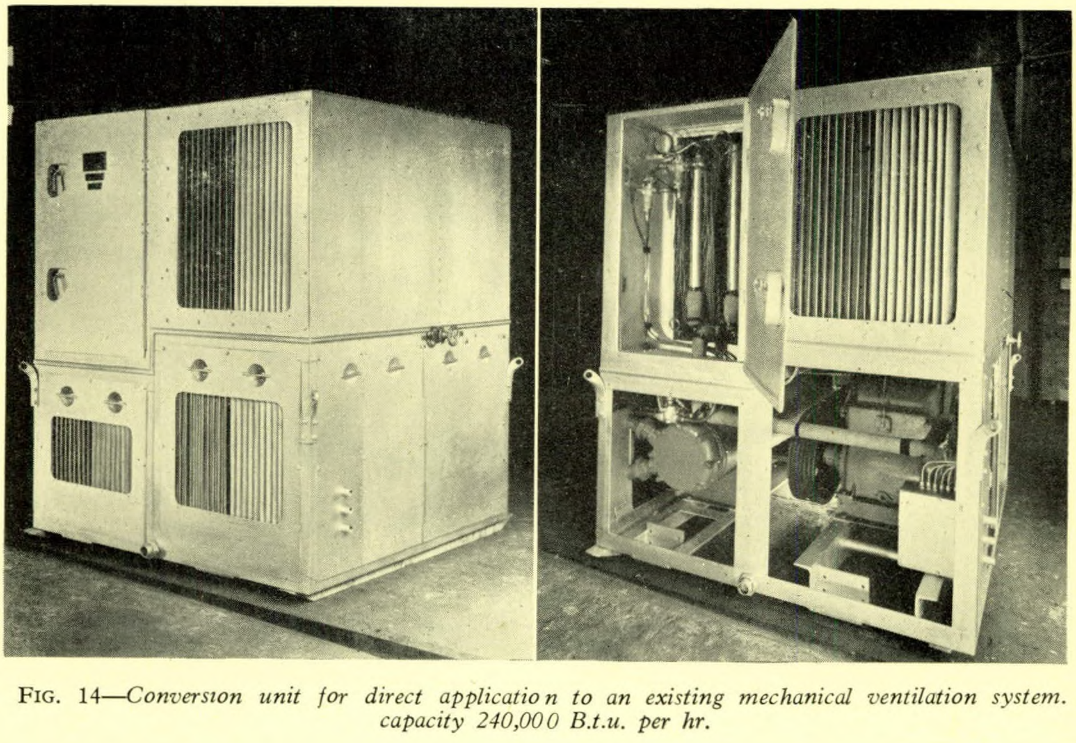


FIG. 14—*Conversion unit for direct application to an existing mechanical ventilation system. capacity 240,000 B.t.u. per hr.*

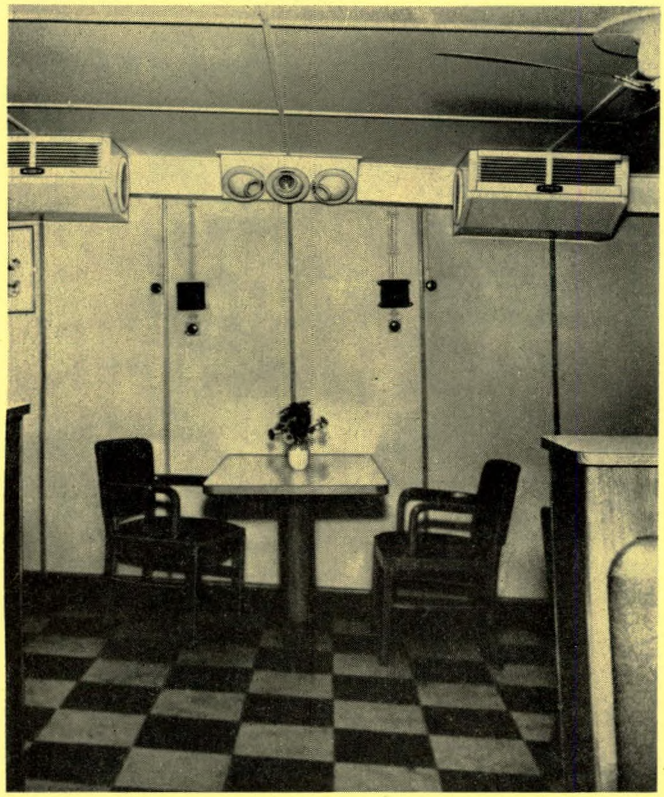


FIG. 15—*Ceiling type cooling units can be served from central brine system or by direct expansion from semi-remote condensing unit*

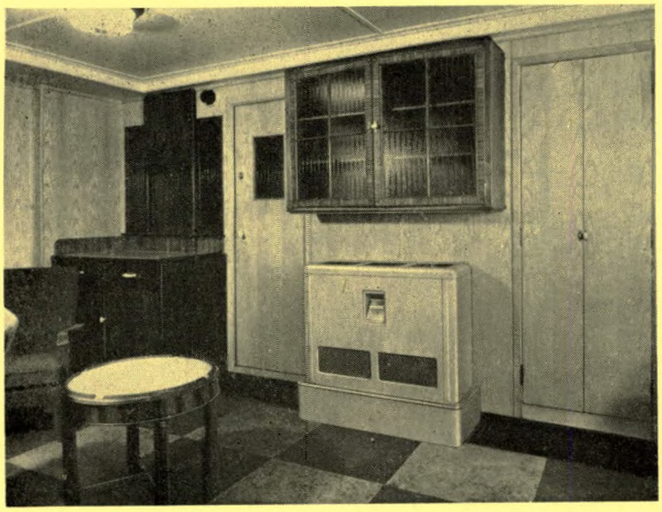


FIG. 16—*Floor type cooling unit in ship's lounge; this would be served with brine from the central circulating system or could be arranged for direct expansion from semi-remote condensing unit*

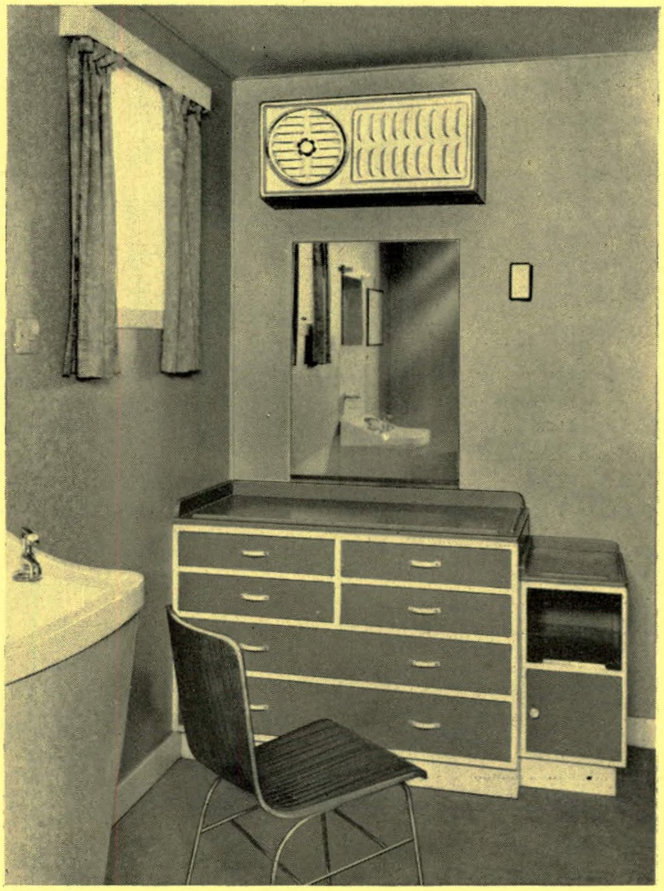


FIG. 17—*Self-contained hermetic type unit installed in two-berth cabin: capacity 7,500 B.t.u. per hr. suitable for a.c. electrical supply only*

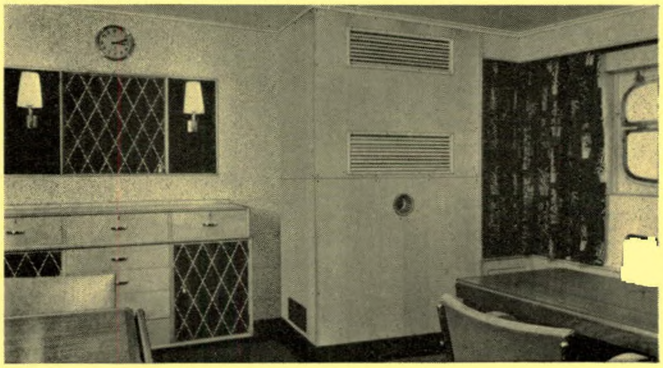
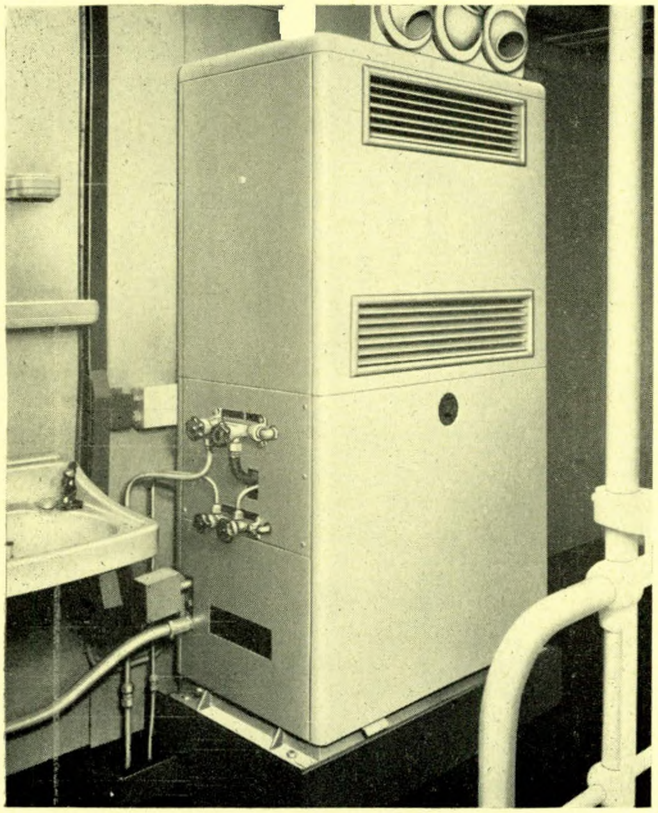


FIG. 18—*Self-contained air cooling unit arranged in ship's dining saloon; these units are made for a.c. or d.c. electric supply with capacities of 12,000, 24,000 and 36,000 B.t.u. per hr.*



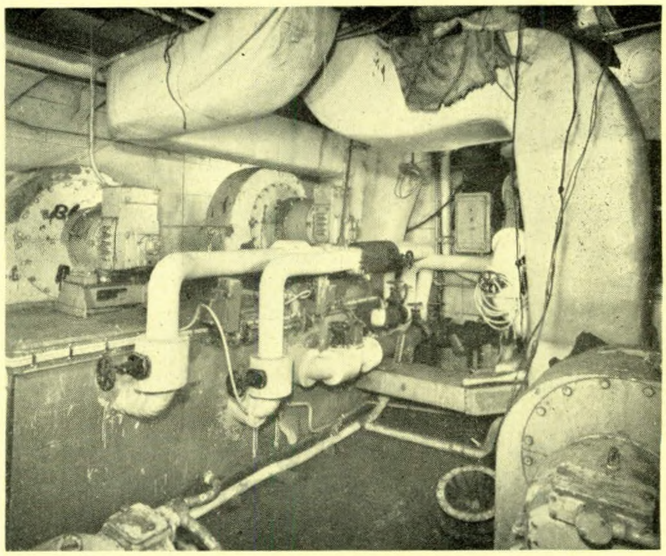


FIG. 20—*Unit room of a large passenger liner during the conversion to full air conditioning*

FIG. 19 (*left*)—*Self-contained unit for a.c. or d.c. electrical supply and of 12,000 B.t.u. per hr. capacity arranged in a ship's hospital*

Discussion

Mr. A. J. Sims, O.B.E., R.C.N.C. (Member I.Mar.E. and Member of Council I.N.A.), said that, having had the pleasure of discussing warship habitability and air conditioning problems with the authors for many years he appreciated the honour of opening the discussion. He proposed to direct his remarks to naval applications, although they had possibly been rather more sluggish than merchant shipping owners in the speed with which air conditioning had been adopted and applied.

