INSTALLATION
OPERATION
MAINTENANCE

FROUDE

HYDRAULIC DYNAMOMETERS

TYPES G. and GB.

Instruction Manual
No. 543/4

HEENAN & FROUDE
WORCESTER ENGLAND

INDEX

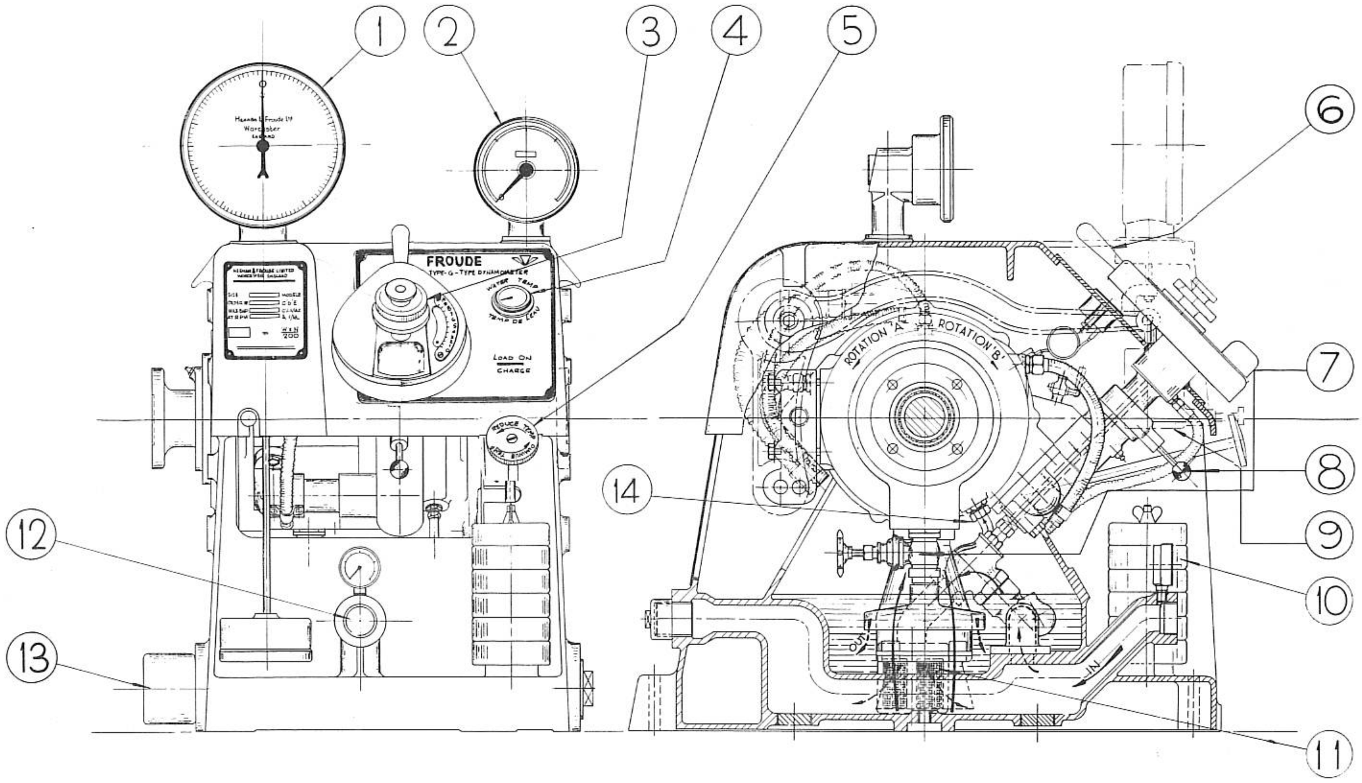

Fig. 2. Typical General Arrangement of Froude G. Type Dynamometer.

