MACHINERY INSTALLATIONS IN H.M. SHIPS

by

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Recent articles in the *Journal of Naval Engineering* on the subject of Propulsion of H.M. Ships by Steam, Diesel, and Gas Turbines have indicated the problems confronting the Installation Engineer when studying a new design.

So far as H.M. ships are concerned the design of installation is principally influenced by the staff requirements for speed and endurance, coupled with a severe limitation in weight and space to keep within a specified displacement for the ship. Depending on the type of ship, the requirements for speed and endurance will vary considerably. For example, an M.T.B. requires to proceed at or near full power for most of its time when on operations whereas a convoy escort will proceed at a comparatively low power for most of its time at sea, with occasional bursts of high speed. At the same time, an M.T.B. would normally only operate over a period of 24 hours as against a convoy escort of as many days.

Except for small servicing craft, H.M. ships have very little in common with other marine services. In the Merchant Service the stringency on weight and space for machinery is in no way comparable to H.M. ships, the accent on the former is almost entirely on economical running. As an example the *Pretoria Castle* and *Daring* class destroyers have approximately the same power, but the weight of the *Pretoria Castle* machinery is over four times that of the *Darings* for a saving of 10% on the steam consumption. Again, the average diesel engine used for propulsion of the larger merchant ships has a weight rating of 90 lb/h.p. and above, against 20 lb/h.p. and below for the Service.

Under present conditions and in the near future, it would appear that all H.M. ships requiring horse-powers of 15,000 and above will have steam installations, and where possible in multiples of 15,000 as required, so that all the development can be concentrated on a single unit. In the not too distant future, subject to continuing satisfactory development, and dependent upon adequate supplies of suitable materials and ability of gas turbines to burn low grade fuels, no doubt the steam turbines will give way to gas turbines because of the reduction in weight and fuel consumption which may be expected.

Below 15,000 h.p., at present and in the near future, the field is open for either steam, gas turbines, diesels or a combination. To illustrate some of the considerations necessary when investigating a design of a craft in this lower horse-power range, the steam gunboat referred to in Vol. 3, No. 2, of the *Journal of Naval Engineering* is taken as a convenient example. In paragraph 1 of the article it was pointed out that there was no alternative to a light weight steam installation. Let us now tackle the problem in the light of subsequent developments and see what answer we would get. The shaft horse-power of this craft was 8,000 and the maximum permissible installation weight, *i.e.*, machinery and fuel to keep within the specified displacement, was approximately 100 tons.

