WASTE HEAT FROM DIESEL ENGINES

by

LIEUTENANT (E) E. H. OTTEN, R.N.
Engineer-in-Chief's Department

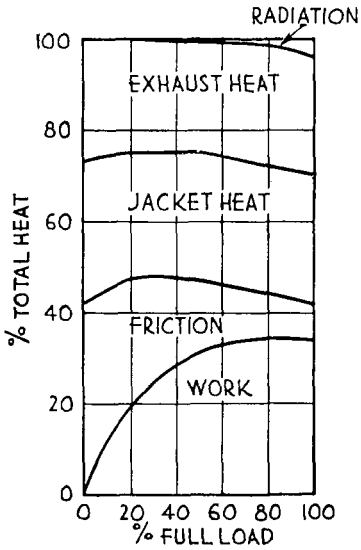


FIG. 1

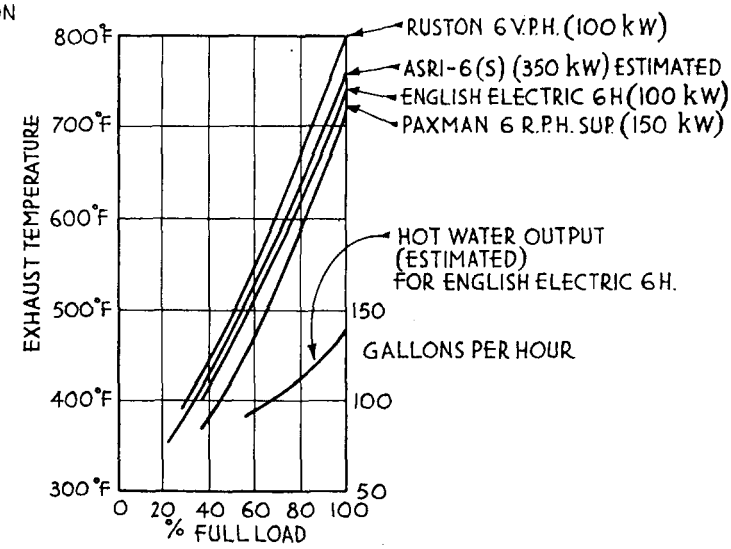


FIG. 2

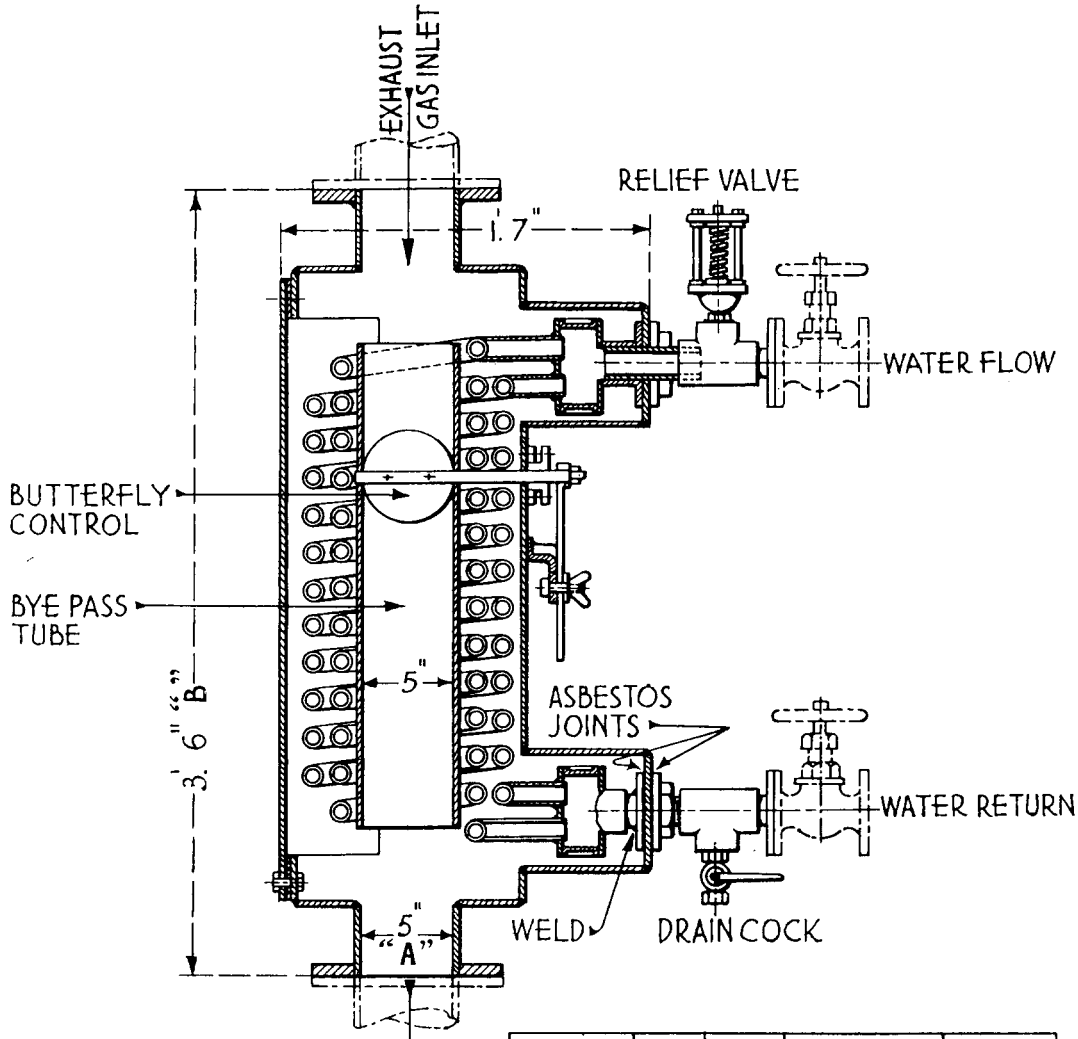
Waste heat from Diesel engines, which is mainly rejected in the exhaust gases and the circulating water, has been used extensively in the Merchant Service and in shore generating stations for some time as the source of heat for domestic water-heating, space-heating, and in some cases to provide steam to run the auxiliary machinery.

In the Naval Service, little consideration has been given to this problem in the past due to the fact that, apart from submarines, Diesel engines were not used onboard except in a small way for generators. However, during the Second World War there was a rapid expansion in the use of Diesel engines and the problem, which had been shelved after unsuccessful early attempts to use waste heat in H.M.S. *Medway* and certain *O* Class submarines (to generate steam for evaporators), is now receiving serious consideration and it is hoped that by restricting its use for domestic water and space-heating, successful plants can be kept in operation with a minimum amount of maintenance.

