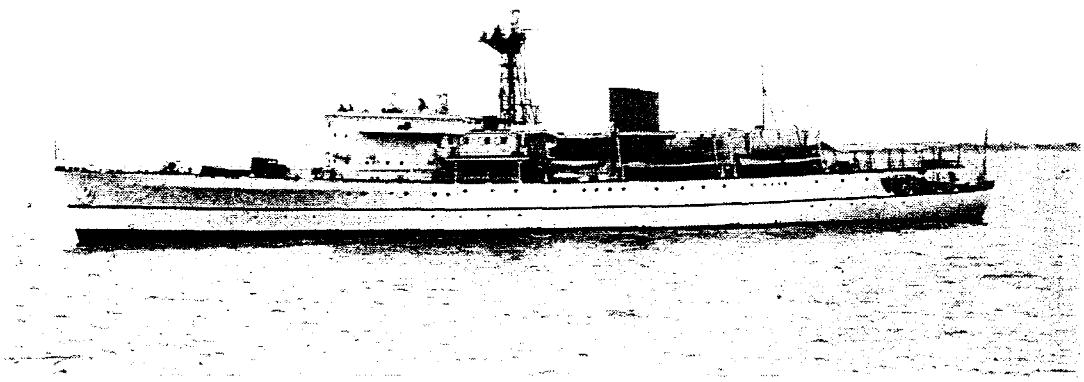

H.M.S. 'VIDAL'

HEAT PUMP IN H.M.S. 'VIDAL'

BY

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H.M.S. *Vidal* is the first survey vessel to be built for the Hydrographer of the Navy since the war especially for that purpose, and she includes many novel features in her design. The hull is of all-welded construction and provision is made to carry a helicopter. The main engines are the first to be built to the new Admiralty A.S.R. 1 design ; they are connected through fluid drives and reverse and reduction gear boxes to each shaft, the engines always revolving in one direction, and each capable of developing a maximum of 800 h.p., whether the ship is going ahead or astern. Two Admiralty designed supercharged Diesel generators are also fitted in each engine room. The unsupercharged main engines each have twelve cylinders arranged in two V-banks of six ; the generator engines are identical in all main dimensions, but have only one bank of six cylinders each. Waste-heat boilers in the exhausts provide hot water for domestic purposes. All main engines are controlled together by the E.R.A. of the Watch, from a separate machinery control room on the upper deck.

Two arcton-6 main refrigerating plants, each capable of extracting 40,000 B.Th.U. per hour when evaporating at -10°F and supplied with sea water at 90°F in an ambient temperature of 110°F, are fitted to cool the refrigerated provision rooms, the ice tank and the lithograph drawing office cupboard. Each plant is entirely independent and cools brine, which is circulated through the room. The flooded shell-and-tube evaporators (brine coolers) are supplied with refrigerant through H.P. float-controlled expansion valves, and conventional oil return systems are fitted.

The ship, including her main machinery, was designed, built and fitted out in H.M. Dockyard, Chatham, and completed early in 1954.

Design Considerations

When the ventilation and heating requirements of this ship came to be considered, it was realized that she would have to be capable of operating for long periods in any part of the world, from the Persian Gulf to well inside the arctic or antarctic circles. This meant that adequate control of the air conditions throughout most of the ship was essential, if the crew was to be able to carry out its duties efficiently and without undue mental and physical strain.

An air-conditioning plant capable of cooling all living spaces and other important compartments, therefore, became an essential requirement for use in tropical waters.

However, before deciding on the incorporation of the heat pump principle in the design of the air-conditioning plant, consideration was given to various alternatives, including direct electric heating (from the Diesel generators), steam or hot water heating from waste-heat boilers and steam heating from a separate domestic boiler. It must be remembered that the heating plant provided must be capable of operating in sea water temperatures not very far above freezing (about 29°F for sea water), and this means that there must be no danger of freezing the sea water if a heat pump is used. After careful analysis of available statistics, it was eventually concluded that, at depths of 10 to 15 ft below the surface, sea temperatures lower than 35°F were very unlikely to be encountered and, provided the flow of water was sufficient, there should be no difficulty in obtaining low-grade heat from this source. However, from an economy point of view, it is obviously desirable to have as high a temperature level of low-grade heat as possible, and provision has been made for the supply of a proportion of warm water from the Diesel generators' circulating water system ; this can be mixed with the normal sea water supply to raise its temperature.