1. Spring Balance } with Swivelling Dials
2. Tachometer }
3. Load Control Handwheel
4. Water Outlet Thermometer
5. Water Temperature Control
6. Release Load Control
7. Water Outlet Valve (with Orifice)
8. Locking Catch for item 6
9. Weighing Gear Dashpot
10. Balance Weights
11. Water Inlet Strainer
12. Water Inlet (either side)
13. Water Outlet (either side)
14. Pump Seal Water Feed

DESCRIPTION

1. PRINCIPLE AND CONSTRUCTION

The G. type Dynamometer is a later type of machine, and while the rotor and liners follow the conventional Froude pattern, this dynamometer differs from the earlier DPX. type as follows:

(*a*) The sluice gates are replaced by a self-contained pump and small load control valve, which results in a smoother water flow around the power absorbing cups.

(*b*) The Dynamometer, complete with weigher gear, instruments and load control, is completely housed within an outer casing, which also forms the bedplate and is thus streamlined and compact.

(*c*) There are no contact shaft seals or glands thereby reducing maintenance and shaft wear.

(*d*) The torque weighing gear contains a high ratio breakdown lever, which enables small and easily handled balance weights to be used.

(*e*) The Dynamometer is designed to be readily adaptable to cater for conditions of higher power absorption and higher speeds (see Section 7); also the design is so arranged that any of the standard accessories listed in Section 7 can be added to the machine without much difficulty.

(*f*) An alternative and lower minimum power absorption can be obtained by running the machine in the opposite direction to normal (see Section 4).

(*g*) The rotor, stators and pump impeller are in high grade cast-iron and in the GB. type machines they are in bronze.

A typical general arrangement of the G. type Dynamometer is shown in Fig. 2 and a general idea of the appearance of the machine can be obtained from the illustration shown in Fig. 1.

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2. SCIENTIFIC ACCURACY

It will be seen that the forces resisting rotation of the Dynamometer shaft may be divided into four main classes:

(*a*) The hydraulic resistance created by the rotor.

(*b*) The hydraulic resistance created by the pump impeller.

(*c*) The friction of the shaft bearings which are of the ball and roller type.

(*d*) The power required to drive the tachometer.

It will be noted that every one of these forces reacts upon the casing which, being free to swivel upon anti-friction trunnions, transmits the whole of the forces to the weighing apparatus. Therefore, every force resisting rotation of the engine shaft is caused to react upon the weighing apparatus, thus ensuring scientific accuracy. In addition the weighing gear can be checked and adjusted, if necessary, to maintain high accuracy (see Section 18).

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3. METHOD OF LOAD CONTROL

Referring to the cross sectional arrangement of the Dynamometer, Fig. 3, it will be seen that the rotor and stators incorporate power absorbing cups of the conventional Froude pattern and the power absorbing cups are vented to atmosphere by means of holes drilled in the stator vanes communicating with the vortex centre of the power absorbing cups.

Integrally mounted on the Dynamometer shaft on one side of the Dynamometer rotor is a simple pump impeller which draws water from the inlet feed sump formed in a portion of the bottom half of the Dynamometer outer casing. The water is delivered from the periphery of the impeller in a tangential direction (Rotation 'A') to the load control valve from whence it is fed to the water inlet compartments behind each of the two half stators. The water then passes through feed holes drilled through the stator