The increase in efficiency by using waste heat water-heaters will be felt in the reduction of electrical load in small ships, especially destroyers, where, during the severe winter of 1946-1947 it was found necessary to run at least two out of three Diesel engines almost continuously.

A preliminary investigation showed that in a destroyer fitted with 100 kW Diesel generators, each Diesel running at two-thirds full load would be able to heat about 80 gallons of water per hour from 60° F. to 160°F. by means of an exhaust gas water-heater. Using two sets, as is usually necessary during daywork hours, 160 gallons of hot water could be heated each hour which compares favourably with the 100 gallons/hour available from the electric immersion heaters in this particular installation.

It is hoped to fit some units in the *Battle* and *Weapon* Class destroyers, some of the *Dampier* Class survey vessels as well as in the future Diesel survey vessels



EXHAUST PIPE DIA. "A"	B.H.P. APX.	GAS TEMP.	OUTPUT B.Th.U./HR. WATER 180°F	OVERALL LENGTH "B"
5"	150	700°F	142,000	3' 6" DOUBLE COIL
Do	100	500°F	92,900	Do

FIG. 3

and frigates. In these last two, it is intended to use the waste heat from the generators only as these will be running both at sea and in harbour. The large size of these generators (about 330 kW) should ensure at least 250 gallons of hot water per hour, which for a complement of 200-250 is a satisfactory allowance when storage tanks are taken into account.