The ventilation arrangements required were worked out in the Naval Construction Department, and it was decided that the ship should be divided into three separate sections, each supplied by its own air-conditioning unit. An estimate of the heating and cooling loads was then made and the results of these calculations are given in Table I. On the cooling cycle, the plant is required to maintain inside conditions of 85°F.d.b. and 73°F.w.b. (56 per cent R.H.) when the outside conditions are 88°F.d.b. and 80°F.w.b. (70 per cent R.H.) and, as shown, this involves an estimated cooling load of 810,000 B.Th.U. per hour. When heating, the plant is required to maintain an inside temperature of 60°F when the outside temperature is 20°F, and this involves an estimated heating load of 750,000 B.Th.U. per hour. When heating or cooling, a minimum of 10 cu ft per minute per man of fresh air is required for hygienic reasons.

The plant is also required to operate as a normal ventilation system in temperate climates with forced air supply and exhaust.

The machinery has been designed to operate on the cooling cycle with sea water and ambient air temperatures of 90° and 110°F respectively. When heating, it is designed for a sea temperature of 35°F but the water actually supplied to the plant is slightly heated by a minimum of 5,000 gallons per hour of sea water at not less than 40°F, obtained from the Diesel generator cooling water system. The makers' estimated performance figures are given in Table II.

As has been stated, cooling was a definite requirement and, in the event, it has been found that, when used for heating under the worst conditions, a saving in electric power of at least 140 kW is achieved. Some direct electric heating is, however, provided, in case the air-conditioning plant breaks down and for use when the heating load is not sufficient to warrant running the plant.

TABLE I

DETAILS OF AIR-CONDITIONING UNITS AND HEATING AND COOLING LOADS IN H.M.S. 'VIDAL'

	Forward Block (No. 1 Air-conditioning Unit)	Superstructure Block (No. 2 Air-conditioning Unit)	After Block (No. 3 Air-conditioning Unit)	
Situation of Unit	Fo'c'sle deck house starboard side, between frames 21½ and 27½.	Partly on upper deck starboard side, between frames 30½ and 32½, partly in fo'c'sle deck house.	Upper deck centre line between frames 48 and 53.	
Compartments served	Seamen's and stokers' mess spaces on upper deck for'd. C.P.O.s', P.O.s', E.R.A.s' and seamen's mess spaces ; lithographic drawing office ; canteen ; naval, gunners' and medical storerooms; A/S instrument room on lower deck for'd. Printing rooms and dark room on hold deck, for'd.	A/S and E/S office on bridge and signal deck. Type 972 office ; chart rooms ; C.O.'s accommodation, etc., and cabin on superstructure deck. W/T office ; Bofors magazine ; sick bay and bathroom ; wheelhouse ; instrument room and radio maintenance room on fo'c'sle deck.	Wardroom and pantry ; officers' cabins ; crew's library and reading room : stewards' mess ; C.P.O.s', P.O.s', etc., and crew's dining rooms ; engineers' workshop, office and control room on upper deck aft. Officers' cabins on lower deck aft.	
Fans :—				
Supply and Recirculating	8 h.p. 25 in	5 h.p. 17½ in	8 h.p. 25 in	
Exhaust	5 h.p. 22½ in	—	5 h.p. 22½ in	
Air-circulation rate cu ft per min ..	11,000	6,500	10,500	Grand total 28,000
Estimated Maximum Cooling Load (Admiralty figures) :—				Grand totals
Sensible B.Th.U per hr ..	225,000	136,000	216,000	577,000
Latent B.Th.U per hr	110,000	26,000	97,000	233,000
Total B.Th.U per hr	335,000	162,000	313,000	810,000
Estimated Maximum Heating Load (Admiralty figures)	295,000	175,000	280,000	Grand total 750,000