In the middle of the last war there had been practically no applications of air conditioning in our warships; certainly very few, if magazine cooling arrangements were excluded. No one doubted the value of air conditioning, but equipment could be added to warships only if the balance of advantage over disadvantage was overwhelming. Air conditioning meant more weight, more space, more power, more congestion and more maintenance and less endurance on the same fuel, and its introduction had been held off until the arguments in its favour became very strong. The turning point came in the middle of the war, when our warships were steaming for prolonged periods under shut-down conditions, more and more heat producing equipment was being installed, crews were being increased, and the problem of the habitability of British ships when the theatre of war turned towards the Far East assumed increasing importance.

It became clear that ordinary ventilation had reached something like its maximum performance. The heat and humidity build-up of the outside air when entering the ship could be restricted, air movement could be increased and the quantity of air entering could be improved, and attention could be paid to the insulation of hot surfaces. But what else? The ambient air in some sea areas was near the threshold of comfort (as defined by the authors), which posed an impossible problem in making many warship spaces comfortable in the tropics under the severe operating conditions applying in those days. Thus it came about that in 1944 he became associated with a panel of Admiralty and industrial experts, who examined the possibilities of applying air conditioning in H.M. ships. The authors had been valued contributors to that panel, and he gladly paid tribute to the help received from them and many others in industry.

From that there emerged a "new look" in the application of air conditioning to our warships. Priority was given to important control compartments where the highest degree of mental alertness was essential if expensive and complex equipment was to be operated efficiently, and air conditioning had been applied to other spaces where the efficiency of work on board could be markedly increased as a result. It had also been extended to living spaces when practicable and essential. The total of installed air conditioning in warships since 1944 was now approaching the 100,000,000 B.t.u. per hr. mark, which, although perhaps not very much in terms of the big ship requirements to which Mr. Jones referred in his introduction, was nevertheless quite an effort in the present-day congested warships.

The question was not merely one of marginal comfort for the personnel concerned, but of giving conditions whereby the highest standard of fighting efficiency could be achieved. Despite advances in equipment, a ship was still only as efficient as her crew. Air conditioning had passed out of the "nice to have" category; it was indispensable in many compartments of modern warships, and its application would grow.

He had always felt that the concept of effective temperature referred to on pages 102 and 103 of the paper was ingenious, and praise was due to American workers in that field, and also to Dr. Bedford, for developing the relevant charts, which were of enormous use despite the qualifications which had to be introduced in applying them.

He was glad the authors had, on page 109, highlighted the practical design problems for marine applications. With the increase of complicated equipment being fitted to warships, the maintenance load requiring the services of skilled personnel was an acute problem, and it was of prime importance to reduce that load in all installations and equipment. The maintenance demand for air conditioning systems must be kept low. Only the simplest forms of control, for example, could be accepted in warship applications, which meant that a reasonable margin of variation of range in the resulting conditions must be accepted.

Naval experience had not shown that vacuum refrigeration plants required more or more careful maintenance than Arcton plants. The preference for Arcton plants was based on such factors as their requirements for less fuel, they could be available in harbour when boilers were shut down, they took up less weight and space—at present anyway—and they required less circulating water. Vacuum refrigeration plants, however, had attractive advantages, such as simplicity, general reliability and absence of refrigerant problems, and were therefore still being fitted in some ships in which steam would always be available, as, for example, depot ships.

The policy in Naval ships was to fit centralized plants of large capacity to avoid multiplicity of small units and excessive maintenance. Two or more such plants of a total capacity equal to the air conditioning load under the extreme specification requirements—not necessarily the extreme outside requirements—were usually provided, thus giving a necessary stand-by capacity. They aimed at Arcton reciprocating compressor plants for capacities up to about 3,000,000 B.t.u. per hr., and Arcton plants using centrifugal compressors for capacities of 3,000,000 B.t.u. per hr. or above.

A paper on the subject under discussion given by the present authors would be expected to be full of valuable information and of great use to workers in this field, and he was sure that expectation had been completely fulfilled.

Mr. E. G. Russell Roberts (Member I.Mar.E. and Associate I.N.A.) said that as an addition to the historical notes given in the most interesting paper under discussion, in the last few days he had come across an extract from the periodical *The Siren* of 2nd February 1900. It was of interest, not only in that it gave an instance of comfort cooling in ships earlier than those mentioned in the paper, but also because it showed that British shipowners were probably first in the field with this amenity for their passengers. It read:

> "From a recent paragraph sent round the Press about the cooling of state-rooms on board some new ships of the North German Lloyd Company, it might appear that the German company have been more enterprising in this

matter than our British shipowners. But this is not the case. It seems that so far from the North German Lloyd Company being the first to have their state-rooms cooled by means of refrigerating machinery, the Union Steamship Company's s.s. *Norman* was fitted some four years ago with appliances for reducing the temperature in the library and music room by J. and E. Hall, Ltd. This was much appreciated by the passengers, who flocked into the spaces so cooled at every available opportunity. Needless to say, their comfort during the passage through the tropics was greatly enhanced by this cooling process."

Unfortunately, no records of this plant had been traced.

In the section on physiological considerations mention seemed to have been omitted of one of the most important ways in which the human body got rid of its heat, namely by exhalation from the lungs.

Commenting on the authors' reference to materials used in brine systems, he said their remarks could be interpreted to imply that special metals were necessary when brine circulation was used but not with water circulation. There was, in fact, no need to use any special materials with a properly designed closed brine system. For several decades that type of brine system had been fitted in innumerable large marine installations with practically all normal metals indiscriminately mixed up in the systems, and without troubles resulting. A standard brine system would probably have cast iron for valve and pump bodies, mild steel or stainless steel for pump spindles, gun metal or phosphor bronze brine pump impellers with gun metal wearing rings, brass fittings in the stop valves, mild steel tubing and thermometer pockets and copper lengths for the large bore brine mains where bends or sets were too sharp for mild steel, and an assortment of other fittings, having for example tinning on distance thermometer pockets, and possibly white metal bushes in pumps—practically all the usual metals used in a ship.

Enlarging on the subject of the heat pump, he added that a few had been fitted in ships and a considerable number on land, but there were certain essential limiting features which ought to be borne in mind when considering such installations. In the first instance, it should be made clear that the heat pump was a perfectly straightforward refrigerating plant. All refrigerating plants were heat pumps, for whatever purpose they might be installed, whether air conditioning, deep freeze or anything else. They extracted heat from a low temperature source and discharged it to another medium at a higher temperature. A heat pump therefore, was, merely a refrigerating plant in which use was made of the higher temperature heat obtainable from the high temperature side of the equipment in lieu of, or in some cases in addition to, the heat extracted from the low temperature side.

Used purely as a heating medium, the heat pump was not a commercial proposition due to the high capital cost involved. It could be a proposition if all or most of the capital cost must in any case be incurred, such as, for instance, by utilizing equipment already fitted in the vessel for air conditioning, which the authors obviously had in mind. A combined air conditioning plant and heat pump, therefore, would extract heat in the summer from the ship and discharge it to the surrounding sea water, and in winter cool the surrounding sea water, discharging the heat extracted therefrom at a higher temperature into the vessel in order to heat it up.

Arising from that, it was clear that if such an installation was to function, the surrounding sea water from which the heat had to be extracted must be at a temperature which would permit of its being further cooled. In practice that meant that the medium to be cooled must be at a temperature of about 40 deg. F. Any lower temperature would involve heat exchangers of tremendous size to avoid possible danger of freezing sea water being circulated through them. That did not necessarily limit its use only in waters above 40 deg. F. Much waste heat from a ship was pumped overboard. It was quite feasible—and had in fact been done—to heat the sea water inlet to the evaporator of a heat pump by utilizing the water discharged from Diesel generator jacket cooling systems. Other suitable sources of low grade heat would be, say, steam condenser or lubricating oil cooler discharges.

Equally, if an air conditioning plant was to be used as a heat pump without incurring considerable additional cost, it must be possible to use it without major alteration to meet the heating demand. In practice, that meant placing a considerable limitation on the temperature at which the heating medium would leave the plant, which would be at or around 105 deg. F. to 110 deg. F., i.e. at a much lower temperature than that at which hot water would be circulated when used for heating purposes, and of course than that of steam.

As regards the possible application of the heat pump to the basic types of air conditioning plant mentioned in the paper, a heat pump was perfectly feasible with a central station plant as shown in Fig. 8. It could also be applied to the unit system served from a central plant, as illustrated in Fig. 11. The pipe and fin surfaces in the air conditioning units normally required for marine purposes were large, because they were designed for low temperature differences, and were in the majority of cases quite ample for heating the ship with the fairly low temperature heating medium obtainable from a heat pump. Furthermore, the pipe system was so arranged that only one circulating medium was required at a time, which would be either hot or cold depending on climatic conditions. It would be quite another matter to adapt the heat pump to either the reheat system shown in Fig. 9 or the twin duct system illustrated in Fig. 10. With either of those two systems, twin pipe systems would have to be arranged throughout the ship to supply simultaneously both hot and cold brine or water, and owing to the relatively low temperature of the warm water those for the latter would need to be of considerable size, and certainly much larger than the steam pipes usually associated with systems of that type. It was already usually a matter of the greatest difficulty to accommodate the insulated chilled water or chilled brine mains associated with the large air conditioning plants fitted nowadays in ships, and the thought of duplicating the system to provide also the warm brine or water to each air conditioning unit was likely to be fraught with very great difficulties.

The control of such a system was also liable to be rather tricky. Each refrigerating machine would clearly have to have an additional heat exchanger. Since, however, the cooling and heating demands in the ship were very seldom likely to be in balance, the excess heat on whichever side had a surplus would have to be either taken from or rejected to the surrounding sea. The additional unit would therefore be sea water circulated, and so arranged as to work either as a condenser or an evaporator, which would be something of a headache for the operating personnel.

It was impossible to generalize on the type of ship in which a heat pump application might be a more attractive proposition than one of the more normal heating systems at present employed. A good deal of calculation work was carried out in connexion with the large heat pump installation fitted in s.s. *Southern Cross*—which no doubt the authors would remember vividly. The results could be summarized very briefly. A large air conditioning plant suitable for use as a heat pump was in any case to be fitted, thus limiting capital cost. To provide the maximal estimated heating demand it was calculated that approximately 7·25 tons of boiler oil would be required daily if the heating were carried out by direct steam working with the usual type of calorifier. As steam had not been available, the original intention in this vessel was to heat the ship electrically by power supplied from Diesel generators. To meet the anticipated maximal heating demand would have required approximately 15·6 tons of Diesel oil daily. Finally, the refrigerating plant had been electrically driven with power supplied from Diesel generators. The maximal calculated daily consumption for the complete refrigerating plant working at peak heating load was 4·78 tons of Diesel oil per day. He had not heard whether the figure was checked in service. On the other hand, had the vessel been fitted with turbogenerators supplying the current for driving the heat pump, the fuel consumption would have risen to about 8·7 tons per day; in other words, a greater consumption than would have resulted from heating the ship by direct steam.

In brief, it would seem as if the economic application of the heat pump was likely to be limited to vessels in which steam was not available for heating, and even so it was unlikely to be a proposition in cases where a reheat or twin duct air conditioning system was employed. He could think of only two reasonably large marine plants which had been fitted in ships in that category.

At the moment, no major saving in power consumption of air conditioning plants could be foreseen. The average overall volumetric efficiency of reasonably large refrigerating compressors, whether centrifugal or piston, operating under air conditioning conditions was probably of the order of 85 per cent, so there was not much scope there. Heat exchangers were already about as large as could conveniently be accommodated in ships, so that further improvement by reducing the temperature differences and obtaining more output from the refrigerating machines was not likely to be of a very large order. It was possible that in the next few years there would be produced a new refrigerant which would give greater output per B.t.u. than any of the existing refrigerants, but even so it would be some years before it was widely available all over the world, and he could see no immediate prospect of any major improvement.

Captain H. M. Rome said that, having studied the paper very closely, there were one or two very practical points he wished to mention, the first being the question of insulation, and the importance of erecting pre-insulated ducting in certain areas. By reason of piping, other ducting and close fitting trunking, it had to be studied more carefully, because the insulation could not be carried out efficiently on the ducting *in situ,* particularly in congested areas behind the overheads and panellings, where warm air could be trapped with consequent condensation. Apart from the problem of condensation there was also loss of efficiency consequent upon inefficient insulation, and the greatest danger occurred where air conditioning ducting passed through a normally ventilated space.

Under such conditions the slightest crack in the insulation film or seal would result in fairly heavy condensation. That, of course, occurred particularly when passing through the tropics with high humidity and high temperature. He did not know whether all superintendents and naval architects were fully conversant with the problem, but more supervision should be given to insulation in the initial stages.