Current figures for hot water supply are $1\frac{1}{2}$ gallons per hour per man during the peak period. This figure, which includes storage, is a big advance on most of the smaller warships, although the larger units of the fleet have usually more than this.

Heat Available

In a Diesel engine only about 35% of the heat in the fuel is turned to useful work (Figure 1); the remainder is divided almost equally between the circulating water and the exhaust, and a small amount is lost in radiation.

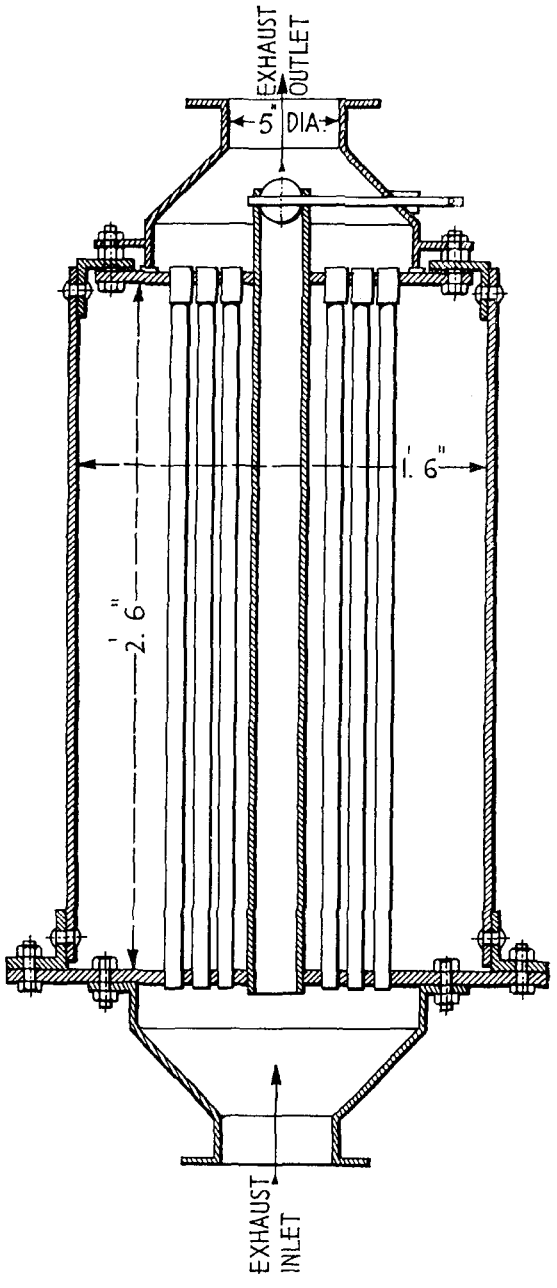


FIG. 4

The exhaust temperature of Diesels varies somewhat with the type of engine and the rating, but at full power it lies between 550°F. and 1,000°F. Typical curves of exhaust temperature with load are shown in Figure 2. This high grade heat may readily be reclaimed with some form of heat exchanger in the exhaust pipe, which can usually be substituted for the silencer. Temperatures and velocities are generally high and these factors greatly assist heat transfer and keep down the size of the heat exchanger.

At present, for design purposes, a load on the generator of two-thirds full power is taken, and as a rough figure, one gallon of hot water is produced per hour for each kilowatt of full load at this power ; this figure varies somewhat with the type of Diesel. The efficiency of exhaust-gas water-heaters can be taken as 30-40%.

Low grade heat may be obtained from the circulating water. About the same amount of heat is available as that from the exhaust. With a circulating water temperature of 160°F., it is not feasible to use this to heat domestic water by means of a heat exchanger to more than about 140°F.

