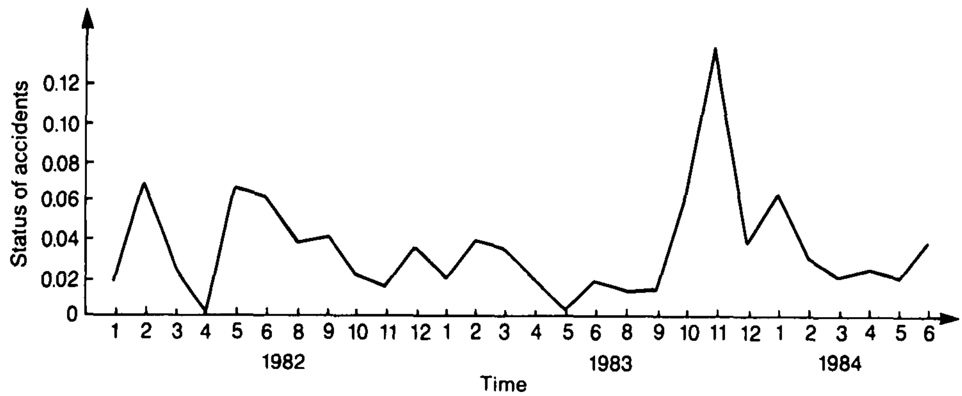

Fig. 2

and the effectiveness of newly-introduced safety measures. Its use could lead to more effective safety management.

KEY WORDS

1. Risk analysis. 2. Safety.

'Fuel Planning in Small Power Craft'

from George Huxtable

Tim Bartlett's thought-provoking article on fuel planning in small power craft[1] in the September 1991 issue of the *Journal* shows some shortcomings which hamper understanding of this topic.

(1) In his Figure 3, 'engine performance data', there are large discrepancies between the two scales of torque, in lbf and in Newton–metres, which are not even proportional to each other. Assuming the Nm scale to be correct, the power output calculated from torque times speed diverges significantly from the 'power curve to BS AU41' shown in the same diagram (an amended Fig. 3 is shown here). These errors do not affect the author's arguments, but are likely to puzzle anyone who tries to use these data to evaluate them, as I did.

(2) The calculation of power-required makes the big assumption that at maximum output the engine is running at its rated speed and supplying maximum torque at that speed, and then scales down this maximum power according to some law at lower speeds. This assumes that the propeller has been correctly chosen to match exactly the engine characteristics at maximum output. Propeller-matching is, however, an inexact science, so how is the owner or the charterer to know that it has been done correctly?

(3) The author accepts that his momentum theory argument used to derive his 'propeller law' has several fundamental fallacies, but he has compounded the problems by using the same letter, V, to express two fundamentally different quantities. When he assesses the momentum transfer, V represents the change in velocity of the water

(initially assumed stationary) as it passes the propeller. This V is assumed to be proportional to pitch times revs.

However, V has also been used to represent the velocity of the craft through the water (see, for example Fig. 5d and table 1). There is no reason for this to correspond in any way with the other V. Nor can it be proportional to the product of pitch and revs; if it were, the curve of Fig. 8a would be a flat line. This V, however, must be closely related to the rate at which water is fed into the propeller disc and should perhaps be used for that part of the momentum transfer calculation. As a result of all this, the derivation of the revs-cubed 'propeller law' is both oversimplified and jumbled.

(4) The argument presented for using boat-speed/rpm as a measure of propeller efficiency is unconvincing (though this does not necessarily invalidate the conclusion). Anecdotal evidence only is provided for Fig. 8a. Although Fig. 8b is claimed to derive from published results, no reference is given, and it is not stated whether the curves 8a and 8b relate to the same craft under the same conditions.

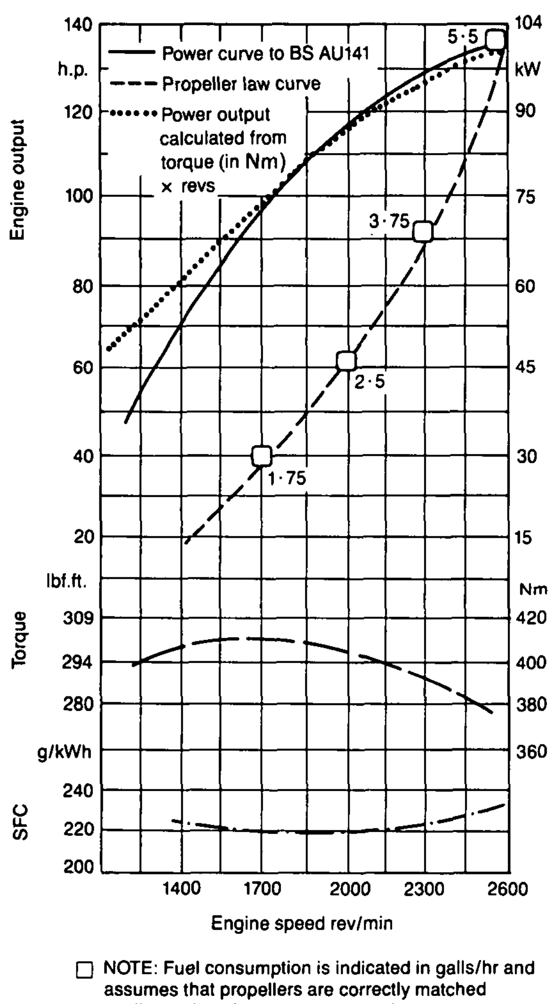

Fig. 3 (amended). Shows (i) corrected scale for torque in lbf. ft and (ii) dotted line indicating power output calculated from torque (in Nm) × revs.

