TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 288

STIEBER DYNAMOMETER HUB FOR AIRCRAFT PROPELLERS.

By W. Stieber.

From "Zeitschrift für Flugtechnik und Motorluftschiffahrt," April 26, 1924.

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In the "Technische Berichte der Flugzeugmeisterei," Volume III, No. 6, pages 221-229, the basic principle and the first form of the dynamometer hub are described.** This hub was adapted for a torque of 100 mkg (67.2 ft.-lb.). Exhaustive experiments were made with it by F. Müller and reported in Supplement 8 of "Zeitschrift für Flugtechnik und Motorluftschiffahrt."*** The knowledge thus acquired was utilized for the construction of a dynamometer hub for 200 mkg (134.4 ft.-lb.) torque and 1200 kg (2646 lb.) thrust suited for a Liberty "12" engine.

Fig. 1 shows a longitudinal section; Fig. 2, different cross-sections; Figs. 3-4, outside views.

The hollow cone 101 (Fig. 1), which is held on the conical end of the engine shaft by nut 105, is made thicker at its base, so that the assembling stresses are absorbed without damage. The hub 103, which can both rotate and slide horizontally, fits the cylindrical outer surface of cone 101 (Fig. 5). The propeller is secured to the hub by means of flange 104 and bolts 114. A cone

* From "Zeitschrift für Flugtechnik und Motorluftschiffahrt," April 26, 1924, pp. 69-73.

** See N.A.C.A. Technical Note No. 18; also N.A.C.A. files No. 5345-14, "Propeller Hub Dynamometer for Aircraft."

*** Friedrich Müller: "Über den Einfluss der Flughohe auf das Verhalten der Flugmotoren," "Berichte und Abhandlungen der W.G.L.," 1922, pp. 170-182.

with three keys connects the hub with the pressure-box carrier 102 (Fig. 8). They are held together by nut 106, which also serves, in dismantling, to remove cone 101. Safety nuts 107 and 108 prevent loosening of nuts 105 and 106. Nut 108 also serves for removing pressure-cylinder carrier 102 from cone 101.

In pressure-cylinder carrier 102 (Fig. 8) there are three specially adjusted pressure cylinders for receiving the torque and thrust. Fig. 1 shows the arrangement of the thrust cylinders 160, whose rear ends are closed by cover 164, for offsetting the centrifugal force of the oil, and are filled with oil while in use.

The force is transmitted from the socket bearing 118 in the hub through a long rod 163 to a small intermediate piston 166 and thence to piston 162. The accurate adjustment of these pistons is maintained in the usual way, through the introduction of oil under high pressure by means of a regulating piston-valve 168 (Fig. 6). The torque pressure-cylinder 140 (Figs. 2 and 7), with piston 142 and piston-valve 141, operates in the same way. The centrifugal forces of the hub and of the oil mutually offset one another in the torque pressure-cylinders. The position of the piston thereby required, likewise enables the introduction of long piston-rods for increasing the accuracy. If a piston-rod breaks, piston 162 is prevented from escaping by cover 164, and piston 142 by split-ring 169. If other disturbances occur in the force transmission, there come into action, in both directions, stops which allow a play of only one degree between pressure-cylinder carrier 102 and hub 103 (Figs. 5a,b and 8 f,g).

The oil transmission is accomplished the same as before, through plug 121 with three delivery holes and plug-guide 120 with three circumferential channels (Fig. 8). Safety device 125 was also retained, with ball bearings 130. Intake pipes 185 pass through this safety device and are joined to plug 121 by means of connections 138.

The oil transmission from plug-guide 120 to the individual pressure cylinders was considerably modified (Fig. 8). All pipes were eliminated, since they had often caused trouble by breaking. All conduits consisted of holes drilled in parts 120 and 102 and in the pressure cylinders. All transitions from one part to another are made, without the use of packings, by grinding the parts so they fit one another perfectly. Plug-guide 120 is secured to the pressure-cylinder carrier 102 by means of a flange and screw-caps 164 of thrust pressure-cylinders 160 (Figs. 1, 3 and 8).