Materials

Most commercial waste heat boilers are constructed of steel. This material is unsuitable for waste-heat water-heaters due to the electrolytic action with the rest of the hot water system which in new construction is made of copper. It is intended to use copper or a copper alloy for these heaters, and this feature restricts the choice of commercially-available heaters to some extent.

Types of Heaters

There are many types of heaters available ; two have been provisionally selected which combine the various features required. These are shown in Fig. 3 and 4. That in Fig. 3 consists of a coiled tube through which the water passes ; this coil can be readily renewed by local labour if required. Fig. 4 illustrates a fire-tube type which is rather more robust. These two heaters are little greater in size than the silencers they replace, although they are usually heavier. For a 100 kW Diesel engine, typical weights and sizes are :—

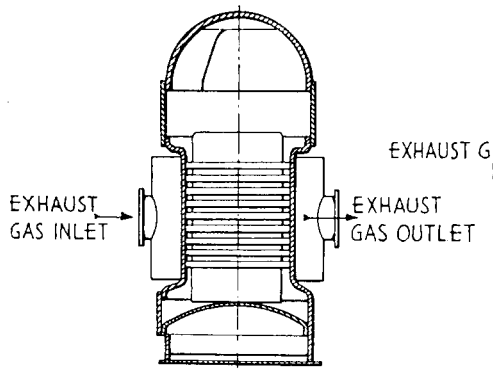


FIG. 5

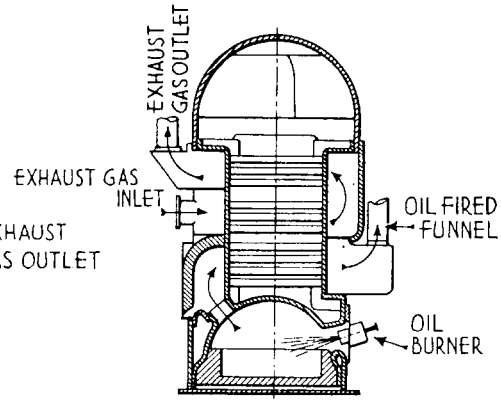


FIG. 6

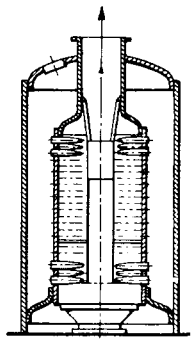


FIG. 7

		Length	*Diameter*	*Wet Weight*	
Fig. 3	...	3 ft 6 in	12 in	260 lb	Approx. weight of silencer would be 250 lb.
Fig. 4	...	2 ft 6 in	1 ft 6 in	800 lb	

Commercial types of waste-heat boilers for merchant vessels are shown in Fig. 5, 6 and 7 ; these can be fitted with a sprayer for use in harbour, as shown in Fig. 6.

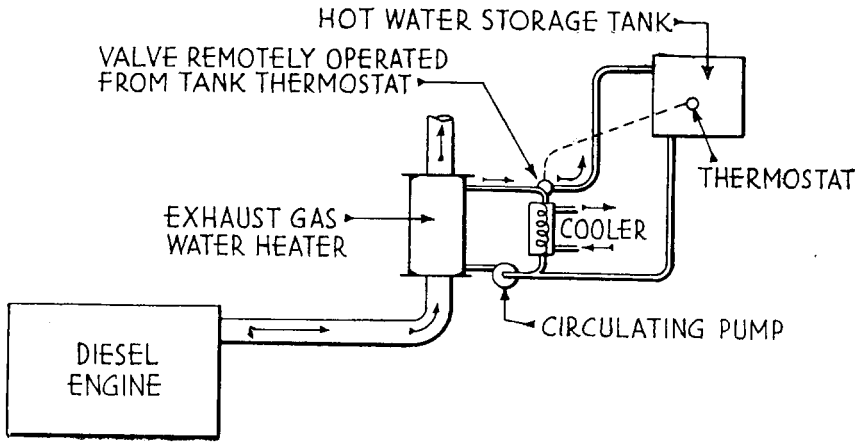


FIG. 8

Systems and Control of Temperature

Because of the irregular demand for hot water, and the fluctuating load on the Diesel generators, it was deemed advisable to devise some control system which would hold the temperature of the water reasonably constant. Any possibility of boiling in the system is dangerous to the user and it has been decided that a maximum temperature of 170°F. should be aimed at. A simple automatic system is a great advantage in small ships where few watchkeepers are available.

