CORRESPONDENCE

The Secretary,
Royal Aeronautical Society,
7, Albemarle Street, London, W.1.

July 17th, 1929.

SIR,—Some further torsiograph observations have been made on the Tornado III. engine since Wing Commander T. R. Cave-Browne-Cave read his paper, entitled "The Machinery Installation of Airship R.101," and the following information on the matter is communicated in response to your esteemed invitation.*

In his contribution to the discussion of the paper (published in the March issue of the Journal), Professor Haigh has explained the apparent anomaly of "administering a sedative with one hand and at the same time a stimulant with the other." There was, however, a further consideration, namely, that the step taken in stiffening the shaft might in itself suffice if, for any reason, the fitting of the elastic coupling should prove to be inexpedient. Moreover, the stiffening of the shaft does not involve an appreciable increase in the coupling flexibility required to bring the fourth order major critical speed down to the desired value.

The dynamic system corresponding to the Tornado III. engine is shown in Fig. 1, which shows also the relation between the fourth order (major) critical speed and the flexibility of the connection of the crankshaft flange to the airscrew mass. It will be noted that the points corresponding to experimental observations with spring hubs of different flexibilities of connection are reasonably close to the theoretical values—which were calculated from an estimated crankshaft stiffness value and upon the assumption that the airscrew is absolutely stiff in the plane of rotation. The effect of flexibility of the airscrew in its plane of rotation, and of imperfect frictional grip, is to reduce the critical speeds.

Two "elastic curves" or "amplitude graphs" are shown, one corresponding to a rigid connection, and the other corresponding to an elastic connection having a stiffness of 5.2 million pounds inches per radian.

It will be seen with the spring hub drive there is no steep run in the amplitude graph. With the rigid drive, however, the slope of the amplitude graph changes rapidly along the crankshaft, the node being located between the crankshaft flange and the first throw.

Theory indicates that in an eight-cylinder in line engine having the firing order that obtains for the Tornado engine, the $5\frac{1}{2}$ order minor critical single node vibration may possibly be troublesome. This critical occurs at 4/5.5 times the fourth order (major) critical speed, and thus, if the latter is at 1,100 r.p.m., the former is at 800 r.p.m.

Fig. 2 shows some torsiograms taken with a wooden airscrew directly attached to the crankshaft. It is clearly indicated that the fourth and $5\frac{1}{2}$ order vibrations have maximum amplitude at the speeds mentioned. Eighth and twelfth order (major) critical vibration is revealed at appropriate speeds, *i.e.*, at one half and near one third of 1,100 respectively. The $6\frac{1}{2}$ order minor critical is indicated at 650 r.p.m. which is near to 4/6.5 times 1,100 r.p.m.

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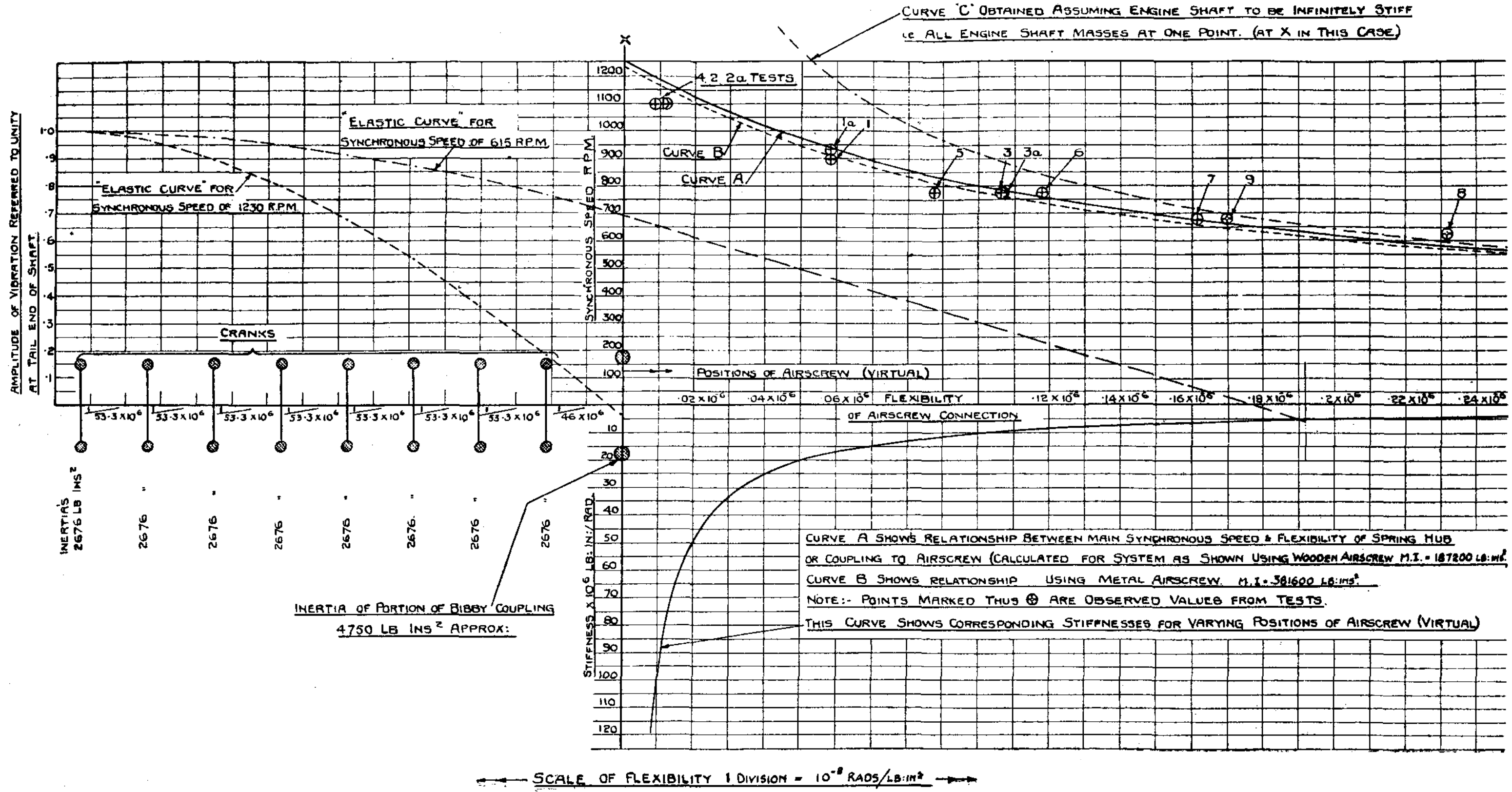