All conduits are continued to or through the pressure-cylinder carrier 102 by means of this flange, which completely closes 102 and 101 and carries still another stop which holds nut 108 fast and thus prevents the loosening of any part inside the dynamometer hub. Fig. 9 shows the dynamometer hub on a 400 HP Liberty "12" engine on a test bench of the D V L at Adlershof. Fig. 10 shows it on the electric test bench with the protecting hood removed.

The apparatus for furnishing the requisite oil pressure was mounted on the instrument table along with the recording devices (Figs. 11 and 12). The oil pressure was produced by a one-liter cylinder a of compressed air and was kept at about 30 atmospheres by an automatic regulating valve b. The cylinder was also provided with a pressure gage and safety valve. The pressure acts on a piston in a closed oil cylinder c. The amount of oil in the cylinder is indicated by the manometer d. More oil can be added from an oil tank i by means of a hand pump e. The latter is so constructed that the requisite oil pressure can be maintained by it alone, in case of failure of the compressed air.

The torque and thrust pressures are recorded on the drum g by the indicators f. A third indicator records the dynamic pressure generated by a Stieber disk. The drum g is turned 12° per minute by clockwork and moves the paper 1.6 cm (0.63 in.) per minute. A three-way cock h enables the transmission of the high-pressure oil directly into the torque-measuring pipe. This drives the torque piston 142 forward until the stops of the pressure-cylinder carrier 102 (Fig. 8g) and of the hub 103 (Fig. 5a) come together and eliminate all motion of these parts with respect to each other, thus blocking the hub. This blocking is effected while starting, during glides and when the engine runs irregularly, in order to spare the hub. The connections k for the hub and for the dynamic pressure disk are on the back of the instrument table (Fig. 12).

Test.- The dynamometer hub was mounted on an electric test-bench, as shown in Fig. 10, the instrument table being in the small booth in front of the test bench.

The load was applied by stages, as shown by Fig. 13. Q represents the torque and T the thrust. During the test a rather strong, gusty wind blew on the front of the building and made the motion of the propeller very unsteady. This was indicated both by strong oscillations of the balances and especially by irregularities in the records (Fig. 13). Hence the mean values had to be found under the different loads, as indicated by the vertical lines. Regarding diagram stages 5 and 6, consisting of two parts each, it is to be remarked that the first part was obtained during the adjustment of the test bench, while the second part gives the constant loading and is taken for the evaluation. Fig. 14 shows the values obtained on the test bench, as taken from Fig. 13. It is apparent that the test-bench deviations from the constant torque and thrust curves are just as large and often larger than those of the dynamometer hub. The errors of the dynamometer hub in comparison with those of the test bench were therefore omitted. The test gives the following constants and expressions for the dynamometer hubs:

$$Q = 9.96 \times \frac{h}{s} \text{ mkg} = 1830 \times \frac{h}{s} \text{ ft.-lb.}$$

$$T = 60 \times \frac{h}{s} \text{ kg} = 3360 \times \frac{h}{s} \text{ lb.}$$

in which Q is the torque in meter-kilograms (mkg) or foot-pounds (ft.-lb.); T thrust in kg or lb.; h height of diagram in mm or inches; s the unit of the indicator spring in mm/atm.

The dynamometer was also tested on the engine test bench (Fig.9).

Fig. 15 gives the resulting diagram for torque and thrust under various loads. It will be observed that the thrust indicator at one point does not immediately follow the torque, probably on account of the freezing of a drop of water. The diagram shows how well and quickly the indicators responded to the load changes. The torque curve even shows the torque impulses of the individual cylinders. Such sensitiveness is not desirable in flight experiments. A finely drawn line was obtained by reducing the size of the pipe. This line was retained for a short time (over the first Q in Fig. 15) at the beginning of the torque curve.

Moreover, there was only a very small oil consumption, so that an experiment was often performed with only one filling of the oil cylinder without using the compressed air. The consumption was only about 0.3 liter (.08 gal.) per hour, though a consumption of one liter per hour was planned for. This fact not only rendered a longer experiment possible, but it also enabled the observer, even without air, to continue the experiments, since he had to pump only once or twice a minute.