Lack of efficient insulation involved the shipbuilder and shipowner having at a later date to face removals and possible delays and expense. Of course, in a fully air conditioned vessel those problems would be largely overcome, but there was still the possibility of limited condensation behind panelling. For instance, in a ship warmed through in a cold climate but later passing into the tropics—perhaps going from New York to Panama in winter—there was a danger of warm air being trapped in the overheads, and when changing over to cooled air there was, with inefficient insulation, a possibility of condensation forming in areas behind the panelling, which over a period could and would result in rusting of the trunking and further deterioration. He looked forward to the time when pre-insulated ducting was sufficiently advanced so that the problems associated with condensation would be largely obviated.

As regards air conditioned unit rooms, he agreed wholeheartedly that further detailed preplanning of the space was needed in order to achieve a happy mean between the working requirements and space requirements—in other words, earning capacity.

One should bear in mind the necessity of having a reasonably airtight unit room otherwise there would be a considerable amount of dust laden air coming through ill-fitting doors and crevices, even keyholes, thus bypassing the filters. This was brought to his attention in the *Southern Cross,* where the areas of deckhead panelling round certain distributors became extremely dirty. It had been discovered that a steward, when sweeping out the alleyway every day, had opened the door of the air conditioning unit room in order to get a nice draught of air down the alleyway, with the result that the dust went into the unit room, bypassing the filters, and out through the distributors.

It was well known that the condensate from the units might be considerable in amount. In present-day large passenger ships, in which ballasting was a necessary evil, it was a blessing in disguise to obtain a large amount of condensate, which might amount to 60 tons, and in large fully air conditioned passenger ships as much as 100 tons per day. In this respect, he stressed that the arrangement of piping from the units required considerably more care and thought than had been given to it hitherto, because a lot could be done in that direction.

Mr. B. Hickmott said that he had read the paper with considerable interest, and he was certain the authors would not feel some of his remarks were intended to be over-critical; he wished only to express, and possibly encourage others to see that there were other points of view.

The passage on page 101 that "The stage has now been reached where to build a tropical going ship without full air conditioning would mean that she would be out of date before she makes her maiden voyage", could not be overstressed. That was not merely a plea from air conditioning engineers or companies but was something for which pressure built up, not only as each new ship was air conditioned, but also from officers' and crews' associations because they did not like transferring from an air conditioned ship to one with no air conditioning. That was a serious warning that the problem could not be sidestepped but must be dealt with immediately.

It was most important to maintain a minimum differential temperature between the outside and inside of the vessel—a problem referred to at length by the authors—and much harm had been done immediately after the last war when many people were convinced that the minimum differentials given in the paper were not acceptable, so that a 15 deg. F. to 20 deg. F. temperature differential was specified and then surprise was expressed at the cost of such an installation. The figures indicated in Table III were adequate for most circumstances, and in the past he himself had said that 5 deg. F. to 10 deg. F. below ambient was adequate provided the relative humidity of 50 per cent to 60 per cent was maintained.

Reference was made in the paper to effective temperature and the care with which this must be interpreted. This was a matter in which a little learning could be a dangerous thing. In deciding what temperature was satisfactory, consideration must be given to the personalities, and possibly the way of life, involved; one could never arrive at an exact effective temperature. For example, their wives were already tired of winter; they were sitting at home, looking at magazines, waiting and hoping for hot days so that they could wear the minimum of clothes. Was that to be taken from them by switching to too low an effective temperature? And what of the woman who loved to complain of the little draught on the back of her neck in order to justify the mink stole her husband would have to buy her? One of the pleasures of living was change and individuality in clothes and their thickness.

He expressed surprise at the figures used in Table I for the sensible and latent heat for calculating B.t.u. loading. His experience had shown that for sensible heat it was essential to use a figure of at least 220 B.t.u. per person and for latent heat at least 280 B.t.u., and therefore the figures in the paper for latent heat were on the low side.

Referring to Fig. 5, he was not at all happy about the curve for exterior effective temperature being shown. Although the intention was to convey a comparison, from the air conditioning engineer's point of view there was no such thing as an exterior effective temperature. He could not see how air movement and other factors which must go into the production of such a chart could be related, unless it was being used merely for comparison purposes.

On page 108 there was reference to high velocity, and full endorsement must be given to the fact that the air conditioning engineer was always trying to increase velocities to get trunk sizes down. The pressure on engineers to reduce trunk sizes would result in reducing the volume of circulated air, with the secondary effect of reducing the off coil temperature and the temperature in the trunk, which would make a lovely condition for the sweating of ducts. They were dependent upon the work of the insulating contractor, and presumably they had to "wear" the normal divergences of workmen nowadays, and they could at least be helped by an effort made to keep internal temperatures as high as possible.

While greater use of thermostatic controls ought to be encouraged, care must be taken about the lengths to which this development was carried. The engineer and the superintendent might feel that by having a thermostatic control in each cabin there would be no further complaints, but experience on Transatlantic liners showed that it produced a community of knob-twiddling passengers. A passenger did not necessarily spend a long time in his cabin; he would set the thermostat to a temperature in which he would be happy, then be called into the next cabin for a drink, return to find his cabin too cold or too hot and start twiddling the knob again. Serious thought should be given to the fact that there was a stage at which there could be over-control.

Establishing close liaison between air conditioning engineer, naval architects, and others could not be too highly stressed. The sooner they could be brought in for consultation the better in every way, including the matter of keeping down costs.

He had naturally been intrigued with the photographs of the conversion unit, as he believed his own company pioneered them in 1953. The conversion unit was a reasonable answer to the problem which had to be faced by shipowners of vessels built post-war but not fitted with air conditioning. As tonnage had to be brought up to date the conversion deck unit was, undoubtedly, a fine solution to the problem.

The accent of the paper was on the need for air conditioning, with perhaps a little thought on ambient conditions. As Mr. Sims rightly said with reference to naval craft—which applied equally to the modern type of construction—the more one crowded into ships, the bigger the engine horse power and the more the electrical load, the greater the need for air conditioning, irrespective of ambient conditions.

The old Ministry of Transport regulations presented a problem and gave rise to confusion. They had been prepared, no doubt very wisely at the time, when air conditioning was not accepted, and they were long overdue for revision.

Commander M. B. F. Ranken, R.N.(ret.) (Member I.Mar.E. and Associate Member I.N.A.) said that with the enormous and rapid increases which had been and were taking place in the field of air conditioning it was useful to have so clear a paper setting out again the elementary principles, and also the numerous practical difficulties. It was to be hoped that the paper would be widely read by the seagoing engineers concerned in the efficient running of the plants, as well as by those responsible for their design and installation. Practical training in air conditioning was very desirable if the best results were to be achieved at sea.

In a new ship, where the air conditioning plant was built into it in the earliest stages of its design, many of the current difficulties were eliminated, and the operation, maintenance and reliability were correspondingly improved. However, a corollary of that was that the plant must be absolutely reliable, as if the plant broke down only a minute amount of fresh air could be supplied compared with older ventilation systems, and one was therefore worse off than before.

It was considered to be essential to make modern air treatment units completely automatic and to provide individual control of cabin accommodation. Automatic humidification during the heating cycle was also important. He well remembered the complaint of the officers in the survey vessel H.M.S. *Vidal* that their wine bills had risen considerably while the plant was on its heating cycle! That was a result of the low relative humidity produced on the heating cycle due to no provision whatever having been made in the early stages for humidification.

Whether automatic control of the refrigerating machinery was necessary depended on its size and situation. Obviously, small self-contained machines were better automatic, but modern ships had air conditioning plants taking as much as 2,000 b.h.p. to drive them, and it was generally undesirable to start or stop large machines automatically, though they should be provided with predominantly automatic capacity controls and safety devices.

There was a great deal to be said for centralizing the air conditioning machinery of large ships in one place, as that greatly simplified its control, maintenance and supervision. Also it kept all the refrigerating machinery and its valuable refrigerant in a small area, which eliminated many of the difficulties associated with leak detection, quite apart from the reduction in refrigerant charge and in the number of refrigerant controls which generally resulted. In a number of cases the plant might be partly shared with the ship's domestic and/or cargo refrigerating plant. Clearly, in such cases it was virtually essential to have all the equipment in one compartment.

The effects of heat losses and pressure drop in long pipe lines were much more important in direct expansion than in brine systems, and any means of reducing their effect, such as pump circulation or liquid undercooling, would inevitably increase the power required; larger pipe sizes were obviously undesirable. Direct expansion plants were also difficult to control on light loads.

Brine systems, on the other hand, were easy to control and maintain, and they did not require so much specialized knowledge of refrigeration. Brine mains were admittedly of large diameter, but in a new vessel the larger mains could be led through machinery spaces, e.g. along the keel in the *Oriana,* and only the relatively smaller mains had to be taken through the accommodation. There was no objection to using relatively higher pressures to reduce pipe sizes, provided the pump powers were not allowed to become excessive. Heat losses from the smaller brine pipes were not so great as would occur with direct expansion pipe systems of the same cooling capacity.

Very low figures were given in the paper for brine cooled and direct expansion plants relating refrigerating capacity to compressor b.h.p. They should read about 10,000 and over 12,000 B.t.u. per compressor b.h.p. respectively. However, it would probably be more realistic to compare the refrigerating capacity with the total absorbed b.h.p. of the compressors and pumps, in which case the figures would be approximately 8,600 and 11,300 B.t.u. per total b.h.p. respectively. The figures for direct expansion plants did not, however, take into account the effects of pressure drop in long pipe lines on their actual operation, which might be expected to reduce the output to around 10,500 B.t.u. per compressor b.h.p., or 9,600 B.t.u. per total b.h.p. In a poor or congested layout these figures might well be lower. The figures did not vary much with the size of the plant, but obviously for small plants it was often simpler and preferable to use direct expansion systems, more than two or three air coolers in parallel being avoided unless they could be sited close together.

The insulation of all cold pipes and air ducts passing through the ship was of great importance, and it must be properly vapour sealed. Moulds, and even small ferns and other plants, had been found growing out of insulation in some ships.

A point which should be emphasized was the desirability of using brine and not chilled water. All air conditioning plants required temperatures only a little above freezing point, and in some cases it would be desirable to run with primary refrigerant temperatures even below that. At reduced output there was then a danger of cooling chilled water below freezing point, and it was thus necessary to fit quite expensive controls and safety devices to prevent it. Brine, on the other hand, was quite safe down to very low temperatures; it could readily be prevented from going acid and it presented no great difficulty in mixing or in keeping clean. Brine was, of course, essential where domestic or cargo plants, which called for temperatures below 32 deg. F., were cross-connected to the air conditioning equipment. Moreover, the use of brine or some other non-freezing secondary refrigerant avoided any possibility of air coolers freezing up in cold weather when they were not in use.

Mention had already been made of the large size and horse power of the air conditioning plants in modern ships, requiring as they did over 100 b.h.p. per million B.t.u. per hr., quite apart from fan power. In ships which had been converted, over 1,200 b.h.p. had been fitted in some cases, and new ships such as the *Oriana* and the *Canberra* would have plants absorbing some 2,200 b.h.p. To drive these large auxiliaries had become a considerable problem, as electric motors involved large electric generators, while steam drives required additional boiler power or even reduced main engine speed in extreme cases. So far, only reciprocating compressors had been fitted in British ships, and a number of them were now to be driven in certain passenger ship conversions by small geared steam turbines. The *Oriana* and the *Canberra* would each have four two-stage centrifugal compressors direct coupled to 550 b.h.p. steam turbines. The stage had now been reached when it was a major problem to keep the condensers and evaporators down to a manageable size, and work was in hand to find ways of reducing their size for a given output. Such large machinery was inevitably heavy as well as bulky, and it was therefore desirable to fit it low in the ship, which facilitated keeping the fore and aft brine mains below the accommodation decks.

Reference was made in the paper to vacuum refrigeration plants. Following their development about 1909-10 a number had been fitted in merchant ships between and since the wars, and many were introduced during World War II (as Mr. Sims had described) for air conditioning aircraft carriers and battleships, where they were undoubtedly the right choice at the time, as they were comparatively compact for large outputs and could be operated and maintained by anyone familiar with ordinary steam machinery. However, they were prodigal of steam consumption compared with the efficient and compact conventional refrigerating plant which was now readily available, and it therefore seemed unlikely that any more would be fitted afloat, except in times of emergency or for some special application.

MR. W. MCCLIMONT, B.Sc. (Member I.Mar.E.) recalled that it was a number of years ago that he first collaborated with Mr. MacVicar in investigations into environmental conditions in passenger ships, and that he had also had the pleasure of many consultations with Mr. W. H. Glass and Mr. MacVicar on the subject. Although frequently they had not seen eye to eye, he thought they nevertheless remained friendly. However, he would be less than frank if he did not express some disappointment with parts of the paper.

Physiological considerations and design conditions were subjects to which he had given a lot of attention, and on reading the authors' sections on those matters he found it rather heavy going; therefore it seemed to him that to anyone uninitiated in those matters those sections were not likely to be very clear or helpful. The trouble arose, he thought, from condensation—of matter, not moisture! He had in mind particularly Fig. 1, which Mr. Jones elaborated a little in his introduction, but there were other points which might be looked at more closely.