Two systems have so far been devised :—

(i) Passing the surplus hot water produced during periods when little hot water is being used, through a cooler, and

(ii) Using a by-pass on the exhaust gas side of the heater.

These schemes are shown diagrammatically in Fig. 8 and 9 respectively.

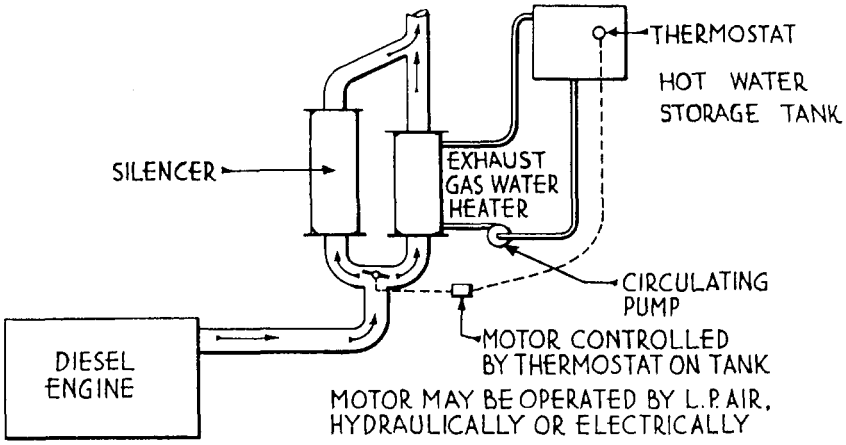


FIG. 9

In the first system (Fig 8) a salt-water cooler is used, similar in construction to the jacket heat exchanger of the engine. When the temperature of the water in the waste-heat water-heater rises to about 160°F., the thermostat starts diverting it through the cooler, instead of to the tank. This scheme is compact and uses well-tried fittings. The silencer can be dispensed with in this arrangement, its place being taken by the water heater.

The second scheme (Fig. 9) uses a damper which diverts the exhaust gas either through the heater or through the silencer. This arrangement is not so compact as the first, and may also be heavier. It needs only one pump—the fresh water circulating pump—whereas the first scheme needs a duplex pump for the fresh water circulation and the salt water supply to the cooler. The thermostatic control of the damper in Fig. 9 necessitates the use of a relay type of thermostat, the power being supplied by L.P. air, or hydraulic system.

Some types of heater, such as those shown in Fig. 3 and 4, also have a central flue with a butterfly valve. When this valve is open, some of the exhaust gas is by-passed from the water side and the output of the heater is then reduced by about two-thirds. This form of control probably does not allow sufficient range of operation for service use ; during the silent hours, too much heat would be passed to the water. In certain types of boilers, however, it is so easily incorporated in the design that it is being retained and used as a form of fine adjustment.

Use of Jacket Heat

Jacket heat alone, or combined with exhaust heat, may be used to heat water for domestic purposes or for space heating. The temperature control arrangements are more complex than those used for exhaust gas heaters alone.

Use of jacket heat for domestic water-heating is being considered for the A.C. ships of the *Daring* Class. The Diesels to be fitted have a low rating and in consequence a low exhaust gas temperature. The temperature of the water heated will be about 140°F. and a small electric immersion heater is used to raise the temperature to 160°F. It is estimated that about 150 gallons of water will be heated each hour and a 10 kW immersion heater should suffice for heating this quantity of water from 140°F. to 160°F.

Hot Water when Diesels are not in use

When steam is available, and with the turbo-generators running, their ouput can be used to heat the water, using immersion heaters, and these heaters can also be used when the ship is connected to an electrical shore supply.