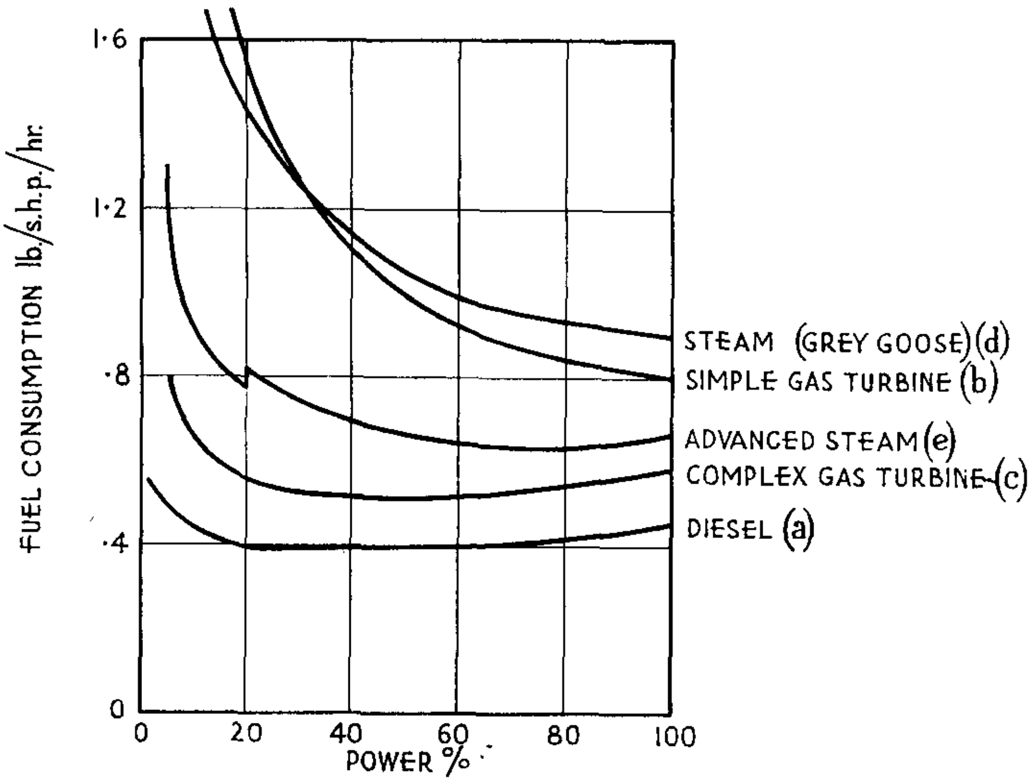

FIG. 1

Fuel Consumption

Let us start off by examining the fuel consumptions of the competitive installations (see Fig. 1). These consumptions are typical for

(*a*) Diesels

(*b*) Simple Gas Turbines (*i.e.*, without heat exchangers)

(*c*) Complex Gas Turbines (*i.e.*, with heat exchangers)

(*d*) Steam Plant as fitted in *Grey Goose*

(*e*) Future Steam Plant Light Weight Long Life designed for economy at low cruising powers as well as high powers (called hereafter Advanced Steam).

It is evident from these curves that for continuous high power running the order of merit on the count of fuel consumption only would be (*a*) (*c*) (*e*) (*b*) (*d*). On the other hand, for continuous cruising at say 10% power the order would be (*a*) (*c*) (*e*) (*d*) (*b*).

Machinery Weight

Unfortunately the most economical types of engines are usually the heaviest, although development is, in the case of diesels, rapidly reducing the power weight ratio. For the purposes of our particular problem the following weights for the machinery and propeller shafts of the craft under consideration are factual in the case of the steam plant as fitted in *Grey Goose*, and estimated for the remainder. They are :—

Diesels	(i) Present day long life	35 lb/h.p.
	(ii) Light weight medium life	7 lb/h.p.
Gas Turbines	(i) with heat exchangers (complex) ...	6 lb/h.p.
	(ii) without heat exchangers (simple) ...	3 lb/h.p.

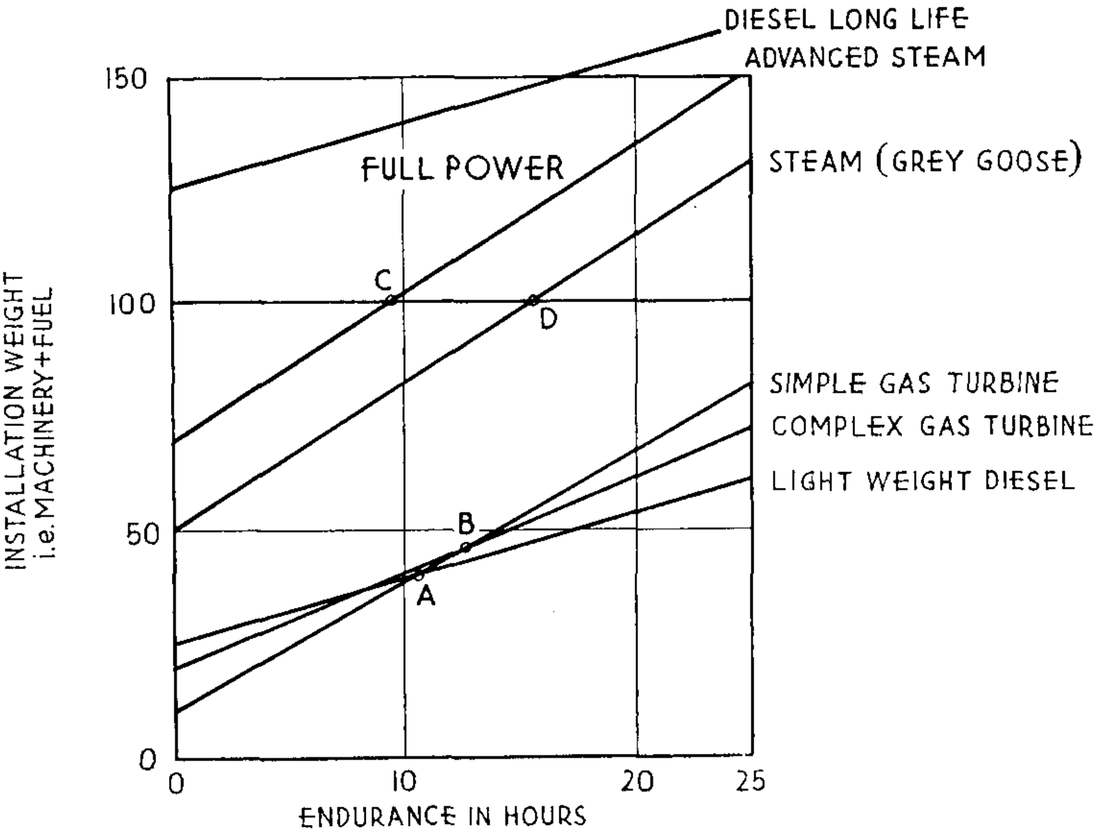
DIESEL LONG LIFE
ADVANCED STEAM
STEAM (GREY GOOSE)
SIMPLE GAS TURBINE
COMPLEX GAS TURBINE
LIGHT WEIGHT DIESEL
FULL POWER
C
D
B
A
INSTALLATION WEIGHT
i.e. MACHINERY+FUEL
ENDURANCE IN HOURS
0
10
20
25
50
100
150