FIG. 1.

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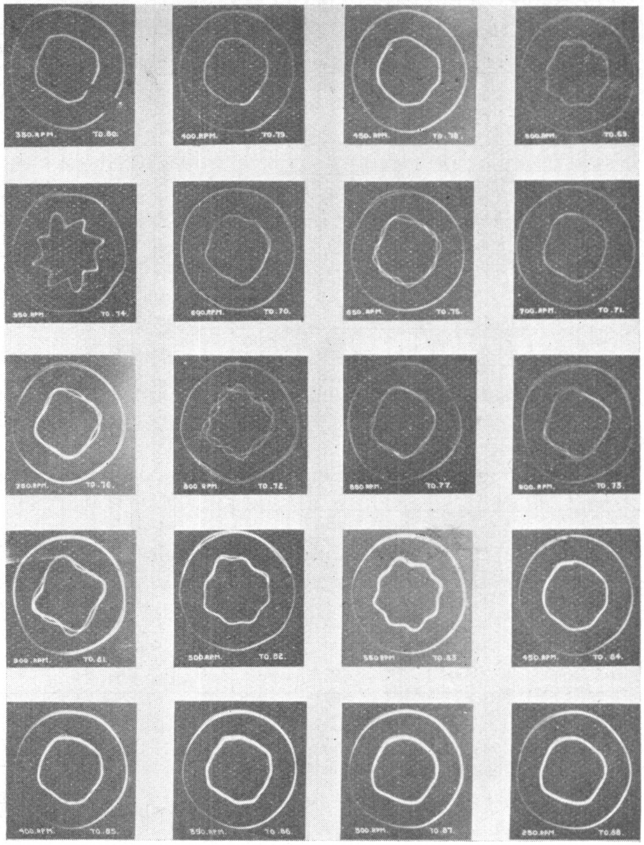

FIG. 2.

Torsiograms for an eight-cylinder in line engine with a direct driven wooden airscrew.

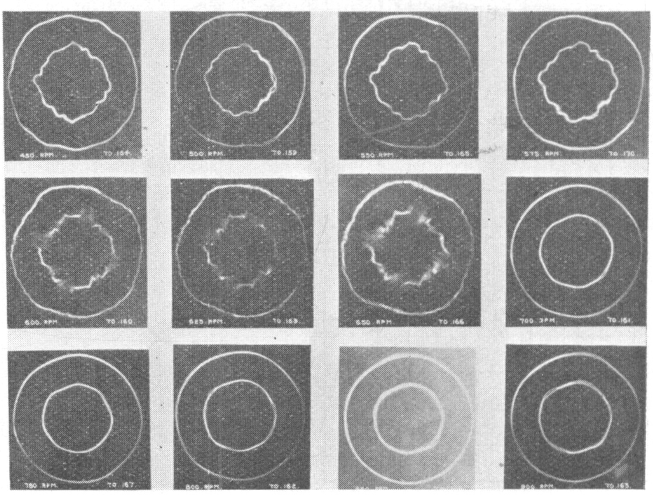

FIG. 3.

Torsiograms for the same engine (see Fig. 2) but with a special spring hub.