Mention had been made of applications in which only a limited number of the spaces were air conditioned, but that was a poor arrangement in economy compared with complete air conditioning. When only some spaces were air conditioned there was the maximum of leakage, and tests conducted a few years ago had indicated that it was a problem not so much of heat leakage between the conditioned and unconditioned spaces as of moisture leakage. It was surprising how quickly and easily moisture would diffuse from one space to another even when there was no air flow and very little heat flow. The moral to be drawn from those tests was that complete air conditioning was always very much the advantageous arrangement.

It might, he continued, be of interest to observe that the 400 B.t.u. per hr. given for the quantity of heat to be dissipated from the body was the value applicable to people undertaking a light sedentary occupation; for someone resting in bed the value fell to about 270 B.t.u. per hr., and for someone doing moderately hard work a figure of 600 B.t.u. per hr. was applicable; hard work produced a value of about 850 B.t.u. per hr., and extremely hard work a little over 1,500 B.t.u. per hr. Contrary to popular belief, mental work had little effect on heat production, even though such work was prolonged and severe. As a matter of interest, each person sitting in the hall was producing heat at a rate of 360-380 B.t.u. per hr., depending to a considerable extent on what they had eaten, and possibly even more on what they had drunk, during the day.

The effective temperature scale shown in Fig. 2 was what was known as the normal chart and related to people wearing the light clothing normal to United States summers. There was another chart, known as the "basic" chart, which was compiled for people stripped to the waist, used very much for calculations in Naval vessels. Some eyebrows had been raised when he had suggested in a paper a number of years ago that many women passengers wore clothing at social functions in the evenings which made the use of the basic scale more appropriate! However, he repeated the suggestion in all seriousness for the authors' benefit. In an investigation a few years ago it had been observed that, with inside values of effective temperature 7 deg. F. lower than the outside temperature, ladies in evening dress felt the difference very sharply as they entered the dining saloon, and it was only towards the end of the meal that they appeared to become acclimatized, which rather underlined the need to limit the change from outside to inside temperature.

More than one reference had been made to 98·4 deg. F. as the body temperature, but it was to be observed that that was the mouth temperature in man; in the deeper tissues of the body the temperature was about 99 deg. F., while the general skin temperature of a man feeling comfortable was about 91-92 deg. F.

The authors' observations on the requirements of passengers on Transatlantic liners were in keeping with some which he had made a few years ago. During winter Atlantic crossings it had been found that the most desirable conditions were an effective temperature of 63 deg. F. for Britons and 71 deg. F. for Americans. There was also, in general, a discrepancy of as much as 3 deg. F. between the requirements of American males and American females. That again underlined the remarks made earlier about the difficulty of converting what was really an art into a science. However, it had been noted that in artificially heated rooms humidities might range from 25 per cent to 70 per cent without much variation in standards of comfort, although the most desirable relative humidity was probably 55 per cent.

With temperatures in the 65-70 deg. F. region there was no real discomfort with humidities as low as 25 per cent. When the humidity got lower than that—say below 20 per cent—there was a distinct drying of the membranes at the back of the throat, but there was no evidence that that was undesirable. (In fact, there was quite a lot of evidence from seagoing engineers that it was extremely desirable!) Indeed, it might be said that some drying of that sort occurred under conditions which were generally considered quite comfortable and pleasant. Out of doors in cold, or even cool, weather one inhaled air with a moisture content well below that necessary to prevent such drying, yet one might find the conditions exhilarating. He emphatically expressed the opinion that no artificial humidification was desirable in occupied spaces in ships.

He was not altogether happy at the definition of 78 deg. F. effective temperature as the upper threshold of comfort. While it was true that 78 deg. F. effective temperature was on the threshold of sweating for lightly clad people in living accommodation, he suggested that discomfort arose at lower conditions than that and that the upper limit for reasonable comfort should be set at an effective temperature of 74 deg. F. Although Mr. Glass had disagreed with him when he had said this some years ago, he still held to that view. He noted with interest that the authors stated that experience had shown that figures of 74 deg. F. effective temperature or better were normally maintained.

It was necessary, he thought, to stress that the figure of 77-78 deg. F. effective temperature proposed by the authors for design purposes was not quite what it appeared, and that it was really only a means of determining the effective temperature drop for which a plant should be designed. He would prefer to see them go about it in a different way, namely by using a design figure for maximum inside conditions of 74 deg. F. effective temperature and adjusting the outside values in Table III to allow for the "flywheel" effect of the structure. To adjust Table III, one could reasonably take not only the maximum outside conditions experienced but also the minimum outside condition experienced within 24 hours of the maximum—the daily cycle; the outside condition for design purposes could then be taken as the mean of those two values, which he thought would cope with the cycling effect. Having looked at the figures, he did not think that would make much difference to the actual design load in the authors' suggested examples in Table III, but he put it forward as a more logical basis, and one more suitable for extension to other parts of the world. Undoubtedly the time had arrived when some standardization of design conditions might be a good thing.

The authors suggested that the large quantities of condensate from the air conditioning coolers might be put to use as cooled drinking water after suitable treatment. If any measure of recirculation were employed on such an installation, that proposal was completely impracticable. The removal of the noxious elements of sweat, particularly if combined with the products of French perfumiers, was an impossible task.

Correspondence

MR. G. LAING (Associate Member I.Mar.E.) commented that the paper referred briefly to the need for insulation on ducting and steelwork and this point had been raised by several contributors to the discussion. Although insulation was supposed to be complementary to any system involving the flow of heat the remarks made about the insulation industry were generally not complimentary. Reference had been made to the fact that the method of fitting insulation on ducting left much to be desired, leading to (1) dissipation of heat at the wrong place, or (2) formation of condensation. There were two general conclusions which followed from this, the first rather obvious, the second not quite so obvious.

1) The work must be executed under a high degree of supervision.
2) The main criterion for deciding on the suitability of an insulation material or specification should be its ability to be fitted properly. In other words, the technical characteristics should be of minor importance and the practical characteristics of major importance.

Unfortunately, in the majority of cases the insulation specification was not decided by the person responsible for fitting it, which fact not only created difficulties pointed out in the discussion, but also produced a large proportion of the unprintable language in a shipyard, when the specification ultimately filtered through to the operative on the ship. It was assumed that the ventilation contractors or others were in a position to advise the insulation contractor on materials but the insulation contractor had hardly the temerity to advise the ventilation expert, for example, that his fans were not the correct size. What the insulation contractor could do, however, was to tell the ventilation contractor and shipbuilder that it was impossible to vapour seal a duct which was fitted hard against the deckhead beams or was a force fit through a divisional bulkhead, to mention only two of the many hazards with which the insulation contractor was faced.

Turning from the defence of insulation, there were several queries arising from the paper. It was said that the likelihood of condensation and therefore the need for insulation became less as the ship became fully air conditioned. This assumed that the condition of the air inside the trunk was exactly similar to the air surrounding the trunk. Was this not rather an ideal and temporary situation?

It was mentioned that insulation was required on the outer skin of the ship, presumably to reduce the refrigeration load. What was the authors' opinion of the necessity of vapour sealing on such areas? Surely it was not required during the cooling period, but was it required during the heating period? Insulation was regularly fitted on the deckhead of crews' accommodation in lieu of wood decking, but the relevant M.O.T. regulation did not request the fitting of a vapour seal and to the writer's knowledge it was never fitted in such cases. If one considered the heating design conditions in Table II of the paper, i.e. 70 deg. F. internal and 0 deg. F. external, in conjunction with the statement that "it may be necessary to add moisture to increase the humidity within the space", it was obvious that the theoretical conditions leading to moisture migration, and, in this specific example, ice formation on the shell were present. The absence of complaints would appear to indicate that this phenomenon did not arise in practice and it would be helpful if the authors' experience could throw some light on this matter.

Referring to coefficients of heat transmission shown in Tables I and II, it would be interesting to know if such coefficients were calculated or experimental values. The question was prompted by noting that insulation fitted on ships' sides could vary from 1in. to 3in. thick with or without insulation round the frames and the writer was interested to know if the same coefficient was used for all the differing specifications. It was also noted from Table I that the temperature difference for the bulkhead against engine casing was 50 deg. F. This suggested that the engine room temperature was taken as 132 deg. F., which was much higher than the graph of maximum recorded temperature (Fig. 4) indicated.

MR. G. R. PRINGLE (Associate Member I.Mar.E) remarked that the authors had dealt with some of the problems confronting the naval architect and marine engineer and it was in connexion with this aspect of the paper and the recent installation of three units, of the type shown in Fig. 14, in a 26,000-ton dwt. tanker, that he wished to give certain details which might be of interest.

One conversion unit was installed in each of the three heating and ventilating circuits already in the ship, by the same manufacturer. One circuit was amidship and the other two port and starboard aft. From installations in other tankers it was not considered that the noise transmitted through the trunking would cause discomfort, but the vibrations from the compressor were transferred to the steel work of the accommodation and could cause annoyance to the occupiers of the cabins under the units. Accordingly, each conversion set was mounted on vibration mountings and the associated trunking and pipework provided with flexible sections.

Neither individual nor block reheat was considered practicable in this installation, but the existing heater units were not disturbed and were still available when required.

The problem of providing over 70 kW to operate the conversion sets and cooling water pump was overcome by using a water cooled alternator in place of the air cooled type previously fitted, the space requirements being similar. It should be mentioned here that the existing alternators were on peak load and the opportunity was taken of increasing the units by more than 70 kW required for the air conditioning.

The turbine and gearing of the original sets were both capable of a 25 per cent overload and the only modification needed was to enlarge the steam nozzles to allow the turbine to develop the required power without the use of the overload bypass. The sets, as modified, were capable of meeting the 10 per cent overload.

Nine thousand gallons of cooling water per hour were required by each conversion unit and a new pump had to be installed to meet this. It was necessary to supply the amidships unit with water from aft as there was no non-cargo space amidships available for the siting of sea chests or pumps. Steps had to be taken to ensure that the midship unit, which was 300 feet forward and 7ft. 6in. higher than the aft units, got its share of cooling water. After careful sizing of the pipes, lockable gate valves were installed adjacent to the units to enable the engineers attending the plant to make any adjustments necessary.

Three of the problems encountered had been mentioned, and of course there were others, but from reports to date it appeared that the installation had been a success and was much appreciated by the crew.

He would like to ask the authors if they had considered the minimum quantity at which it was economic to install plant to deal with the condensate. In the installation just mentioned it was not considered economic but further information on this point would be appreciated.

Authors' Reply

The authors thanked Mr. Sims for his kind remarks which, as always, were most diplomatically phrased.

Mr. Sims referred to the rather more sluggish approach to air conditioning made by the Admiralty as compared with merchant shipping owners but it was only fair to emphasize that a great deal of the technique which had been adopted and applied to the Merchant Navy resulted from valuable ground work covered by the Admiralty during the war. It was true that in the Navy more accurate forms of control could not be applied due to the need for absolute simplicity in the form of control.

Mr. Russell Roberts had corrected the authors on a historical point and the authors commented that Mr. Russell Roberts could invariably be depended upon to correct something in a paper. Fortunately, however, he had chosen a historical rather than a technological point. With reference to his remarks on the materials used in a brine system, it was perhaps correct to point out that frequently owners specified the use of cupro-nickel for the heat exchangers when brine was used. The paper had merely stated that cupro-nickel might be used, whereas on chilled water systems copper was invariably used. It was perfectly true that there were many installations which had given valuable service over a number of years in which many different materials had been used indiscriminately within the system, and no troubles had resulted. Mr. Russell Roberts's remarks on the heat pump had been very interesting. Probably the most notable example of this application was that in the *Southern Cross* where not only were the full heating requirements readily obtained but maximum control of the heating medium was also readily available.

Captain Rome had confined himself to practical points relating to insulation and since his remarks were based on most intimate experience of the difficulties which could be encountered where insulation had been incorrectly applied, his comments were worthy of considerable study. The suggestion that he had suffered considerably from problems associated with inferior insulation were undoubtedly true, but in view of his position one could rest assured that those responsible for the troubles had suffered even more, and rightly so. The average insulation would do everything the makers and contractors claimed it would do but unfortunately difficulties associated with access to fitting, etc., and possibly slipshod methods adopted by the contractor's men, frequently mitigated against the best of jobs being obtained. It was essential that the closest supervision should be given to the insulation of duct work, etc., through which cold air was passing.