FIG. 2

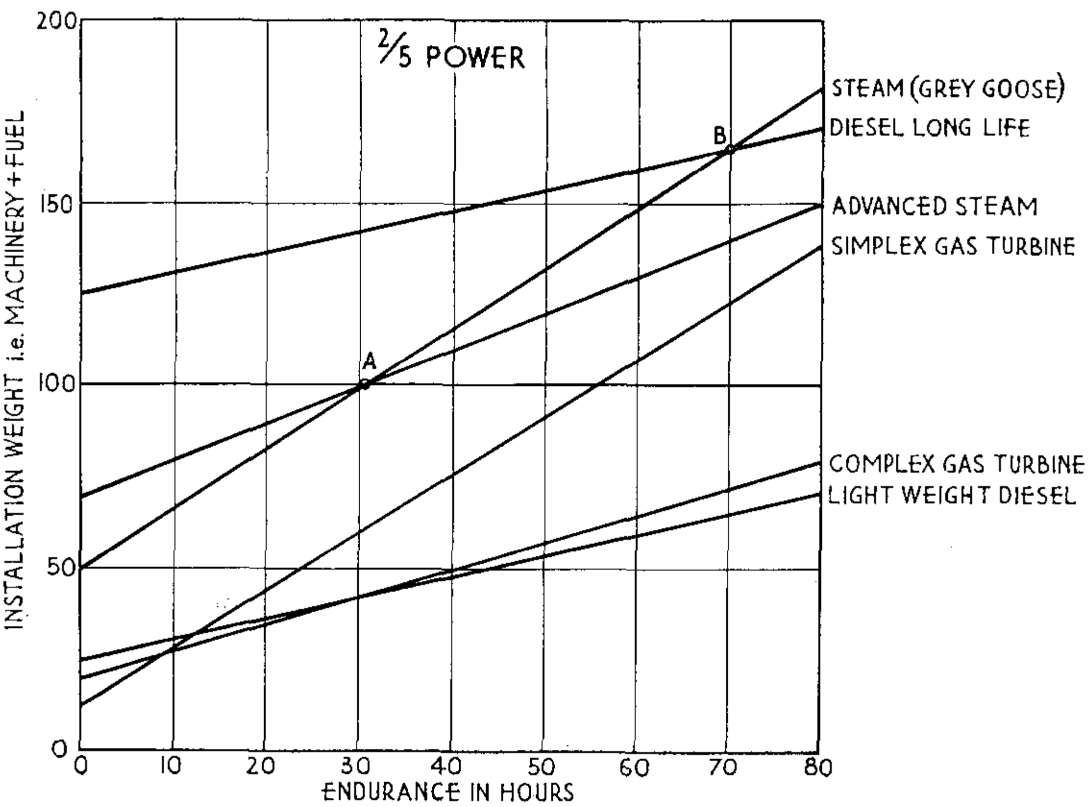
2/5 POWER
STEAM (GREY GOOSE)
DIESEL LONG LIFE
ADVANCED STEAM
SIMPLEX GAS TURBINE
COMPLEX GAS TURBINE
LIGHT WEIGHT DIESEL
A
B
INSTALLATION WEIGHT i.e. MACHINERY+FUEL
ENDURANCE IN HOURS
0
10
20
30
40
50
60
70
80
100
150
200