The dynamometer hub ran without disturbance for several days of experiments, which had to be performed in an open shed. Only in the pressure transmission there occurred slight throttling effects, which were caused by frozen drops of water which had gotten into the pipes while being installed (Fig. 15). These obstructions were easily removed by blowing out the pipes in a warm room. After removal from the test bench, the parts were examined and found uninjured.

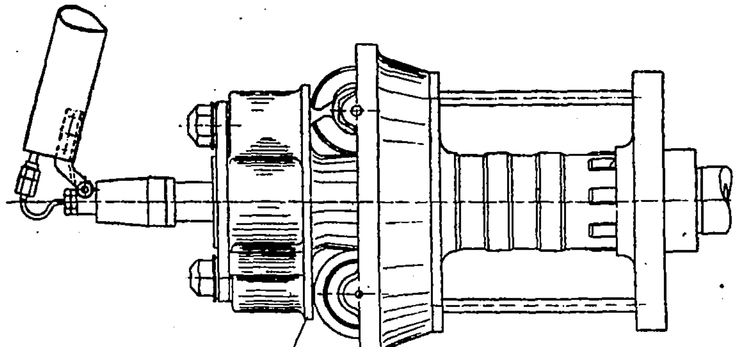
Reversing device.- Figs. 15 and 17 show a so-called reversing device with which compression forces, instead of traction forces, are measured. This particular example was designed for a 400 HP Maybach engine. It consists of a cone 351 with a flange, which is fastened to the flange of the engine and receives the dynamometer hub. It has a flange 352 instead of the propeller flange 104 of Fig. 1. It has three socket bearings 360 and three bushings 368, which lie in the exact direction of the socket bearings 118 (Fig. 16). In bushings 368 and 369 there move the rods 362 in whose sockets sit the thrust piston-rods 163. On flange 351 (Fig. 17) there are three pairs of double levers, 353 and 373, movable on ball bearings. On both ends of these levers, likewise on ball bearings, are the sockets 357. In these sockets there work, on the one hand, three rods 361, whose opposite ends press on the rods 362, and, on the other hand, three rods 376 (not represented) which end in sockets 360 of flange 352.

Hence the forces generated by a pusher propeller, after starting from flange 352, operate in turn on sockets 360, rods 352, reversing levers 353 and 373 with sockets 357, rods 363, 362 and 163 and then on the pressure-cylinder piston rods 163.

This reversing device was designed in order to enable the installation of dynamometer hubs on the ZR-3, built at Friedrichshafen. It is intended to use them on the trial flights for determining the drag of the airship.

Translation by Dwight M. Miner,
National Advisory Committee for Aeronautics.

Fig.3(Views of hub with hood 190 removed)Fig.4



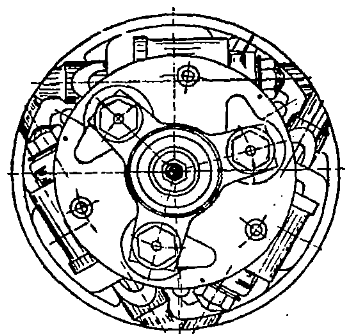
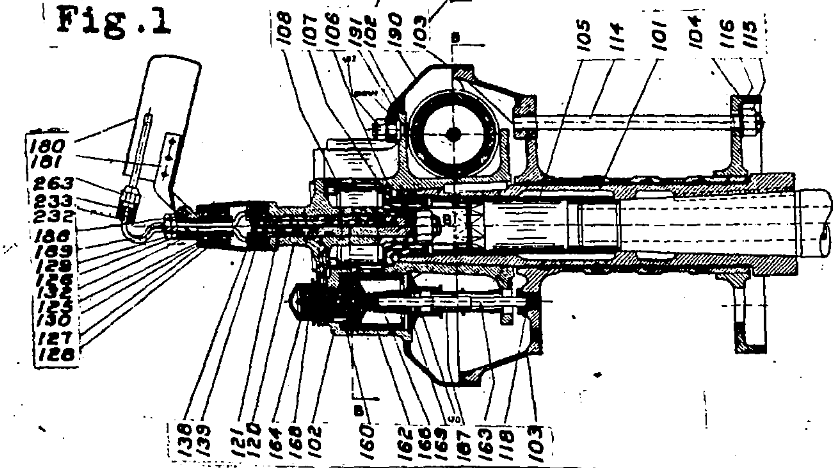