Mr. Hickmott stressed that there were different points of view regarding air conditioning but naturally since the question of personal comfort was the main criterion of the efficacy of any system, human reactions must necessarily be taken into consideration. He stressed how important it was to maintain a minimum differential between the outside and inside of a vessel and a considerable amount of work had already been done with a view to establishing a basis for this somewhat thorny problem. Unfortunately, if, during the design stage, temperature drop inconsistent with comfort had been decided upon, then the person travelling on the ship who made the complaint was almost invariably much more important from the owners' point of view than the person who made the original decision.

Mr. Hickmott's concern over the effect on ladies of a relatively high differential in temperature had been met by Mr. McClimont's reference to naval practice and the use of the basic temperature chart. It was difficult to appreciate Mr. Hickmott's rejection of the use of effective temperature for external purposes, particularly when the chart had been prepared to show the difference, showing one basic measurement between the outside and inside. From that point of view the authors had thought it was quite in order to use it. Assuredly the members of the Ministry present at the meeting would pay court to the plea for an improvement in the Ministry of Transport Regulations regarding ventilation and indeed provide a new code of Regulations covering air conditioning alone.

Commander Ranken, in referring to the use of the heat pump on the survey vessel H.M.S. *Vidal,* had made particular reference to the question of low humidities during the heating cycle. This, presumably, occurred when the vessel was operating with very low ambient temperatures when the moisture content of the outside air was also extremely low. In this ship no steam was available to permit easy humidification of the air and this could only have been achieved by the introduction of somewhat cumbersome evaporating equipment involving the use of immersion heaters. There was no real problem in adopting this arrangement, but naturally in the *Vidal* lack of space was a very severe handicap when the question of additional equipment arose and the question of humidification could not be taken into consideration. Commander Ranken had discovered that with a low humidity during the winter his consumption of liquor went up, but the authors would suggest that no naval officer had previously been heard to complain when his potential capacity for absorbing wine, etc., was increased.

Mr. McClimont, as befitted one with his extremely wide experience, had presented some points of view which were of extreme interest. It was also interesting to note that during the heating cycle Mr. McClimont would be quite happy with a 25—75 per cent relative humidity, provided of course that the associated temperature was correct. Undoubtedly this state of affairs occurred in North American houses when, with the very low outside temperatures prevailing, there were bound to be extremely dry conditions inside.

In connexion with his reference to the effective temperature to be maintained within a conditioned space, and particularly his suggestion that 74 deg. F. effective temperature would be more logical than 78 deg. F., there could be no argument that 78 deg. F. effective temperature was merely the threshold of comfort, but when this was associated with the maximum design conditions likely to be encountered, then it was surely comforting to know that when such extremes were met the plant would be capable of maintaining even the threshold of comfort. Any other method of presenting the problem on the basis of merely indicating the drop in effective temperature between outside and inside would mean that purely hypothetical figures were being considered and no true basic established. It was felt, therefore, that the method of presenting a threshold of comfort and a maximum design condition was much more readily understood, provided it was also appreciated that when extreme conditions were not encountered, then even more comfortable temperatures within the vessel were possible.

Reverting to Mr. McClimont's very pertinent remark that air conditioning only a few spaces on the ship was not good economy, there could be no gainsaying this point of view since some examples existed of vessels with air conditioned public rooms and cabins which were merely ventilated, the resultant effect being that the good conditions within the public rooms merely exaggerated the discomfort within the cabins.

Mr. Laing had referred to the not very complimentary remarks made on the subject of insulation and it must be conceded that, at times, the work of the insulation contractor was made much more difficult for him than it ought to be. It was true, however, that where close consultation and collaboration took place between the insulation contractors, the shipbuilders and the ventilation contractor, many of the difficulties which had been enumerated could be overcome.

The problem of insulating a duct which was fitted hard against bulkhead beams was, of course, only too common, as also was the case where a duct was fitted too tightly through the opening in a divisional bulkhead, but in these cases the difficulties could be overcome provided each understood the other's difficulty and steps were taken to consult together and collaborate.

With regard to the question of condensation and the elimination of insulation on duct work where a ship was fully air conditioned, it was true to state that this would only be possible if the dewpoint of the air in the space through which the trunk passed was not appreciably higher than the duct temperature. On board ship this was rather an ideal condition to assume as there were many factors which might tend to raise the dewpoint of a space at certain parts and the condensation on the ducts which resulted. An example of this type of thing was a duct situated close to a deck pantry which, at times, might have a very high moisture content and as this water vapour would naturally tend to diffuse throughout the surrounding spaces, a higher dewpoint in these spaces would result.

With regard to the insulation of ship side structure, it was true that no vapour sealing was required during the cooling period but this was not necessarily true during the heating season. In many cases owners insisted on a minimum humidity of 50 per cent and, as pointed out by Mr. Laing, the theoretical conditions leading to moisture migration were present. In passenger ships particularly, ship side insulation was almost invariably protected by panelling and this, if well fitted, also acted as a vapour seal. The absence of complaints which indicated that the phenomenon of condensation to ship structure did not arise in practice was surely a tribute to the efficacy of the vapour seal which the insulation contractor had adopted.

The coefficients of heat transmission shown in Tables I and II were calculated values based on the probable insulation to be fitted and it was very rarely that when the air conditioning engineer was designing the installation any knowledge was available of the final specification of the insulation which would ultimately be fitted. Consequently a number of assumptions had to be made which, in practice, might not be achieved.

Mr. Laing suggested that a temperature of 132 deg. F. in an engine room in the vicinity of the bulkhead was much higher than one would expect and was indeed higher than the maximum recorded temperature (Fig. 4) indicated. Here again temperatures of this order were not unknown and might readily be encountered in certain cases and it must not be assumed that the temperatures shown in the graph recorded in Fig. 4 applied to all ships, but merely to the ship for which the particular log was taken.

Mr. Pringle had referred to a recent installation in a 26,000-ton tanker and, as an owner and one who was responsible for operation, his remarks were naturally of extreme value. Up to the present any papers presented to the Institute on the subject of air conditioning had almost invariably been submitted by those responsible for the design of such plant and it might be that in time a member who had dealt with the problem of installing and operating equipment might be persuaded to give the industry the benefit of first class practical experience.

In connexion with the suggestion that the condensate from air conditioning units should be collected, Mr. Pringle raised the point of the minimum quantity which it would be economical to cater for. Much of course, would, depend on the length of time any particular vessel spent in the extreme tropical zone, as during a very large part of the average vessel's life the amount of condensate might be negligible. So far, the authors had knowledge of only one vessel where collection of condensate was the general practice but the subject had been very closely under consideration even since the paper was submitted and it might be that within the next year or two a great deal more on this subject would be known when no doubt the results would be published. There were many factors which required to be taken into consideration, viz:

1) Purity of the condensate.
2) Methods of treating condensate which might be impure due to the presence of animal fats, etc.
3) The actual amount of condensate which might be obtained regularly as against the maximum potential.

Annual Dinner

The Fifty-sixth Annual Dinner of the Institute was held at Grosvenor House, Park Lane, London, W.1, on Friday, 13th March 1959 and was attended by 1,253 members and guests.

The President, Mr. E. L. Denny, B.Sc., was in the Chair.

The guests included: His Excellency General Abranches Pinto, The Portuguese Ambassador; The Right Honourable The Viscount Simon, C.M.G., Chairman, The Port of London Authority; The Right Honourable The Lord Geddes, C.B.E., D.L.; His Excellency Mr. P. R. Gunasekara, The High Commissioner for Ceylon; Sir Nicholas Cayzer, Bt., President, The Chamber of Shipping of the United Kingdom; The Right Honourable The Lord Winster, P.C., K.C.M.G., President, The Merchant Navy and Air Line Officers Association; Sir Victor Shepheard, K.C.B., R.C.N.C., Director, The British Shipbuilding Research Association; Sir Gilmour Jenkins, K.C.B., K.B.E., M.C., Permanent Secretary, Ministry of Transport and Civil Aviation, and Past President; Air Marshal Sir Owen Jones, K.B.E., C.B., A.F.C., President, The Institution of Mechanical Engineers; Captain Sir Gerald Curteis, K.C.V.O., R.N.(ret.), Deputy Master, Trinity House; Sir William Wallace, C.B.E., LL.D., The President-elect; A. C. Grover, Esq., Chairman, The Corporation of Lloyd's; Instr. Rear-Admiral Sir Arthur E. Hall, K.B.E., C.B., Honorary Treasurer, The Institution of Naval Architects; R. Munton, Esq., B.Sc., Chairman of Council; K. R. Pelly, Esq., M.C., Chairman, Lloyd's Register of Shipping; Captain R. L. Shimmin, R.A.N.; R. D. Hyde, Esq., Chairman, The Baltic Mercantile and Shipping Exchange; Captain R. S. David, I.N.; Dr. G. B. B. M. Sutherland, F.R.S., Director, The National Physical Laboratory; Commander(E) G. F. Webb, R.C.N.; Captain J. O'C. Ross, R.N.Z.N.; A. Logan, Esq., O.B.E., Denny Gold Medallist, 1958; Captain M. Hasan, P.N.; R. B. Shepheard, Esq., C.B.E., B.Sc., Director, The Shipbuilding Conference; Commander R. Gabbett-Mulhallen, R.N., Captain Superintendent, H.M.S. *Worcester;* D. C. Haselgrove, Esq., Under Secretary, Ministry of Transport and Civil Aviation; Commander E. G. Pollak, U.S.N., Assistant Naval Attaché; E. J. Hunter, Esq., B.Sc., President, The North East Coast Institution of Engineers and Shipbuilders; Dr. T. W. F. Brown, C.B.E., S.M., Research Director, Pametrada; S. E. Tomkins, Esq., O.B.E., Secretary, The Salvage Association; E. Ower, Esq., B.Sc., Institute Silver Medallist, 1958; Colonel H. Randal Steward, T.D., B.Sc., Chairman of Council, The Institute of Refrigeration; Dr. A. D. Third, B.Sc., Institute Silver Medallist, 1958; E. C. V. Goad, Esq., Assistant Secretary, Ministry of Transport and Civil Aviation; R. W. Bullmore, Esq., M.B.E., Director of Sea Transport, Ministry of Transport and Civil Aviation; Ronald Ward, Esq., F.R.I.B.A.; T. C. Bailey, Esq., President, The Institute of Fuel; F. R. Lindley, Esq., President, The Society of Consulting Marine Engineers and Ship Surveyors; A. W. Wood, Esq., Assistant Secretary, Ministry of Transport and Civil Aviation; D. S. Dodsley Williams, Esq., President, The Diesel Engineers and Users Association; Victor Wilkins, Esq., F.R.I.B.A.; D. S. Tennant, Esq., C.B.E., Secretary, The Merchant Navy and Air Line Officers Association; W. T. C. Smith, Esq., Clerk, The Honourable Company of Master Mariners; F. G. Wright, Esq., Secretary, The Shipping Federation; J. D. C. Stone, Esq., F.C.A.; Captain A. D. Duckworth, R.N.(ret.), Secretary, The Institution of Naval Architects; R. W. Reynolds-Davies, Esq., O.B.E., Secretary, The Institute of Fuel; K. H. Platt, Esq., M.B.E., B.Sc., Deputy Secretary, The Institution of Mechanical Engineers; T. S. Nicol, Esq., Secretary, The North East Coast Institution of Engineers and Shipbuilders; H. A. J. Silley, Esq., Past President.

The Loyal Toasts, proposed by the Chairman, having been honoured, Sir William Wallace, C.B.E., LL.D. (President-elect), proposed the toast of "The Royal and Merchant Navies".

He said: I have the honour of proposing the toast of "The Royal and Merchant Navies of the British Commonwealth". It has been a tradition at this dinner that normally this toast should be proposed by a distinguished representative of a friendly country. Tonight would have followed tradition, but, unfortunately, and literally at the last minute, it was necessary to find a substitute, who now stands humbly before you conscious, as a marine engineer, of the difficulty of proposing a cheerful toast embracing two great services when one examines the position of these services today.

How one longs to see again the great inspiring Naval Reviews that many here have seen, the Fleet of the British Navy, the long line of great battleships, battle cruisers, cruisers —I am slipping back now—and aircraft carriers, not forgetting the destroyers and submarines and that wonderful collection of all sorts of ships that we used to see, specially designed to carry out the duty of guarding and patrolling the seas around the countries of our far-flung Empire. Oh! to see again the proud day when we had the largest merchant fleet in the world, and to see the day when our shipyards produced the greatest tonnage per annum of the world. (*Hear, hear.*)

Time marches on. That proud position is no longer ours today. Are we downhearted? No! It is unfortunately true that in our struggle for the freedom of the decent peoples of the world, we lost our pre-eminence in shipping—11 million tons of ships, and the loss of the lives of our merchant seamen reached staggering proportions. The Roll of Honour which reposes in the Institute of Marine Engineers' Memorial Building records the names of 33,000 seamen of the Merchant Navy who lost their lives in the last war.