Fig. 3 shows some torsiograms taken with a spring hub fitted of 4.3 million pounds inches per radian stiffness. The fourth order (major) critical is in the region of 625 r.p.m. and the torque variation is small at all running speeds above 650 r.p.m. It may be mentioned that with the hub stiffness in question the engine runs remarkably smoothly in this speed region.

At speeds well above the fourth order (major) critical, the torque variation in the drive is less than the variation of the combined cylinder impulses—the reason being that the crank masses function as an oscillating flywheel having an

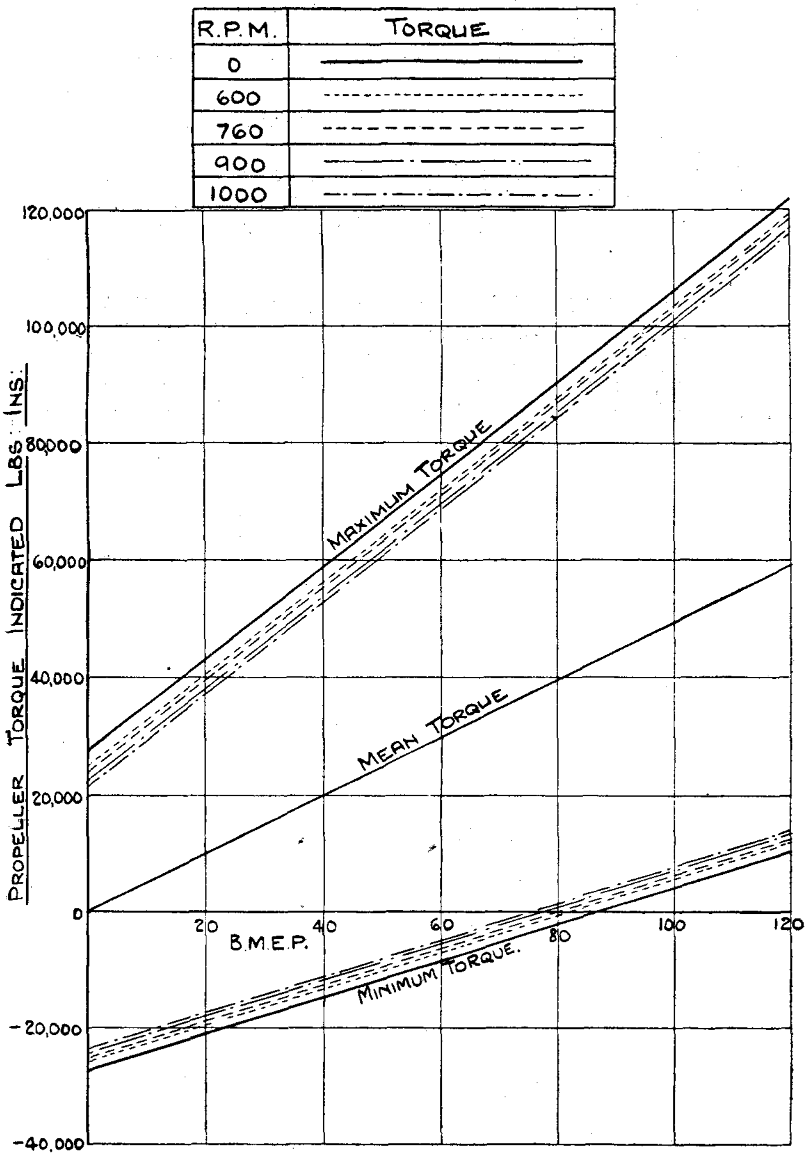

FIG. 4.

Tornado (indicated) propeller torques due to gas forces only at various brake mean effective pressures, also including inertia forces.

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amplitude of swing which is too small to produce much variation in the airscrew driving torque. This condition is not only favourable to the engine, but also to the airscrew.

As regards the variation of the combined cylinder impulses, the value given by Wing Commander Cave, namely, 75 per cent. of the mean, is an underestimate, and was given to him by myself without the opportunity of referring to the Tornado torque curves. The variation is given in Fig. 4, for different brake mean effective pressures and speeds. The influence of speed is relatively small. The reduction of torque variation with reduction of B.M.E.P. (with full throttle opening) is much less than for a corresponding petrol engine—owing to the difference of compression ratio.

To reduce the variation at low B.M.E.P.s, and to obtain improved low speed running, air intake throttles have been fitted, and it was by using such that it was possible to get steady running down to 250 r.p.m., to obtain the low speed torsiograms of Fig. 2.

The test results substantiate the importance of avoiding dynamic conditions which bring about serious amplification of the explosion impulses, and indicate the advantage to be gained by lowering the main synchronous speed to a low speed low throttle region—a matter concerning which there has been some controversy.

They also constitute additional evidence that the simplifying assumptions which are made for the purpose of theoretical treatment are satisfactory in respect of high speed engines.

In conclusion, I should like to express my indebtedness to my colleagues at the R.A.E. who have taken part in the tests partially described above, and in particular to Mr. N. S. Muir, B.Sc.

Yours faithfully,

B. C. Carter.