Fig.1



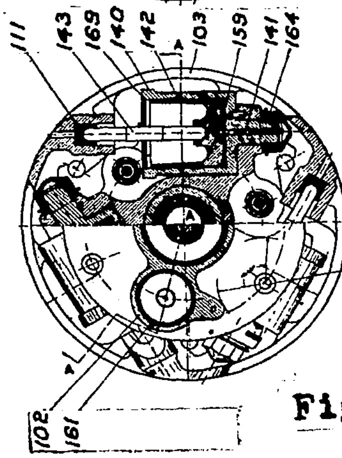
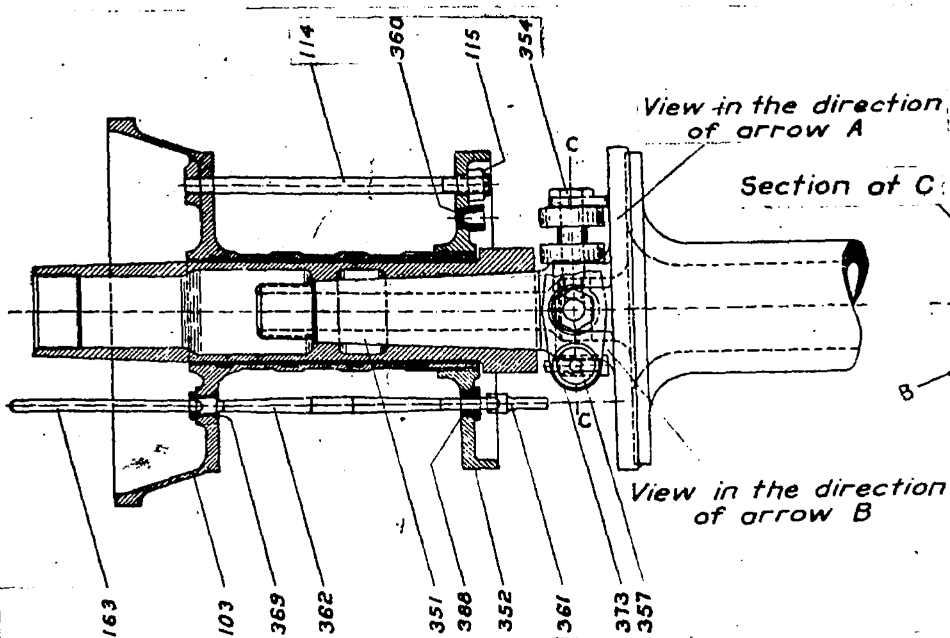


Fig.2

Longitudinal section at A Cross-section at B



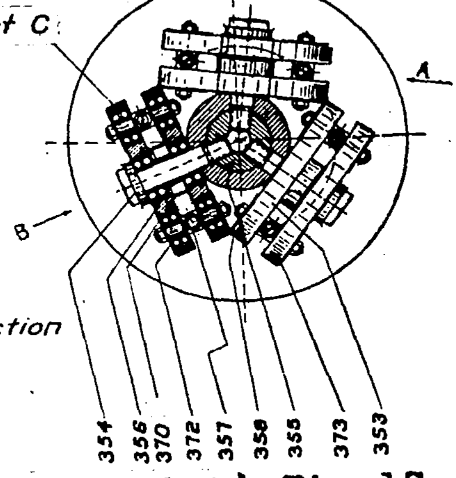


Fig.16 (Reversing device for dynamometer hub) Fig.17
for pusher propeller.