What of our future? We have weathered thirteen years of so-called peace and our strength, both in men and in materials, is surely growing. The upsurge of youth will shortly embarrass our education facilities. Despite the loss of income from £1,000 million of overseas investments and the end-of-war burden of about £6,000 million, we are strong today. We must export to live and of all the exports from the countries of the world we, with only 2 per cent of the world's population, exported one-fifth of its exports of manufactured goods. (*Applause.*) I was once a banker. We are the bankers of the sterling area and thanks to our stability, at least half the world's trade is conducted in sterling. We ought to be very proud of that.

We have the resources. What of our Royal and Merchant Navies? We have heard serious criticism of the Minister of Defence concerning the Navy, but all with knowledge must be aware of the problems facing the Admiralty in this era of rapidly changing requirements and altered design, calling for continuous revision of ship and weapon design.

The Royal Navy is passing through a period of rapid technical change to meet modern concepts of naval warfare. Every unit of the Fleet has become far more complicated and expensive to build and maintain because of the new types of propelling machinery, new types of weapons and their associated horrible electronic devices and the complex equipment which today we see. These expensive developments mean that we in this country must face the fact that we can no longer afford to maintain a large Navy as we did in the old days.

Fifty years ago, the policy was that our Navy should be equal to the combined fleets of any other two naval powers. We must also remember, however, that if we are faced with a future major conflict, surely we shall not be "going it alone" but will be sharing the fight for freedom with powerful allies.

But other aspects of naval warfare are not being neglected. Although the Fleet will be smaller, it will be a thoroughly balanced force of carriers, cruisers, destroyers and smaller ships fitted with the latest weapons, aircraft and other equipment, and will, I am sure, be able to give a good account of itself should the occasion unfortunately arise.

The most interesting ships, from the technical point of view, now being built for the Royal Navy are surely the guided missile destroyers. These will be armed with the "Seaslug" missile, which has been specially developed for the Navy and which, as announced recently, is proving successful on trials. We in this Institute shall be watching with great interest the performance of the unique propelling machinery of these ships, in which half the power is developed by steam turbines and half by gas turbines.

The idea is that these ships will normally cruise on the steam turbines but that the gas turbine boost can be brought into action in an incredibly short time to develop full power. Another advantage is that these ships, lying in harbour with steam shut down, will be able to get under way immediately, at short notice, on the gas turbines.

A great deal has been said and written recently about the parts that each of our Fighting Services would be expected to play in future wars and I do not propose to add to that controversial subject; but if, unfortunately, we must again fight for freedom, we are, I am sure, confident that we can rely on the Navy as our sure defence, showing the same fine spirit and devotion to duty that has always characterized it in the past.

The Admiralty have their problems. What of our Merchant Navy? Think of our shipowners today facing the problem of competition from shipowners of other seafaring nations, many of whom are receiving substantial subsidies from their Governments. Ships and cargoes are being diverted by flag discrimination and ships are flying flags of convenience, thus avoiding the very high rate of taxation which in this country bears so heavily on all.

How are they to survive financially against this competition? They must look to the future, and one could hardly blame them today if they sought the assistance of fortune tellers. In the memory of one generation they have owned ships fitted with coal fired Scotch boilers and triple expansion engines, winning profits and having something left over after taxation with which to build further profit earning ships. Today, what are they to build and how are they to power their new ships? What a bewildering choice faces the shipowner and his technical advisers: nuclear power, free piston engines, gas turbines, steam turbines, Diesel engines, Diesel-electric, engines amidships and engines aft.

How is the shipowner economically to maintain and repair his ships? Is he, patriotically, to have extensive repairs and reconditioning carried out at home ports, facing risks of demarcation disputes and delay, or is he, tempted by the promise of firm earlier delivery dates, to send his ships to the near ports of the Continent?

However, despite these problems, we are blessed in this country with farseeing, courageous shipowners, today facing the future and building magnificent passenger ships equipped with modern efficient machinery suitable for world trade and installed with every amenity to ensure maximum comfort for the passengers on whom they must depend for income. They are building cargo ships and tankers efficiently and economically to transport all classes of goods to all parts of the world.

And so I finish on a cheerful note as, I am sure, we can with complete confidence visualize the continued efficiency of our great sea transport system, with ships to carry our people and cargoes to all parts of the world, supported by a modern, efficient Navy capable of ensuring that our sea lifelines will at all times be safeguarded.

Gentlemen, I give you the toast of "The Royal and Merchant Navies of the British Commonwealth". (*Applause.*)

SIR NICHOLAS CAYZER, Bt. (President, The Chamber of Shipping of the United Kingdom), who responded, said: I am very proud that I should have been chosen to respond to this most important toast, and it is most appropriate that the Royal and Merchant Navies should have been coupled in the toast which Sir William Wallace has so eloquently and sincerely proposed.

The association of the Royal and Merchant Navies goes back right into the past, right into our furthest history. In the first Elizabeth's days, one could roughly say that the ships were dual purpose. In fact, the fleet that went out to face the Armada was as much Merchant as Royal. In those days, when those great seamen set out from the West Country on those stirring voyages to the Spanish Main to help the balance of payments—(*Laughter*)—it will not have escaped your notice, if you have read your history carefully, that the Queen always had a financial interest under the counter. (*Laughter.*) I would say, in passing, that those voyages to the Spanish Main were very much more remunerative than some of our voyages today. (*Applause.*)

The story of the Royal and Merchant Navies gleams as a bright thread in the fabric of the history of this island country of ours. Our history seems to have been that of the sea, signposted by the names of great seamen, names that give us a thrill to think about—Hawkins, Drake, Frobisher, Richard Grenville, Blake and Nelson, and down to the great sea captains of the twentieth century. All conjure up to the mind the saga of gallant deeds.

It is probable that we might have had a quite different history if it had not been that we were a nation of seafarers, and certainly Britain might not have been Great Britain. Over and over again, because of the resolution and the courage of our seamen, Royal and Merchant, this realm has been preserved. One has not to dig very far into our history to find the many battles fought at sea on which the fate of the realm has turned.

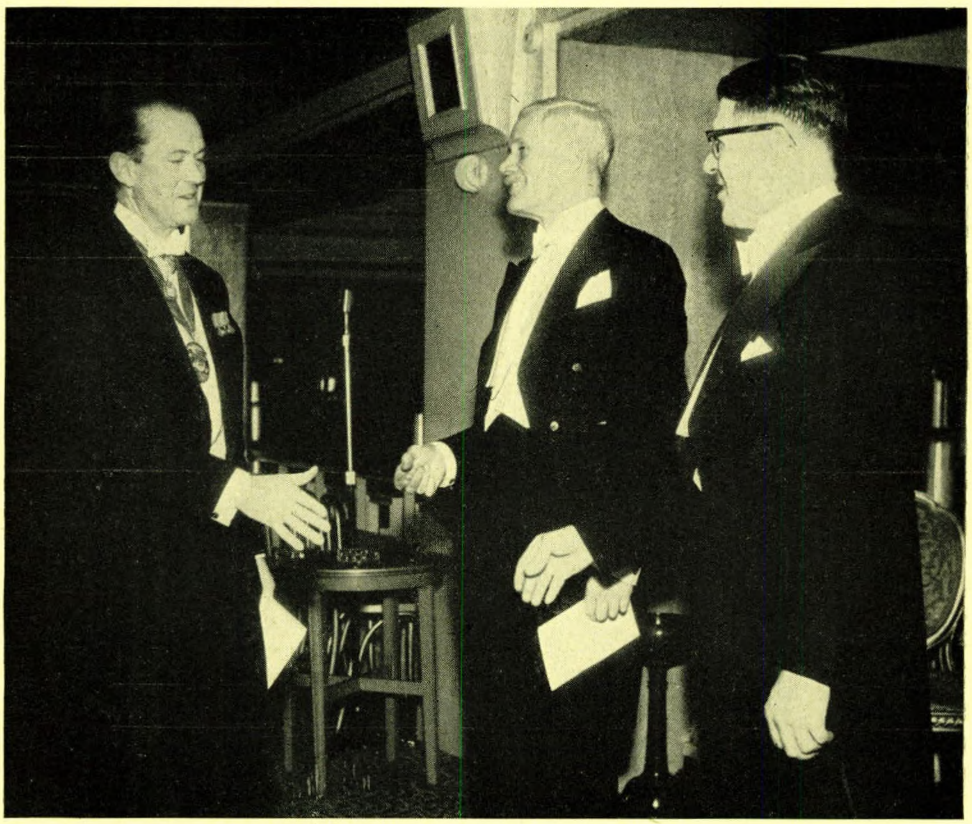
Latterly, in the last two wars, the Royal and Merchant Navies have worked hand in hand and an understanding and comradeship has sprung up between them that only the direst perils faced and overcome could have brought about.

The shipping industry has the closest working arrangements with the Royal Navy, not only in war, but in peace time. As an industry, we are in constant touch with our opposite numbers in the Royal Navy. We have a great many problems that we have to discuss, such as the defence of merchant shipping and research and development in such matters as nuclear power for ship propulsion. There is also, in peace time, a most useful exchange of personnel and our contacts through the Greenwich Staff College are an enduring source of mutual benefit and understanding. I am quite sure that the general public little realizes how closely the Royal and Merchant Navies have worked together in peace time.

As Sir William has said, the ships of the Royal Navy have changed out of all recognition. One has only to go, as I did yesterday, to one of our great shipbuilding yards to realize how great this change is. They are little ships—submarines, corvettes and frigates—but they are packed full of tricks, tricks that I do not know about but which Sir William, I think, understands perfectly well. Yes, we have given the Royal Navy a very "new look". Gone are the great battleships and cruisers of the past.

Annual Dinner, 1959

His Excellency General Abranches Pinto (The Portuguese Ambassador), Mr. E. L. Denny, B.Sc. (President), and Mr. R. Munton, B.Sc. (Chairman of Council)



Sir Nicholas Cayzer, Bt. (President, The Chamber of Shipping of the United Kingdom), Mr. Denny and Mr. Munton

The problems of defence in the nuclear age are, however, very great indeed, and I am not really qualified to speak to you about them. All I would say is that in the past we have underestimated our potential enemies and we have paid for it very dearly indeed. We could not afford to make a mistake like that again. We cannot give the opposition the start that we have done in the past and hope to catch up.

Although it may be true, as Sir William has said, that we ourselves cannot have the great Navy of the past, it is the duty of our Government to see that we make such arrangements with our Allies and friendly Powers that we can, if need be, defend our rights. (*Applause.*)

To turn for a moment to the shipping industry, on which I feel rather more at home and better qualified to speak, we are facing very difficult times. Most of you know the story, but it has to be said over and over again so that the nation begins to realize that it is up against a very great problem that will affect a very large number of people in these islands. Flags of convenience, flag discrimination, nationalism and subsidies have all played their part in bringing about the present situation. We have always been ready to compete on equal terms, but we cannot compete if the dice is too heavily loaded against us.

We must go on until we find a solution to some of these problems, and I do not think that a solution can be found merely by the shipowners alone. It is a matter of sitting down with the Government and working these problems out.

When, from time to time, with other shipowners, I have been to see Ministers of the Crown, they have always said, "What do you want?". I have always felt like being rather rude on those occasions, because it is not a question of what we want, but of what the nation needs. It is a national problem and something that should stir us all to great deeds. (*Applause.*)

Having had that little outburst, let me add that I am quite certain that the Ministers of the Crown are very conscious of the importance of British shipping. I would, however, add that very hard thinking is required, not only by the industry, but by them, if we are to find a way through.

When it is argued, "Why should shipping be a special case?" do not let us forget that four-fifths of our raw material and half our food is brought here in our ships. That makes us a special case. (*Hear, hear.*) And not only that. It is not just a question of the survival of an industry. It is the survival of the nation. It is its very heart's blood. (*Applause.*)

The implications of British shipping, however, are very wide indeed, and the employment that arises in this country from its activities is vital to the health of the country.

Gathered here this evening are some of the best brains in the shipbuilding and marine engineering industry. The Royal and Merchant Navies owe a great debt of gratitude to the marine engineers, past and present, who have led them from reciprocating to turbine and from turbine to Diesel and on to gas turbines and free piston engines; and now, we are in the nuclear age. Not only are they responsible for, and have made a great contribution to, the problem of propulsion in our ships, but they have also, with great ingenuity, invented a multitude of secondary arrangements.

Sir William Wallace, for instance, has contributed two things of vital importance. One of them is to the Royal Navy in the form of catapults of various types for getting aircraft off the decks of ships. The other is to the Merchant Navy, although, I understand, it is also of importance to the Royal Navy, in the form of stabilizers. (*Applause.*) Stabilizers are a tremendous boon to shipowners and to passengers. I was told that Sir William had invented them because he found that the sea made him a little seasick. (*Laughter.*) Whether that is true, I do not know.