TABLE II

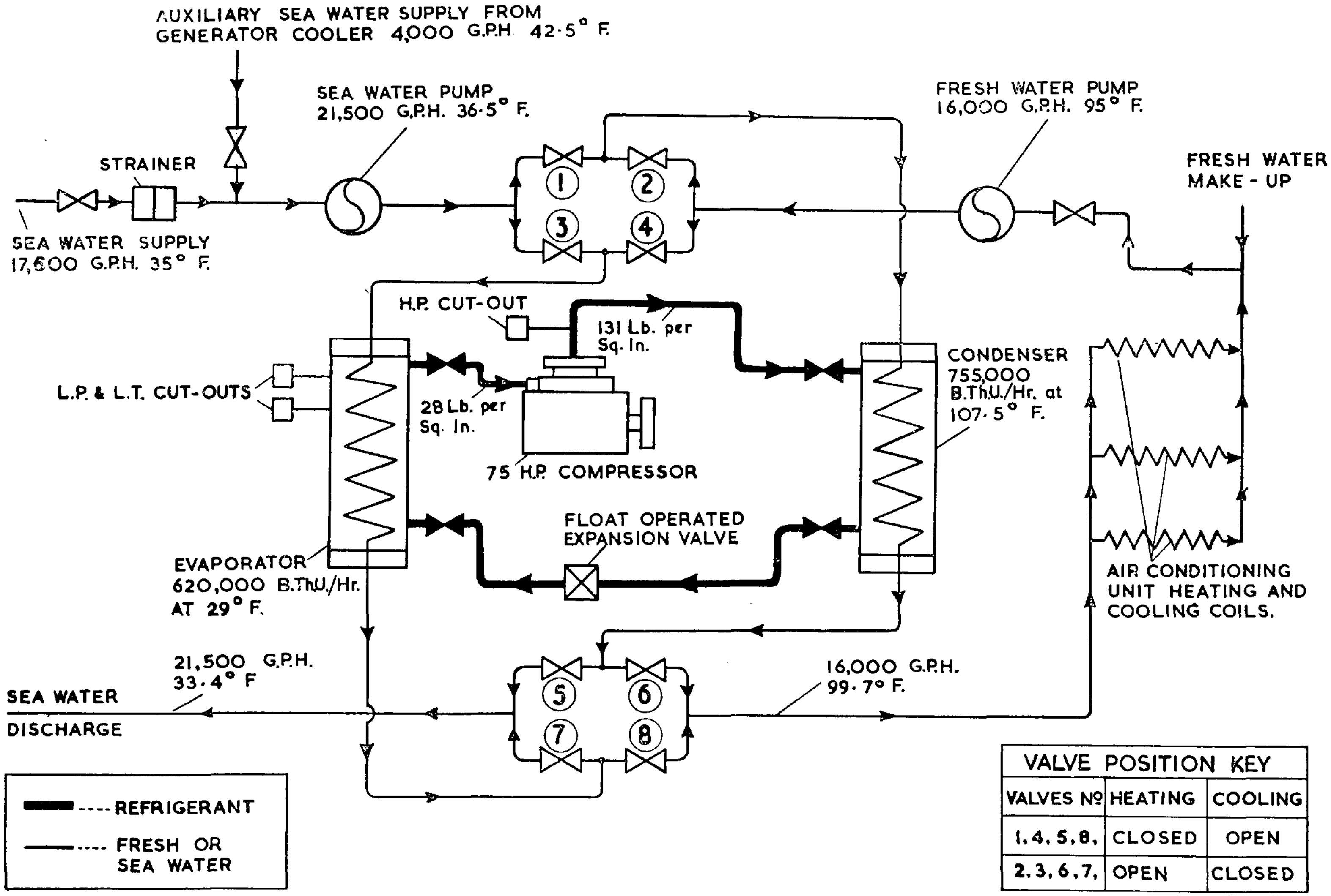
DESIGNED PERFORMANCE OF AIR-CONDITIONING PLANT IN H.M.S. 'VIDAL'