(5) A significant factor in assessing fuel consumption is being missed. The operating regime of an engine covers not only a range of speeds, but also a range of power outputs at each speed. Where the engine maker quotes a single curve of specific fuel consumption, varying only with speed, this will have been calculated at or near the maximum torque output at each speed. Bartlett's arguments all assume that, at a particular engine speed, the specific fuel consumption is constant and the fuel used is exactly proportional to the power demanded.

However, it is clear that specific fuel consumption must increase considerably under low-torque conditions. Consider the *reductio-ad-absurdum* argument of an engine that is being required to deliver zero, or nearly zero, output torque, and so negligible output power, at a particular engine speed. That engine has to consume fuel simply to keep itself going and make up its own losses due to friction and to pumping its own air supply. Remember, a diesel engine must chuff through itself a constant amount of air at a given rotation speed, regardless of how much power it is being asked to deliver. So, as the output power demanded tends to zero, the specific fuel consumption will tend to infinity.

The torque required to drive a craft falls very rapidly as the engine speed is reduced, and I suggest that, in the common situation of a craft with a powerful engine well throttled-back, engine self-losses are a much more important factor than they would be if maximum torque were being demanded. It follows that an augmented value for the specific fuel consumption should be used. Engine-makers would assist by providing figures for fuel consumption (not specific fuel consumption) in grammes per hour, under no-load and full-load conditions, over the designed speed range.

REFERENCE

[1] Bartlett, T. (1991). Fuel planning in small power craft. This *Journal*, **44**, 339.

KEY WORDS

1. Small boat navigation. 2. Voyage planning. 3. Fuel management.

The Author Replies

I thank George Huxtable for his response to my article on fuel planning. To discuss his points in the order in which they are presented:

1. The illustration in question was taken directly from an engine manufacturer's data sheet. Whilst it may have been an unfortunate example to choose, it does, perhaps, demonstrate the point that in dealing with small boats we are in a field in which much of the available information has to be regarded as an approximation.

2. Propeller matching is indeed an inexact science. Racing powerboat owners devote huge amounts of time and effort to getting it right, so I would go further than Mr Huxtable, and say that the chance of finding perfectly matched propellers on a production motor cruiser is virtually negligible. This does not, however, make any difference, because (subject to 1 above) the 'output curve' shows the maximum power available from the engine at any given speed. So if the boat is 'over-propped' (i.e. operating with a propeller so large that the rated speed cannot be attained), the maximum power available will be indicated by the output curve at the maximum speed attained. 'Under propping' seems to be very much less common, probably because

performance trials are usually carried out on lightly-laden boats. Where it does occur, it is usually so slight that I suggest it can be allowed for by extrapolating the published curves.

3. I claim no credit for the momentum theory, nor for the propeller law: both have been widely accepted since (I understand) before I was born. The explanation given was a precis of that offered by Barnaby in *Basic Naval Architecture*.

I accept that I should have used different symbols for different quantities, although as the two in question are, in practice, closely related, I do not believe it significantly affects the conclusion. I did not, however, say that the water flow through the propeller could be regarded as proportional to Pitch × Revs: indeed, the article describes this as one of the fundamental fallacies of the propeller law. Fig. 6 was included to stress the point.

4. Delivery skippers, by the nature of their trade cover thousands of miles in a variety of craft, so I do not believe a rule of thumb used by them should be lightly dismissed. However, I felt its validity should be checked, and did so by comparing the results of boat tests carried out by *Motor Boat and Yachting* with published experimental results taken from a number of different sources, depending on the type of propeller fitted to the boat in question. Rawson and Tupper's *Basic Ship Theory* proved a particularly useful reference, as it includes a diagram of propeller characteristics appropriate to many of the boats in question. Figs 8a and 8b were unattributed because they had been selected merely as typical examples, but they can hardly be described as 'anecdotal'.

5. I completely agree that SFC figures are somewhat misleading, for the reasons Mr Huxtable describes! But unfortunately, we are stuck with what is available: the only alternative would be to measure the actual fuel consumption under actual running conditions – and if that were done, we would have no need of an estimation method in the first place! It may be significant, however, that engine manufacturers generally publish specific fuel consumption figures only for the upper half of the engine speed range, where it seems reasonable to assume that under normal operating conditions the engine's internal losses will be less significant than at low speeds.

To conclude, I completely accept some – though not all – of Mr Huxtable's reservations, but I would stress that my method was intended to provide a more accurate rule of thumb than those currently in use. A rule that attempted to account for every variable would, I believe, demand so much data, and be so complicated, as to be unusable by ordinary boat owners. So my paper was intended to offer a compromise between theoretical precision and everyday approximation.

KEY WORDS

1. Small boat navigation. 2. Voyage planning. 3. Fuel management.