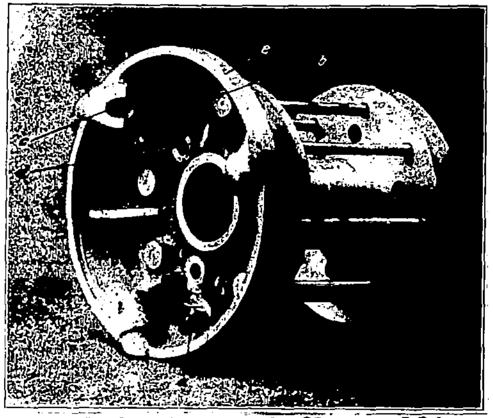


Fig.5 Hub 103 with flange 104
a) Backward stop
b) Forward stop
c) Torque socket-bearing 111
d) Hole for thrust bearing 112
e) Adjustment mark

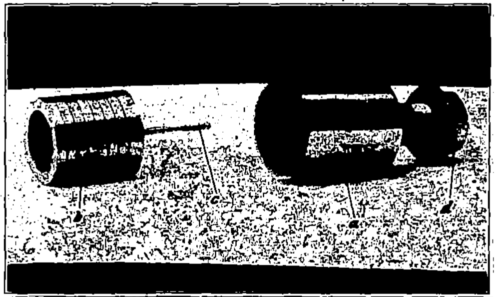


Fig.6 Thrust cylinder 160
a) Cylinder 160
b) Piston 162
c) Piston-support rod 163
d) Screw cap 164

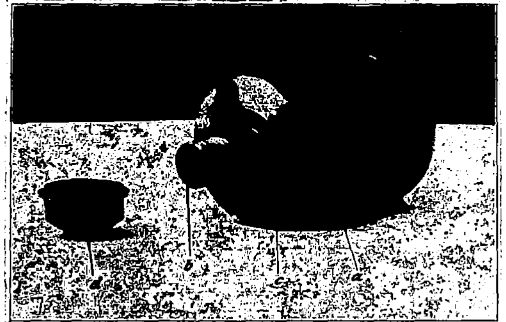


Fig.7 Torque cylinder 140
a) Cylinder 140
b) Piston-support rod 162
c) Oil inlet
d) Screw cap 164

Fig.8 Pressure-cylinder carrier 102 with pressure-cylinder and plug guide.
a) Pressure-cylinder carrier 102
b) Torque cylinder
c) Plug guide 120
d) Safety device
e) Pipes 185
f) Front stop
g) Rear stop
h) Screw cap 164