	Heating cycle	Cooling cycle
Sea water inlet temperature °F	36·5	90
Sea water outlet temperature °F	33·4	94·5
Sea water volume, gallons per hr	21,500	21,500
Fresh water inlet temperature °F	95	53·85
Fresh water outlet temperature °F	99·7	48·75
Fresh water volume, gallons per hr	16,000	16,000
Log. M.T.D. sea water/condensing temperature °F	—	12·5
Condenser gauge temperature °F	—	105
Log. M.T.D. fresh water/evaporating temperature °F	—	10·0
Evaporator gauge temperature °F	—	40
Log. M.T.D. fresh water/condensing temperature °F	10·3	—
Condenser gauge temperature °F	107·5	—
Log. M.T.D. sea water/evaporating temperature °F	6·0	—
Evaporator gauge temperature °F	29	—
Compressor speed, r.p.m.	720	720
Compressor power, shaft h.p.	67	71
Evaporator duty B.Th.U. per hr	619,000	810,000
Heat equivalent of compressor i.h.p., B.Th.U. per hr	146,000	155,000
Condenser duty, B.Th.U. per hr	755,000	965,000
Compressor motor power, h.p. (max)	75	—
(Assuming 85 per cent efficiency) kW	66	—
Sea water pump motor power, h.p. (max)	8	—
(Assuming 85 per cent efficiency) kW	7	—
Fresh water pump motor power, h.p. (max)	8	—
(Assuming 85 per cent efficiency) kW	7	—
Total motor power required, kW	80	—
Power required for direct heating kW	221	—
Total saving in power, kW	141	—
Percentage saving in power, per cent	64	—
Coefficient of performance	3·75	4·25

Machinery Details

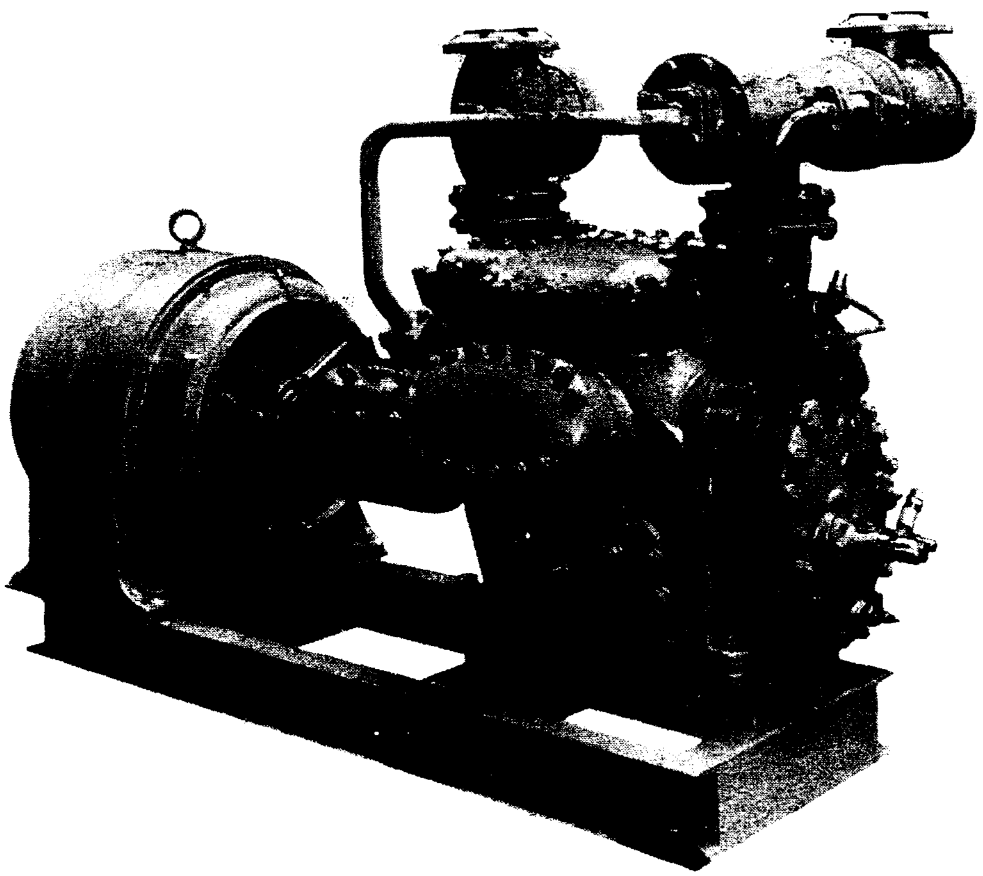
As the plant is so large, it was decided to cool fresh water as a secondary refrigerant and to circulate this through the three air-conditioning units. This made it possible to effect the change-over from cooling to heating, or vice versa, without disturbing the primary refrigerant circuit ; the only safeguard required was to design the secondary refrigerant circuit to resist corrosion due to contamination with sea water. The refrigerant circuit, circulating and fresh water systems are shown.