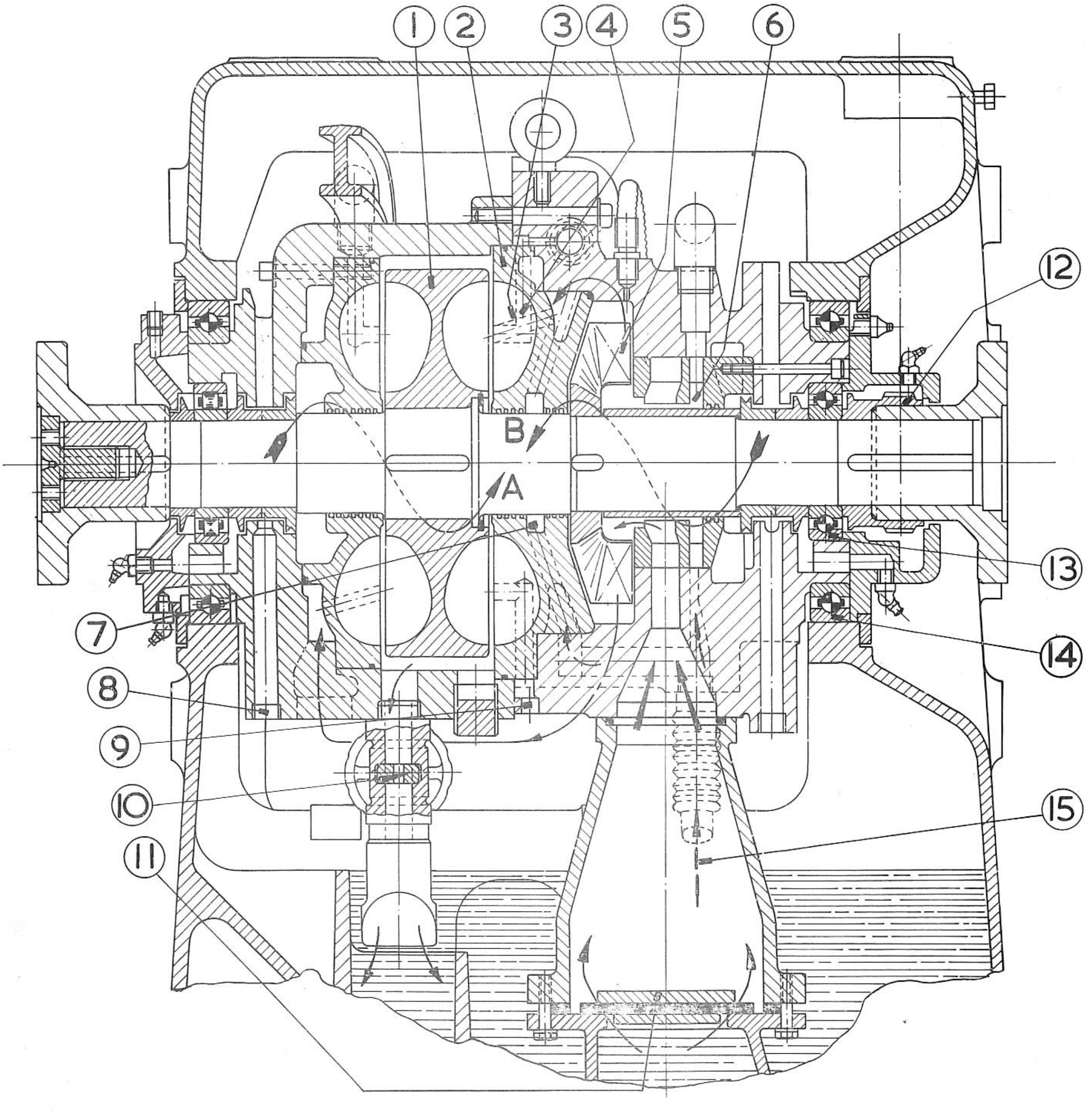

Fig. 3. Typical Cross-Section through Casing, Froude G. Type Dynamometer.

1. Rotor
2. Stators
3. Water Inlet Holes } in Stator Vanes
4. Air Vent Holes } in Stator Vanes
5. Pump Impeller
6. Pump Inlet Water Seal Compartment
7. Stator Annular Water Seal
8. Water Leak-off Holes
9. Air Vent Holes
10. Water Outlet Valve (with Orifice)
11. Pump Suction Flap-Valve
12. Tachometer Drive Gears
13. Shaft Bearings
14. Casing Trunnion Bearings
15. Pump Seal Water Inlet

vanes and is introduced into the power absorbing cups at the vortex centre, from whence it is accelerated into the vortex stream in the power absorbing cups due to the velocity of the rotor.