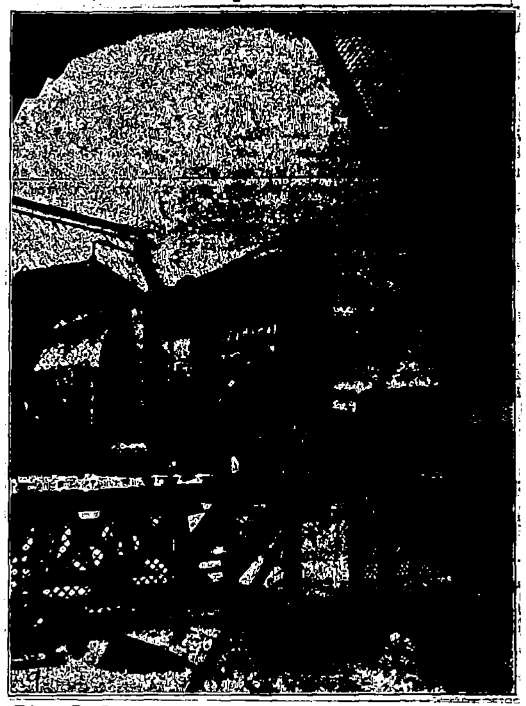


Fig.9 Dynamometer hub on Liberty 12

Fig.10 Dynamometer hub on electric test bench

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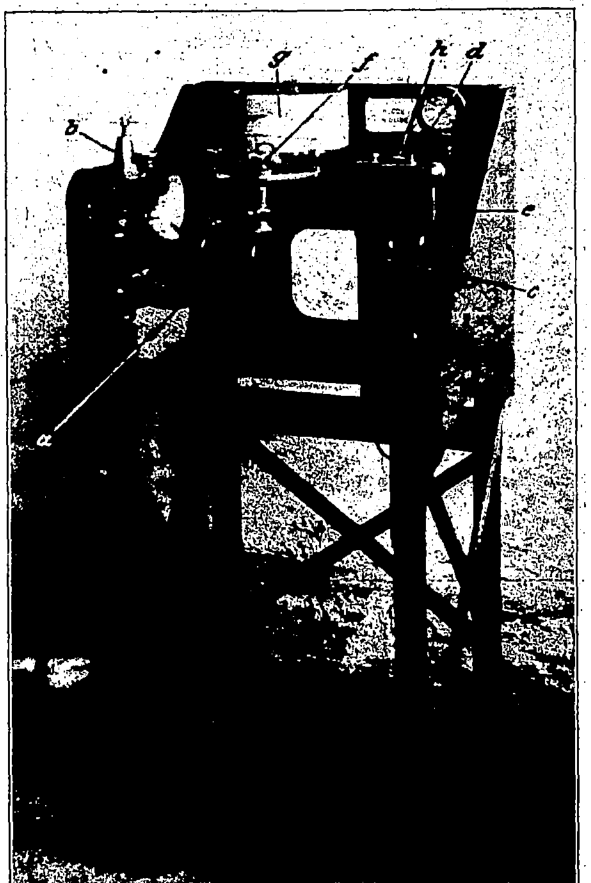

Fig.11 Instrument table
a) Compressed-air cylinder
b) Reducing valve with gage and safety valve
c) Pressure-oil cylinder
d) Manometer for oil pressure
e) Hand pump f) Indicator
g) Drum h) 3-way cock

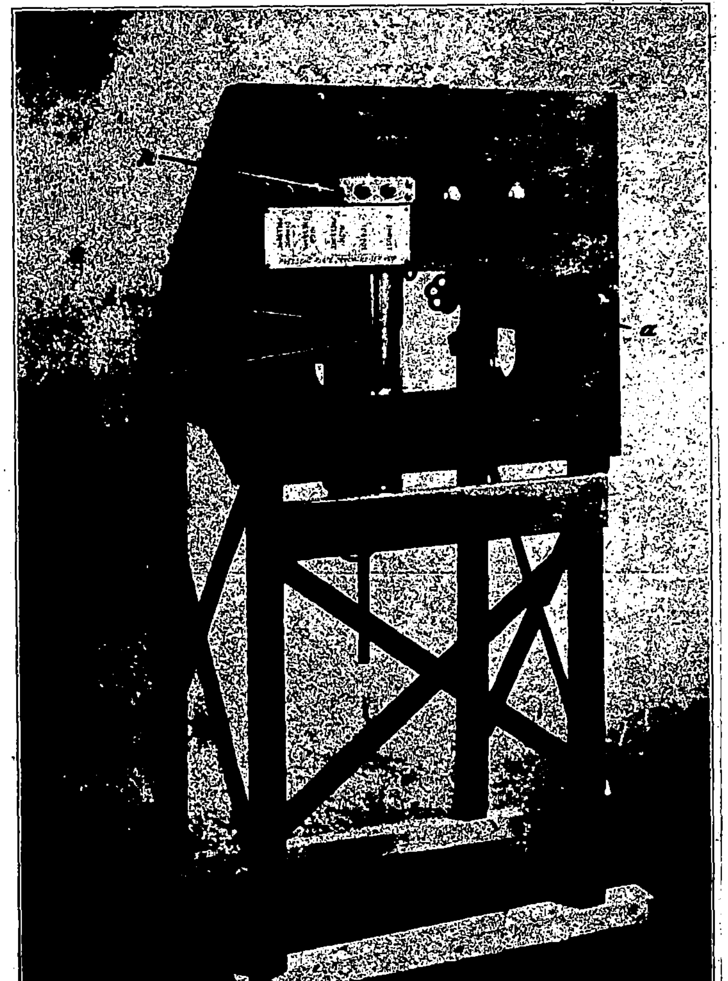

Fig.12 Rear view of instrument table
a) Air cyl. c) Oil cyl. i) Oil tank
k) Connections for dynamometer hub and pressure disk.