I would like to say at this point how pleased I am that my colleague, Mr. Munton, plays such an active part in the Institute as Chairman of the Council. (*Applause.*)

As I have said, I consider that we are in for a very rough time in the shipping industry, which includes shipbuilding as well. It is our plain duty to do everything we can to make sure that we are as efficient and economical as possible and to bring home—this is the great and difficult point—to all those who work in the industry the perils that we face. We must be as competitive as possible and we have to find ways and means of reducing costs. This applies most particularly to shipbuilding, where we are faced with German and Japanese competition, to name only two competitors. They are only too eager and willing to scoop any orders that may be going. It must not be forgotten that the British shipowner has to compete and that the price must be right.

However, as we look back on the past at the difficulties and dangers overcome, one thing of which I am sure is that if we are worthy of all that has gone before and of those who have worked to make this country great, we shall not flag, nor shall we fail, in our efforts to ensure that the Royal and Merchant Navies shall be sustained. (*Applause.*)

The Right Honourable The LORD GEDDES, C.B.E., D.L. (Director, The Peninsular and Oriental Steam Navigation Company), proposed the toast of "The Institute of Marine Engineers".

He said: There is a little story about a dog which seems to me to be appropriate to this occasion. A friend of mine has been in the habit of shooting in Scotland each year and three years ago he was able to arrange with the gamekeeper to obtain the use of a dog which, strangely, was called "Engineer". This was a most outstanding dog. As its name would indicate, it knew exactly what to do, and always did it even before it was told. (*Laughter.*) My friend was so pleased that the following year he made a point of having the same dog, and with the same success. Last year, however, he asked the keeper for the dog and, to his surprise, was told, "Oh, that dog is no good. Some silly fellow came along and started to call it 'Chief Engineer'. You would scarcely believe it, but all that that dog can do now is to sit on its bottom and bark". (*Laughter and applause.*)

Having now offended all of you who are, or have been, chief engineers, it is perhaps appropriate for me to declare publicly the awe in which I have always held those who have achieved that lofty estate and in making this declaration to state that my own experience as a seagoing engineer is to be found at the other end of the scale; for there can be few who have served in a ship's engine room and yet have done so for a shorter period.

Thirty years ago, I had the good fortune to be one of the first of the Cambridge engineering students who were allowed to make the round voyage to New York in the engine room of one of the Cunard Company's ships and was, in fact, the first to do so in *Aquitania*. You will understand, therefore, that it is as the lowest form of life in your profession that I address you tonight.

I emphasize that for two reasons: first, that in thanking your Council for their invitation to do so, I may say how honoured I am to be standing here; and secondly, that you will allow me to take the position of the daft boy looking over the fence into your industry.

I say that because, for as long as you or I can remember, the target of your industry has been efficiency, whereas it now seems to me that there may be a case for some calculated inefficiency. We are all familiar with the many improvements, each of which can produce, perhaps, 2 or 3 per cent improved performance, and which, if added together, would undoubtedly ultimately lead to perpetual motion. Sometimes it is easy to lose sight of the capital cost involved in achieving such savings and to forget that in round figures something like two-thirds of the cost of running a ship, excluding bunkers—I refer particularly to tankers—arises from her initial cost, and only one-third from all of those expenses, such as wages, repairs, stores, insurance, and so on, which come more readily to mind when one thinks of operating expenditure.

For years, engine rooms have tended to become increasingly full of equipment, each piece of which can be justified on its own merits, but there does seem to be a case to stand back and to consider whether the entire installation cannot be simplified and cheapened. I am aware of one large company which has set up a "throwing-out committee", and I would emphasize that they are shipowners and not night club operators! (*Laughter.*) This "throwing-out committee" was established for the sole purpose of reviewing the arguments in favour of each piece of equipment, and I am told that it is surprising how much they have been able to eliminate.

The marine engineering industry has made only two fundamental steps in the past century. From the reciprocating engine of almost 150 years ago, there were the great strides to the turbine, and to the Diesel during the present century; and although in the case of the turbine there has been a considerable increase in steam conditions, and in the case of the Diesel a fairly rapid increase in size during the past decade, there have been few basic changes for many years.

You are now, however, faced with at least two major developments. Your industry appears to be on the threshold of rapid strides, in the one case with the free piston engine and, in the other, with nuclear power; and it may be that by the end of this century these will largely have superseded the prime movers which we know today. If there is any plea which can be made by the outsider looking in to your industry, it is that first cost should sometimes be allowed to persuade you to choose a target slightly short of perfection.

It is an old saying that while Naval machinery should strive for 101 per cent, it may be best in merchant ships to accept 95 per cent of what you want. When sail gave way to steam, and steam partly to the internal combustion engine, the engine room was, on the whole, intelligible to the shipowner. With its increasing complexity, it has become necessary for the shipowner to rely more and more on his technical advisers, and they in turn on the scientists.

The scientific world—and I have in mind particularly the nuclear field—is becoming so much an Ivory Tower as to make it almost impossible for the shipowner to continue fully to understand the complexities of his engine rooms, whilst at the same time he wrestles with politics and economics, low freights and flags of convenience, and all the other factors which bedevil the shipping industry today.

I had had in mind to say something of the factors with which the British shipping industry is faced today, but as many of you will have read, and some of you may have heard, the excellent Presidential address delivered by Sir Nicholas Cayzer at the Chamber of Shipping a fortnight ago, I will not attempt to review what he stated so clearly. I do not think, however, that it can be repeated too often that, partly because of high replacement costs, our shipping industry is having a hard struggle to make ends meet and that the prospects for our shipbuilding industry can scarcely be described as rosy.

It is well known that many foreign shipbuilders have advantages such as one union per shipyard, more modern facilities, and so on; and if there are reasons why this country cannot share those advantages, others must be found to offset them. We are a nation which for centuries has lived by its wits, and we must continue to do so.

That leads me to the final point which I wish to make tonight. I have already suggested that in merchant ships it may be best to accept 95 per cent of what you would like to have. I suggest that there may be a case for a review of the pattern of development of our marine engineers and that, perhaps, we would be better off if they had 95 per cent, or less, of engineering training, in order to give them an opportunity to absorb some knowledge in the wider fields of economics, possibly philosophy, law and certainly history, all of which must affect their thinking if they are to reach wise recommendations when they achieve positions of responsibility. (*Applause.*)

May I, therefore, summarize with a plea for engine rooms which are 95 per cent, designed and run by engineers who also have a margin of safety?

It only remains for me once more to thank you, sir, for the privilege of being allowed to speak to you this evening, and to ask all of you to rise and drink with me the toast of "The Institute of Marine Engineers". (*Applause.*)

The CHAIRMAN, who responded, said: I am sure that you have listened with as much interest as I have to what Lord Geddes has said about excessive striving after efficiency. I find myself entirely in agreement with the sentiments he has expressed. It is a relatively easy matter to produce a highly efficient set of machinery or a very efficient ship, but it requires a great deal more thought, experience and intelligence to design the simplest and cheapest arrangement that will fill the bill adequately. A number of years ago when I was responsible for the technical and cost estimates for machinery installations in our establishment, we received an enquiry from a shipowner for whom we had not previously built. We prepared our technical and cost estimates, we knew what auxiliaries were required, but what we did not realize was the large number of cross connexions that the owner would ask for. Instead of duplicating most cross connexions, the owner in question had triplcated or even quadruplicated them. As a result our technical estimate was low and so also was our price estimate. If we are ever asked to quote for these owners again, we shall know to put in a much higher figure for weight and cost of machinery.

Lord Geddes has talked about a "throwing-out committee" whose job it is to eliminate unnecessary auxiliaries. I suggest that an even more important job for this committee should be to consider and to reduce the number of cross connexions, because in my experience the money spent unnecessarily on such cross connexions may well be much greater than that spent on auxiliaries.

Today the shipbuilder does not usually have very much say in determining what the design of the ship and her machinery will be. This is very different from the position say fifty years ago in almost all cases and thirty years ago in many cases.

There are very great advantages, of course, in a detailed specification being made, because it enables the shipowner to compare the prices he receives and the shipbuilder knows much better what he is to allow for, although of course everyone realizes that it is almost impossible to make a specification so detailed as to cover absolutely everything. Nevertheless, I cannot imagine that it is wholly advantageous to the owner not to have the shipbuilder put up his own proposals.

Another point that occurs to me is that a great deal is decided much more by fashion than by sound technical consideration. (*Hear, hear.*) Mr. So-and-so says, for example, "I want such and such a new type of engine" and immediately he is followed by a host of people who fear that if they do not do so they would be thought probably unprogressive.

We have heard what Sir Nicholas Cayzer and Lord Geddes have said about difficulties, trials and tribulations of shipowners. Those which face British shipbuilders are also many and varied. Shipbuilders' costs are far too high—of course they are—and shipbuilders are certainly only too conscious of the fact. Unfortunately, however, a large number of our employees cannot and will not realize that life is not just all beer and skittles and that some day it is going to change. All in the industry must pull together if they are jointly and severally going to keep their jobs.

We do not have a Toast tonight to the Guests and I do not propose to attempt one. We have many important gentlemen here, both representatives of foreign countries and from many shipping companies as well. I would like to assure them that we are much honoured by their presence and hope that they are enjoying their evening with us.

I thank you all very much for your reception of the Toast.

The proceedings then terminated.

INSTITUTE ACTIVITIES

Minutes of Proceedings of the Joint Meeting Held at The Institute on Tuesday, 13th January 1959

A Joint Meeting of the Institute of Marine Engineers and the Institution of Naval Architects was held at The Memorial Building, 76 Mark Lane, London, E.C.3, on Tuesday, 13th January 1959 at 5.30 p.m. Mr. R. Munton, B.Sc. (Chairman of Council, I.Mar.E.) was in the Chair and was supported by Mr. L. Woollard, M.A. (Honorary Vice-President, I.N.A.).

A paper by S. J. Jones, B.Sc. (Member I.Mar.E.) and J. K. W. MacVicar (Associate I.Mar.E.) entitled "The Development of Air Conditioning in Ships" was presented and discussed. There were 152 members and visitors present. Six speakers took part in the discussion.

A vote of thanks to the authors was proposed by Mr. Woollard and accorded by acclamation. The meeting ended at 7.15 p.m.

Section Meetings

Bombay

A joint meeting of the Bombay Section and the Institute of Marine Technologists was held on Friday, 13 March 1959 at 5.45 p.m. at the B.E.S.T. Conference Hall, Bombay. Mr. G. E. Kerr (Local Vice-President) presided and about 100 members and visitors were present. A very interesting paper on "Marine Centrifugal Pumps" was read by Mr. R. G. Sathaye (Associate Member). A discussion followed, which was inaugurated by the Chairman and to which Captain T. B. Bose, B.Sc., I.N., Messrs. C. G. Stevenson, K. Parthasarathy, K. A. Irani and Lieut. S. Kalidas, I.N., contributed.

A vote of thanks to the Chairman and Mr. Sathaye was proposed by Mr. C. S. Sundaram (Honorary Secretary) and the meeting ended at 7.40 p.m.

Calcutta

The Annual General Meeting of the Calcutta Section was held on 18th March 1959 at 6.30 p.m., at the Marine Engineering College, Behala. The Chairman was Mr. J. Connal (Local Vice-President) and there were 107 members and visitors present, of whom ninety-one were engineering cadets.

The Chairman reported that fifty members had registered as members of the Section and that there were other members resident in Calcutta whom they would be pleased to welcome.

Members were advised that annual subscriptions payable to the Institute can now be paid in India to: The Manager, National Overseas and Grindlays Bank, Ltd., 92/94 Mahatma Ghandi Road, Bombay, 1.

The Chairman appealed for suggestions for papers to be read at forthcoming meetings. It was agreed that there should be further consideration of the suggestion that a social function should be held.

After the business meeting a paper on "Spheroidal Castings" was read by Mr. J. C. Sen, which was followed by a discussion opened by the Chairman, and in which Messrs. C. Tye, T. K. T. Srisailam, R. MacIntosh, K. S. Subramaniam and others took part. To all the questions raised Mr. Sen gave detailed and instructive replies.

The Chairman closed the meeting with a vote of thanks to Mr. Sen.

Kingston upon Hull and East Midlands

"Corrosion in Scotch Boilers"

A meeting of the Kingston upon Hull and East Midlands Section was held on Thursday, 12th March 1959 at the Royal Station Hotel, Kingston upon Hull. Mr. F. T. Green was in the Chair and forty members and visitors attended.

Mr. G. Butler, M.A., Ph.D., presented a paper entitled "Corrosion in Scotch Boilers", an extremely interesting lecture which was much appreciated by the marine engineers in the audience, as was shown by the useful discussion which followed.