FIG. 3

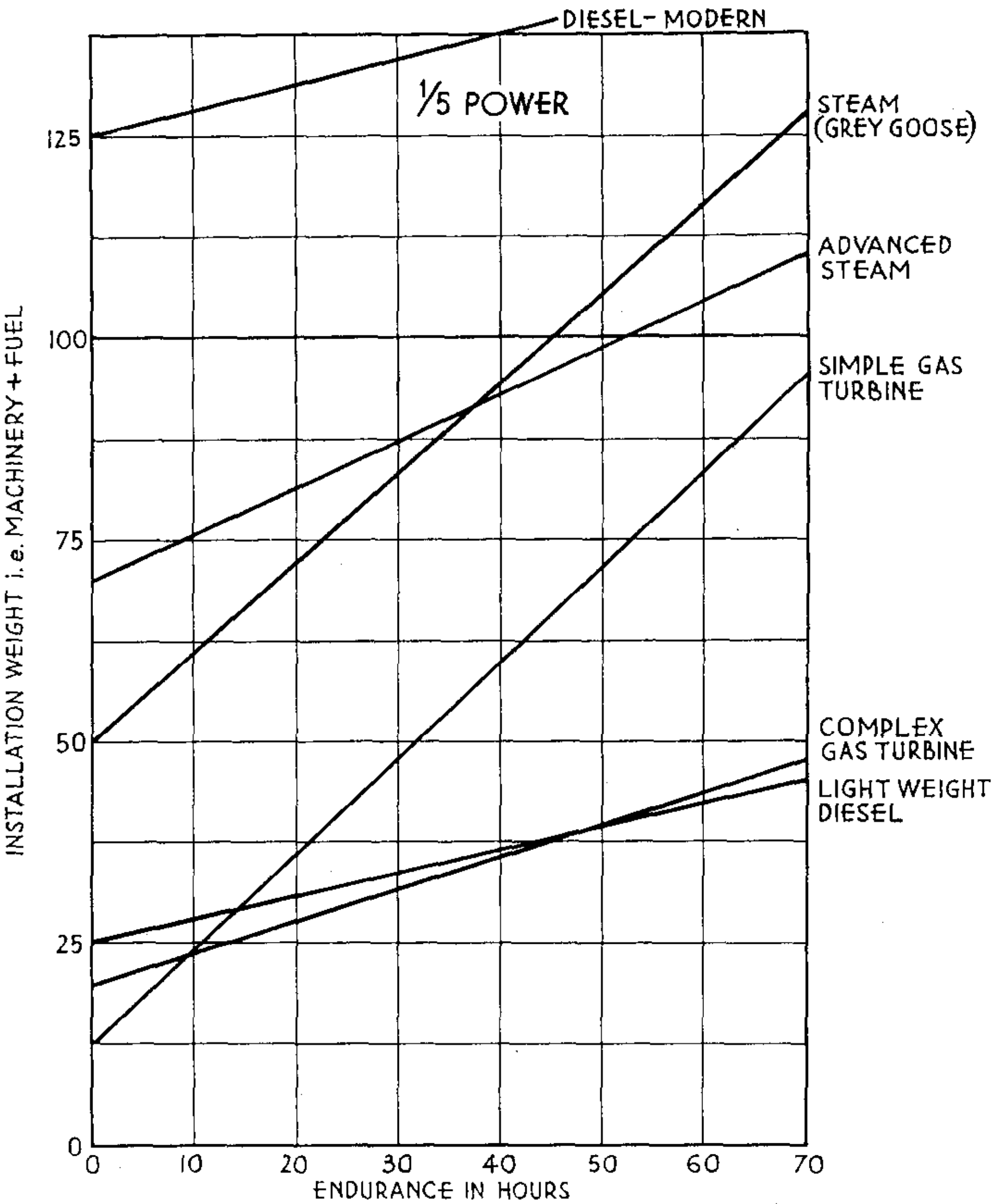

FIG. 4

Steam	(i) as fitted in *Grey Goose*	14 lb/h.p.
	(ii) Advanced Steam	20 lb/h.p.