In operation the Dynamometer does not always work with the casing and power absorbing cups full of water. It is actually by altering the amount of water in the power absorbing cups that the power absorbed by the Dynamometer can be varied widely within the confines of the guaranteed capacity curve. The amount of water in the power absorbing cups depends on two factors:

(1) The rate at which water enters the casing.
This is only dependent upon the pressure exerted by the pump impeller and the consequent volume of water passing through the load control valve according to the position set by the operator. All load control adjustments must be made with this valve.

(2) The rate at which water leaves the casing.
This is controlled by the fixed orifice drilled in the gate of the outlet valve situated at the bottom of the casing and thus is dependent upon the water pressure generated within the Dynamometer casing. Normally the outlet valve itself is shut but, if desired, possibly to improve certain running conditions or to reduce the water temperature within the casing, this valve may be opened slightly by the operator to suit requirements. This valve should be adjusted with care and a consequent change in load and speed due to this should be corrected by re-adjustment of the control valve.

The vortex action in the power absorbing cups due to rotation produces a water pressure rise in the Dynamometer casing on the exterior of the rotor. The pressure thus generated allows the water to flow through the orifice in the outlet valve or, in addition, the partly opened outlet valve in the bottom of the Dynamometer casing, from whence it collects in the hot water sump in the middle of the base of the Dynamometer outer casing or bedplate. A certain proportion of this outlet water also passes through the clearance seals in the bore of the stators, on the one side of which it is discharged into the hot sump and on the other side into the stator annular seal where it mixes with cold water and is re-circulated or overflows to drain.

Due to the water feed pump impeller being mounted directly on the Dynamometer shaft, it follows that, for any given setting of the load control valve, the quantity of water fed into the Dynamometer power absorbing compartment is proportional to the speed of rotation. This feature ensures that the amount of water circulating in the power absorbing cups of the working compartment is maintained substantially constant despite any speed variation. This provides the condition necessary to ensure that the Dynamometer characteristic follows an approximate square law for torque readings, or propeller (cube) law for power readings, with respect to speed at a constant load control setting.

Furthermore, should the speed of the prime mover on test tend to rise, the pump impeller automatically feeds more water to the power absorbing elements, and the speed increasing tendency is checked. On the other hand the opposite effect takes place if the speed tends to fall.

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4. POWER ABSORBING CAPACITY

The Dynamometer can be run in either direction of rotation. The maximum and minimum capacities are, however, very much greater in the forward or 'A' direction of rotation than in the reverse or 'B' direction of rotation. Thus, when consulting the capacity diagram in conjunction with the output and rotation of the prime mover to be tested, the very wide testing range of power and speed which can be obtained should be born in mind, particularly with regard to minimum capacities.

The foregoing applies with the outlet valve shut and water passing through the orifice in the valve gate. However, the minimum capacity may be further reduced by gradually opening the outlet valve. This valve should be returned to the closed position for normal testing, except at very high powers and speeds when it may be re-opened very slightly but only if the water outlet temperature is too high.

When the load control valve is fully open, full maximum capacity of the Dynamometer is obtained. This capacity is shown by the full line on the capacity diagram for the forward direction of rotation, i.e. direction 'A', and by the dotted line for the reverse direction of rotation, i.e. direction 'B'. Normally the outlet valve should be shut.

Similarly, when the load control valve is fully closed and the outlet valve is open the Dynamometer will run on its absolute minimum capacity, and this is shown by the lower full and dotted lines on the above mentioned capacity curve for forward and reverse directions, i.e. rotations 'A' and 'B' respectively.

5. REVERSIBILITY

The Dynamometer rotation is unidirectional insofar as the machine will only absorb the higher powers 'A' shown on the capacity diagram in one direction and the lower powers 'B' in the opposite direction. If it is required to absorb the absolute maximum of power in the reverse direction of rotation, the Dynamometer must be turned through 180° relative to the output shaft of the prime mover.