It will be seen that the refrigerant circuit is a more-or-less conventional system with shell and tube heat exchangers, H.P. float-controlled expansion valve and oil rectifier circuit. However, a novel feature is the refrigerant-cooled oil cooler in the compressor crankcase ; this is a normal small direct-expansion coil fed by a thermostatic expansion valve. Safety devices include H.P. and



VALVE POSITION KEY		
VALVES No	HEATING	COOLING
1, 4, 5, 8,	CLOSED	OPEN
2, 3, 6, 7,	OPEN	CLOSED

SIMPLIFIED SCHEMATIC DIAGRAM OF REFRIGERANT, SEA AND FRESH WATER CIRCUITS, SHOWING CYCLE CONDITIONS WHEN OPERATING ON THE HEATING OR HEAT PUMP CYCLE
(*The Industrial Heating Engineer*)



8-Cylinder Compressor for Arcton 6
(*J. & E. Hall, Ltd.*)

L.P. cut-outs, an elaborate array of safety discs and a back-pressure valve. On account of their size, large gas headers are provided on top of the condenser and evaporator. The refrigerant is arcton-6.

One unusual feature is the enormous 1,000 lb capacity pump-out liquid receiver. This is necessary because of the considerable difference in charge required for the cooling and heating cycles, the excess being stored in this receiver during the cooling cycle. Provision is made to enable the compressors of the provision room plants to be used for pumping refrigerant from the air-conditioning plant into the receiver.

The compressor is of a new design ; it has eight cylinders arranged in W-formation, a bore and stroke of 5-in and 4-in, respectively, and runs at 720 r.p.m. Arrangements are provided so that the suction valves of each pair of cylinders may be lifted, thus enabling the plant to operate with two, four, six or eight cylinders in use, according to the load. This is desirable to avoid excessive stopping and starting of the plant and to facilitate oil return. Forced lubrication is provided, with 'AutoKlean' and 'Tecalemit' filters, sight glass and pressure gauge. In addition to the direct expansion refrigerated oil cooler, the crankshaft gland is provided with salt water cooling. The machine is driven through V-belts by a 75 h.p. 220 volt D.C. motor running at a constant speed of 1,500 r.p.m.

Little need be said about the circulating water and fresh water systems. All pipes are made of copper-nickel-iron alloy and, instead of a separate expansion and replenishment tank, a small header tank is provided above the highest air-conditioning unit ; this is kept full by a float-controlled valve, which supplies water from the ship's fresh water system to make good any leakage. The warm water supply must be operated to prevent the salt water outlet temperature from dropping below 33·5°F, during the heating cycle. High and low salt water suctions are provided to enable the plant to be operated safely in shallow water, but the low suction is used whenever possible, as the water at this level is usually cooler in the tropics and warmer in cold climates than at the level of the high suction.

As no stand-by salt water and fresh water pumps are provided, arrangements are made for sea water to be obtained from the firemain and cross-connections are fitted to enable the salt water pump to be used to circulate fresh water through the air-conditioning units. Thus the plant can be kept running whichever pump fails.

Operational experience has not yet been obtained with this plant, but good results were obtained during the trials and no difficulties are foreseen when the ship goes into service.

Conclusion

The Navy has led the way in the adoption of these interesting plants for marine purposes in this country, but whether they will continue to be used in H.M. ships is still questionable, as so many conflicting requirements have to be met in warships. However, it is confidently predicted that further marine applications of the heat pump will follow, in suitable cases, in merchant ships, and one such plant is already being built for a large new passenger liner ; it will have a capacity of about 10,500,000 B.Th.U. per hour on the cooling cycle and 9,000,000 B.Th.U. per hour when used for heating.

The author wishes to thank Messrs. J. & E. Hall, Ltd., Dartford, for their assistance in the preparation of this article.