Installation Weight

The installation weight, *i.e.*, the weight of machinery and fuel has been calculated under various conditions of running as shown in Fig. 2 at full power, Fig. 3 at 2/5 full power and Fig. 4 at 1/5 full power, on the assumption of a single unit per shaft.

Examination of Fig. 2 shows that for conditions requiring continuous full power for 10½ hours (Point A) there is nothing to choose between a gas turbine and a light weight diesel. Below 10½ hours the simple gas turbine gives the lightest weight installation and above 10½ hours the light-weight diesel is superior.

It is of interest to note that after 13½ hours (Point B) the complex gas turbine overtakes the simple turbine.

In the case of *Grey Goose*, with a limitation of 100 tons on the installation weight, it is evident that the long life diesel is out of the question as the installed weight of machinery alone is 125 tons. The advanced steam plant would give nearly 10 hours at full power (Point C), the plant as fitted in *Grey Goose* just over 15 hours (Point D) and the remainder appreciably more than 24 hours.

For prolonged running at 2/5 power (see Fig. 3) on the *Grey Goose* weight limitation, there is nothing to choose between the advanced steam plant and *Grey Goose* plant in that from both we could get just over 30 hours endurance (Point A). The simple gas turbine would give us 55 hours and the remaining plants in excess of 80 hours.

It is of interest to note that, if higher installation weights were permissible, the long life diesel plant would overtake the *Grey Goose* steam plant at 70 hours (see Point B).

For long endurance at 1/5 power (see Fig. 4) on an installed weight of 100 tons the *Grey Goose* steam plant would give us 45 hours endurance, the long life steam plant 53 hours, the simple gas turbine about 75 hours and the remainder would be about 200 hours.

It is evident from these curves that if endurances in excess of about 10 hours are required at powers up to and including full power the most suitable plants from a total installation weight point of view would be light weight diesels or complex gas turbines. There is another factor, however, to be considered and that is space.

Space

In the case of *Grey Goose* the steam plant required an overall length of 42 ft. Simple gas turbines would require about half this length, light weight diesels and complex gas turbines about three-quarters. A saving in length on the machinery space will effect a reduction in the overall length of the craft, thus decreasing the displacement with a corresponding increase in speed for the same power. On the score of space, the order of merit would be :—

(1) Simple Gas Turbines.
(2) Light weight Diesels
(3) Complex Gas Turbines

followed by steam.

Availability of Suitable Machinery

Unfortunately, it is rarely possible to get machinery from commercial production of the exact power required and therefore we must make use of machinery already available or near completion of development. In the case of diesels the power unit of the near future will no doubt be between 2,000 and 2,500 b.h.p., in which case four would be required for 8,000 h.p. The complex gas turbine unit of the near future will be of the order of 5,000 h.p., in which case two would be required. Both these factors will entail a weight and space penalty.

Other Considerations

Under peace conditions, first cost is usually very heavy for machinery specially developed for Service use. The only possible way to reduce the price is to lay out for quantity production as would be required during war, but this would involve heavy initial expenditure for which money may not be available.

If there is very little to choose between two types of machinery the cheaper would no doubt be chosen. Reliability, life, and subsequent estimated maintenance of the plant on service must also be taken into consideration. For example, the maintenance of a properly developed gas turbine which has very few working and wearing parts should be much less than any other machinery installations. Also if a number of units must be used to provide the power the maintenance will be increased.

The Answer

Having taken all these points into consideration the choice of machinery for a craft similar to *Grey Goose* would now be light-weight diesels or complex gas turbines.

General Conclusions

Although an 8,000 h.p. plant has been under consideration, the following general ideas emerge for present day plants of less than 15,000 h.p. :—

(1) For very long endurances diesels must inevitably require less installation weight than other plant. The extent to which they can be used must depend on the acceptable limit of the number of units necessary to provide the power.

(2) For very short endurances the simple gas turbine requires the least installation weight. Alternatively, the simple gas turbine provides the best boost unit for periodic use in addition to main engines efficient at low powers.

(3) Where multiplicity of diesel units preclude their use complex gas turbines require the least installation weight.

(4) The end of steam plants for ships requiring less than 15,000 h.p. is at hand.