The Dynamometer holding-down bolts, coupling faces, water inlet and outlet connections etc., are symmetrically disposed about the centreline to facilitate turning the machine around. The base of the outer casing of the Dynamometer is provided with a central machined diametral recess which can engage with a male spigot set in the underlying baseplate or foundation. If necessary, a suitable sole plate can be supplied to underlie the Dynamometer outer casing which is provided with the male half of the central pivot to facilitate turning the Dynamometer round end for end. The cardan shaft guard would have to be readjusted for length so as not to foul the Dynamometer outer casing if the machine is turned round for 'B' rotation.

The forward direction of rotation 'A' and the reverse direction 'B' are indicated by arrows on the end face of the Dynamometer outer casing. The load control valve itself is enclosed by a rotatable sleeve operated by a knob (Item 6, Fig. 4) situated immediately above the main control handwheel. Accidental rotation of this sleeve is prevented by means of a spring-loaded plunger (Item 8, Fig. 4) situated below the instrument panel. For normal running conditions this sleeve is set so that the release load control (Item 6, Fig. 4) is vertically above the load control handwheel (Item 3, Fig. 4), and the sleeve remains in this position for both directions of rotation, i.e. 'A' or 'B'. The sleeve need only be moved if load throw-off is desired—See Section 6.

6. LOAD THROW-OFF DEVICE

In addition to the normal setting of the load control valve sleeve mentioned in the preceding section, a second position of the rotatable sleeve, at 90° to the right of the normal control position, is marked "Load Off". When this sleeve is rotated so that the arrow contained thereon lines up with the "Load Off" position on the control panel, the water supply from the pump to the interior of the Dynamometer is cut off. This results in the Dynamometer casing emptying quickly via the orifice in the outlet valve thus throwing off the Dynamometer load entirely except for a very small amount of power which is the minimum absorbed by the pump impeller.

When the control sleeve is turned to the "Load Off" position, the main load control handwheel is not touched. When therefore the sleeve is returned to the normal control position, i.e. "Load On" position, the Dynamometer is able to take up its previous conditions of speed and load. This control is therefore, very convenient when it is required to test the behaviour of the overspeed governor or cut-out of the prime mover on test.

7. DYNAMOMETER VARIATIONS AND ACCESSORIES

The G. type Dynamometer is fitted with high duty iron internals to cater for the capacities and speeds shown on the standard capacity diagram. The design is such, however, that it can easily be converted, firstly, to a higher range of powers and speeds by the incorporation of special bronze internals, the machine then being designated the GB. type; secondly, it can be converted for still higher powers and speeds by incorporating a cropped type rotor and a different method of control, this variation being designated type G. 90. These variations should be covered initially but if an existing machine is to be modified it should be returned to Heenan & Froude Ltd.

In addition to the foregoing, various accessories and alternative methods of indicating torque and speed can be incorporated as follows:

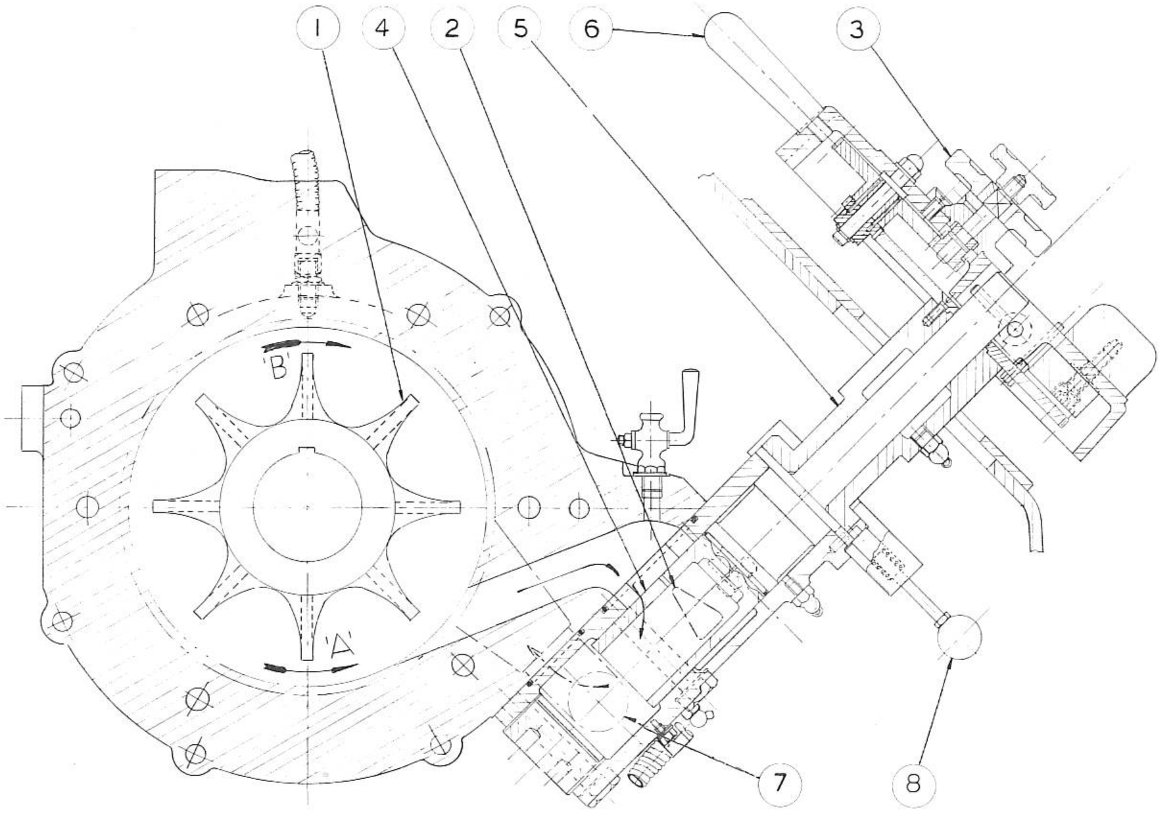

Fig. 4. Sectional Arrangement of Control Valve,
Froude G. Type Dynamometer.

A—Normal Direction of Rotation

B—Reverse Direction of Rotation

1. Pump Impeller
2. Load Control Port
3. Load Control Handwheel
4. Load Control Sleeve
5. Rotatable Valve Sleeve
6. Release Load Control
7. Water Feed Port to Stators
8. Locking Catch for item 6

(*a*) The standard spring balance can be replaced by one having a larger capacity balance capable of indicating the full Dynamometer torque irrespective of dead weights and graduated in weight or torque units.

(*b*) The standard instrument for indicating speed is a mechanically driven magnetic tachometer with counter. This can be replaced by an electrical tachometer for remote indication, or, in the case of high speeds, i.e. GB. or G.90 Dynamometers, by a Sunbury head operated tachometer, with or without a revolution counter.

(*c*) The standard machine is fitted with a manually-operated control valve but this can be motorized for remote control.

(*d*) The standard mechanical type weighing gear can easily be replaced by a pneumatic capsule and indicating gauge or weighing head indicator for remote indication; load cell with pre-selective change scale indicator may be incorporated.

(e) A test arm assembly complete with check weights can be supplied as a standard unit for checking the accuracy of the weighing gear for both English and Metric machines.

(*f*) A simple torque strap can be supplied to lock the Dynamometer shaft coupling to the casing so that the Dynamometer can be used with its shaft stationary for indicating the stalled torque of turbines.