Mr. F. C. M. Heath (Vice-President) proposed a vote of thanks to the author which was seconded by Mr. A. W. B. Edwards.

"Oil Operated Gears for Ship Propulsion"

The last lecture of the session was held on Thursday, 19th March at the Great Northern Hotel, Leeds. Mr. H. F. Hesketh (Chairman) presided over the meeting and there were forty-three members and visitors present. A paper entitled "Oil Operated Gears for Ship Propulsion" was given by Mr. I. Wans (Member) and proved to be stimulating, as was shown in the discussion which followed when he was asked a large number of relevant questions.

Scottish

A paper entitled "The Development of Some Seagoing Hydraulic Machinery" by A. E. G. Clement, B.Sc., and R. C. Russell, was read and discussed at the Works of Mactaggart Scott and Co., Ltd., Loanhead, Midlothian, on 18th March 1959 at 5.0 p.m.

Mr. John Robson, M.B.E., B.Sc., Chairman of the Scottish Section, presided and the eighty-five members and visitors present received warmly this very interesting and instructive paper.

The discussion afterwards was ably dealt with by the authors, and the meeting terminated at 6.35 p.m., after Mr. D. D. McGuffie had aptly proposed a vote of thanks to the authors.

Prior to the reading of the paper, members were shown over Messrs. Mactaggart Scott and Company's Works and this proved of great interest. Tea was served at the conclusion of the tour, thanks to the generosity of the authors' firm.

An informal dinner was held that evening at 7.30 p.m. at the Carlton Hotel, Edinburgh. Some seventy members and guests attended this function, which was enjoyed by all present.

Sydney

A meeting of the Sydney Section was held at Science House, Gloucester Street, Sydney, on Wednesday, 4th March 1959. The Local Vice-President, Captain G. I. D. Hutcheson, R.A.N., was in the Chair, and fifty-five members and visitors were present.

The Annual Report and Financial Statement were presented and their adoption proposed by the Chairman, seconded by the Honorary Secretary and carried unanimously. The names of the office bearers elected for 1959 were announced as follows:

Chairman: Captain G. I. D. Hutcheson, R.A.N. (Local Vice-President)

Committee: W. G. C. Butcher
W. T. Mathieson
J. Munro

Captain(E) R. G. Parker, O.B.E., R.N.
F. J. Ward
G. B. Williams

Honorary Secretary: N. A. Grieves

Honorary Treasurer: J. R. Robertson

When this business had been completed a paper entitled "Propellers Used for the Main Propulsion and Manœuvring of Merchant Ships" was delivered by Mr. W. J. Knight.

Mr. Andrew Betts-Brown then gave a short talk on the cycloidal propeller, well illustrated by means of a film and lantern slides.

A vote of thanks to Mr. Knight and Mr. Betts-Brown was proposed by Mr. F. J. Ward and carried with acclamation.

Meeting in Toronto

A meeting of eighteen members took place in the King Edward Hotel at Toronto on 5th February 1959. A short discussion was followed by a film show and refreshments were available.

It was agreed that members should continue to meet with a view to promoting interest in the formation of a Section of the Institute in Toronto, and that a similar meeting should therefore be held in March to which members should endeavour to bring interested visitors who might be eligible for membership. A committee was formed to assist the Local Vice-President, Mr. A. Newland, in the work involved in the organization of these meetings; those nominated and elected were Messrs. J. Boyle and E. A. Burgess.

Student Section

Film Show

One hundred and eighty students and guests attended a film show held at The Memorial Building, 76 Mark Lane, London, E.C.3, on Friday, 6th March 1959, when the film, "Doctor at Sea", and a supporting programme, were shown to an appreciative audience.

Lloyd's Register of Shipping Award, 1959

The twenty-five students benefiting from the Lloyd's Register of Shipping Award gathered at The Memorial Building on 19th March 1959. They were representatives from the Institute's Sections and from technical colleges throughout the country. A preliminary talk on the history of Lloyd's Register of Shipping by Mr. J. C. Stevens was followed by a visit to the Headquarters of the society in Fenchurch Street. Here the visitors spent considerable time in the Engine Plans Approval Department where Mr. S. Archer, M.Sc. (Member) and his staff gave them an insight into its work. There followed a visit to the basement where the survey records of approximately 15,000 ships classified at Lloyd's Register are kept. One interesting record was that of a ship built in 1879 and still in service. The visitors were then entertained to tea and were given a short talk by Mr. J. McAfee (Member).

The lecture in the evening at the Memorial Building was on the subject of "Gas Turbines" and was given by Commander A. A. C. Gentry, R.N. (Member). The subject matter of the lecture was concerned with marine applications of the gas turbine and dealt with its possible advantages and disadvantages as compared with other types of propulsion machinery. After the lecture the students attended a dinner at the Regent Palace Hotel.

On the morning of the 20th March the party left the Imperial Hotel, Russell Square, by coach and arrived at the Pembroke Gate of Chatham Dockyard at 9.30 a.m. The students were then conducted through various workshops, of which perhaps the most interesting were the moulding shop and the constructive departments ship fitting shop. There was unfortunately no opportunity to visit a ship but various types were to be seen in the basins and docks; these included the latest anti-submarine frigate *Eastbourne*. The visit to the Dockyard ended at 1.0 p.m. and was followed by lunch, after which the party returned by coach to London.

Election of Members

Elected on 13th April 1959

MEMBERS

Ian Cameron
John Burton Davies, B.Sc.(Naval Arch.)
Kenneth Charles Dawson
Raymond Floyd Ellis
Cyril Faulkes
Frank Henry
Gilbert Kelly
Matthew Mackenzie
Frederick Pollak, M.B.E.
Allan Frank Prouten

ASSOCIATE MEMBERS

Alexander Anderson
Andrew Gordon Burnside
Alan Chambers
Keith Beaufront Errington
Malcolm Ferguson
William Graham Fox
George Herring
Michael William Strong Lowe
Norman William Morphet
John Fraser Gordon Munro
Anand Prakash
John Osborne Roe
James Fraser Rose
Thomas Elwick Slack
Tejmohan Naraindas Sujan
Robert Featherstone Theaker
Volkhard Thom
Ian Thorp
Martin Dysart Whitworth, B.A.(Cantab.)
Daniel McLeod Wilson
Cyril Edward Wyan

ASSOCIATES

Fazle Basit
Norman Arthur Fawkes, B.E.M.
Edgar Kurgo
Nigel Oglethorpe McLaughlan
Geoffrey Arthur Robinson
Robert Kesteven Selby
Rafiq Ahmed Shah
Leendert van der Tas
Norman Eldred Webb

GRADUATES

Terence Paul Sydney Foy
Donald Henderson Galbraith
John Bell Grieve
Ronald Albert Allen Johnson
Francis George Jones
Samuel Leith, B.Sc.(Eng.) London
Colin William Stuart Piggott
John Ward
Terence John Wild

STUDENTS

Robert Brooks Burnet
Alan Colin Crowther
Michael J. Hawthorne
D. Price
David William Smith
Robert Anthony Vaughan

PROBATIONER STUDENTS

Trevor Leslie Baker
John Edward Barnett
Brian Joseph Beck
Edward Charles Allanson Bishop
Roger Anthony Booth
Barry Cook

John English
Allan McLeod Hodgson
Augustine Louis Ibanga
James Ian Mann
Robert Crighton Moodie
Terence Alfred Morris
Keith Purvis
Trevor George Robinson
Robin Dudley Southan
Michael Roy Spence
Colin David Wallace
Alexander Wilson

TRANSFER FROM ASSOCIATE MEMBER TO MEMBER
George Johnstone

TRANSFER FROM ASSOCIATE TO MEMBER
Herbert John Davey

Alexander Francis Veitch
Robert Rowland Waddington

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER
Begamudre Ananda
Arthur Holmes
Ronald Alastair Jones

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER
Mahendra Singh Ahluwalia
John Tickle Hilton
James Stanton McKenna
Satya Deo Srivastava
Robert Williamson Weir

TRANSFER FROM PROBATIONER STUDENT TO STUDENT
Michael Anthony Blackman

OBITUARY

Robert Houston Campbell (Member 7032), who was born in 1877, was apprenticed to Fleming and Ferguson, Ltd., of Paisley, and then spent thirty-three years at sea in the service of the Clan Line; he obtained a First Class Board of Trade Certificate. From 1920/31 he was marine engineer superintendent in New York for the Clan Line and Houston Line. In 1932 he went into business in New York as a marine surveyor and consulting engineer but later retired to Florida, where he has now died. He was elected to Membership of the Institute in 1932 and was also a Member of the Society of Naval Architects and Marine Engineers, New York.

John Robert Kinley (Member 5275) served an apprenticeship with George Clark, Ltd., of Southwick on Wear, and then spent eleven years as a seagoing engineer, obtaining a First Class Board of Trade Certificate. In 1915 he joined Messrs. Dudgeon and Gray, marine surveyors, and in 1922 he set up in business on his own account as a consulting engineer and marine surveyor, with an office in the City of London.

Mr. Kinley was a Member of the Institute from 1925 and an Associate Member of the Institution of Naval Architects from 1922. He died on 28th January 1959.

William John Leith (Member 9187) died suddenly while at work on 2nd March 1959, aged fifty-eight years. He was apprenticed to Palmers Shipbuilding and Iron Co., Ltd., of Jarrow from 1916/21, and then went to Queensland, Australia, where he was a fitter for the next five years. He was seagoing from 1927/39 with the Straits Steamship Company and obtained a First Class Board of Trade Steam Certificate. In 1940, at the time of his election to Membership of the Institute, he was refrigeration engineer with the Hedley Vicars Cold Air Stores in London, and the following year he took up a similar position with the Union Cold Storage Co., Ltd. From 1944 until the end of 1948 he was engineer inspector in the technical branch of the Customs and Excise. In February 1949 he was appointed engineer in London County Council sludge vessels and continued in this appointment until his death.

Charles Fraser Robinson (Member 4545) was apprenticed to Messrs. Lobnitz and Company of Renfrew. After fifteen years' sea service, during which time he obtained a First Class Board of Trade Certificate, he became chief engineer of an establishment in Turkey. He served throughout the first world war as Engineer Lieutenant in the Royal Navy and was afterwards retained with the same rank in the Special Reserve.

In 1920 Mr. Robinson joined the Khedivial Mail Line of Alexandria and remained in their service until his death on 7th May 1955. His first appointment was as chief engineer of the s.s. *Mahmoudieh,* but in 1922 he went to the Alexandria workshops as resident engineer and was there for nine years. In 1931 he was promoted superintendent engineer at Alexandria; ten years later he was transferred to Suez as workshops manager but returned to take up his old position in Alexandria in 1949, which proved to be his last appointment.

Mr. Robinson was elected a Member of the Institute in 1922.

George Norman Scott (Member 16321) died very suddenly in Bahrain on 23rd August 1958, aged fifty-six, while serving as chief engineer of the s.s. *Relume,* a light tender owned by the Persian Gulf Lighting Service. He had been an apprentice for six years with C. R. Toomer and Co., Ltd., of South Shields and in 1923 joined the Peninsular and Oriental Steam Navigation Company, serving them for thirty-two years, as chief engineer for the last three. He had a First Class Board of Trade Steam Certificate. He joined the Persian Gulf Lighting Service in February 1958.

Mr. Scott had been a Member of the Institute since 1955.

Charles William Lawrence Slater (Member 8672) died on 21st January 1959 aged seventy-one. He was born at South Shields and served his apprenticeship there with T. R. Dowson and Co., Ltd., from 1902/07 and then spent a year with Vaux, Ltd., of Sunderland. He went to sea for the next three years in ships of the Elswick Steam Shipping Co., Ltd., and obtained a First Class Board of Trade Certificate in 1911. He then spent six months in the *Vespasian,* the first merchant ship to have a geared turbine machinery installation. From 1912/14 he was in charge of experimental work with the Parsons Marine Steam Turbine Company in connexion with gearing and Michell thrust bearings. He returned to sea on the outbreak of the first world war and was on active service in the Royal Naval Reserve until December 1918. From 1920/30 he was manager of the shipyard at the Queens Ferry Yard on the River Dee, Flintshire, owned by Messrs. Abdela and Mitchell, and then came to London as Diesel representative for the Deutz Engine Company. After five years with this company he joined Crossley Brothers, Ltd., as chief marine representative in their London office. He was elected a Member of the Institute during this period, in 1938.

Mr. Slater had joined the Royal Naval Reserve as an engine room rating in 1911 and had been promoted Engineer Commander in 1931. He was called up on 22nd July 1940 and appointed to H.M.S. *President* for duty on the staff of the Engineer in Chief's Department at Bath, where he remained until 1946. He was awarded the Reserve Decoration.

He then returned to Crossley Brothers and remained with them until his retirement in 1956.