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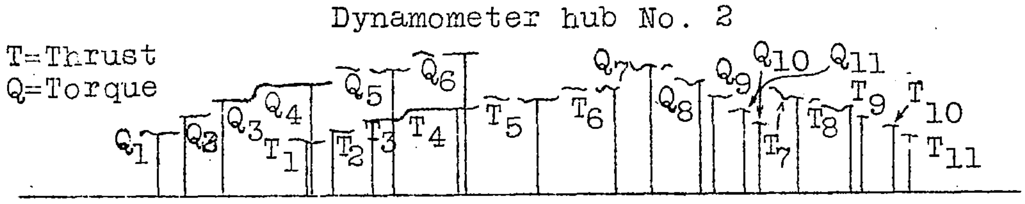

Fig. 13 Test diagram of dynamometer hub, made on electric test bench

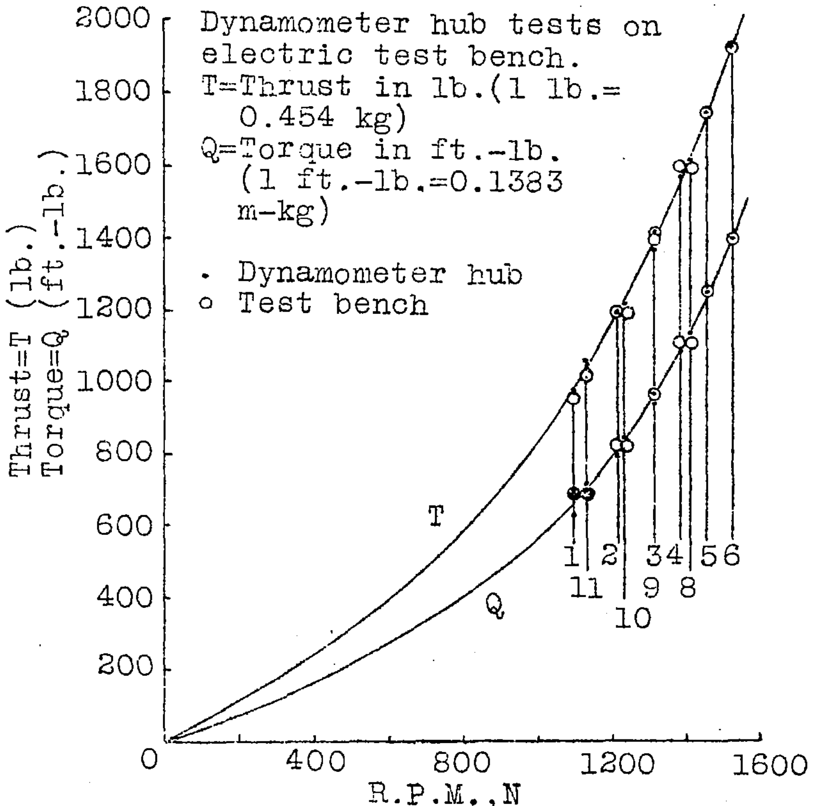

Fig. 14 Test diagram of dynamometer hub according to values obtained from Fig. 13

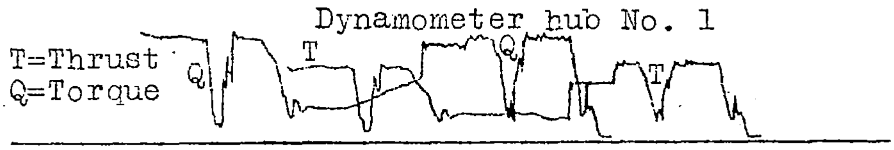

Fig. 15 Diagram of dynamometer hub for Liberty engine at different loads.