(*g*) A self-contained friction brake can be supplied to increase the inherent capacity of the Dynamometer at low speeds down to stalled conditions. This unit is fitted to the end of the Dynamometer opposite to the tachometer drive but does not interfere with the connecting of the prime mover to this end of the Dynamometer shaft. This unit (if supplied) makes item (f) unnecessary.

For continual use at high speeds the bearing lubrication can easily be changed from grease to oil-mist lubrication.

Separate instructions are supplied for any of the above accessories when fitted to a Dynamometer.

In addition, standard or special designs of test house accessories are available including the following:

Water Coolers	for continuously re-cooling and re-circulating the water required by the Dynamometer and the engine on test, if necessary. Such water coolers save 90 to 97 per cent of the water circulating, according to atmospheric conditions, thus providing a large financial saving. They also render the Test House almost independent of the town's mains supply.
Engine Stands	of which several sizes of standard design are available, universally adjustable to permit a range of engines to be mounted.
Cardan Shafts	in a range of standard sizes, for connecting the engine on test to the Dynamometer.
Engine Starting and Running-in-Gears	electric-motor driven, with self-disengaging coupling to the Dynamometer shaft.
Fuel Flowmeters	for measuring instantaneously the rates of flow of fuels such as petrol.
Fuel Consumption Weighers	for measuring consumption of petrol or diesel fuels by weight over a time interval.
Control Panels	usually designed to meet individual needs, fitted with instruments to suit requirements and arranged remotely from the Dynamometer if necessary.

GENERAL INSTALLATION INSTRUCTIONS

8. FOUNDATIONS

To assist steady running and eliminate vibration the Dynamometer should be set down and carefully levelled on a reasonably substantial foundation. The holding-down bolts should be made perfectly secure. If the machine is set down on a concrete foundation, levelling shims should be used before grouting in the holding-down bolts and the latter should be allowed to set hard before the machine is run. Grouting may be made up around the baseplate of the outer casing if desired.

Means should be provided to connect the Dynamometer coupling to the prime mover and to carry the latter in correct alignment. If necessary, engine starting arrangements should be provided at the end of the Dynamometer opposite to that of the prime mover. Water inlet feed piping and outlet piping should be provided to couple up to the appropriate connections on the lower half of the outer casing of the Dynamometer. An inlet or isolating valve should be fitted close to the inlet connection on the Dynamometer outer casing. This is required in addition to the water temperature control valve fitted inside the outer casing of the Dynamometer.

The control levers of the engine or prime mover should be arranged in a convenient position as near as possible to the load controlling handwheel of the Dynamometer, and of a type which permits instantly shutting down the engine in emergency. In addition, an ignition switch should be permanently attached to the control desk. We can supply special tachometers which automatically shut down the engine at a predetermined but adjustable overspeed.

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9. WATER SUPPLY

The quantity of water required to carry away the heat generated by the destruction of power can be calculated with a very close approach to precision. Each Brake Horse Power absorbed generates 2,545 B.T.U. of heat per hour, or 42.4 B.T.U. per minute, nearly all of which passes into the cooling water. The quantity of water supplied to the Dynamometer must be sufficient to prevent the temperature at the outlet rising about 140°F. (or 60°C.).

If the water supply on site is very restricted, it is permitted in unusual cases to allow the temperature at the Dynamometer outlet to reach 150°F. (or 65°C.). Higher temperatures than this (165°F. or 75°C. maximum), while they would not affect the safe and accurate working of the Dynamometer, tend to decrease the working life. Water outlet temperature means casing outlet temperature indicated by the thermometer on the control panel and not the mixed water outlet temperature of water issuing from the Dynamometer baseplate. A minimum allowance using mains water and assuming an inlet temperature of 50/60°F. (or 10/15°C.), is 3 gallons of water per B.H.P. per hour. The pipe lines, however, should be designed to pass 5 to 6 gallons per B.H.P. per hour without undue loss of pressure, particularly if operating in conjunction with a water cooler where it is possible that the water inlet temperature may be as high as 95° to 100° F.

In order to protect the power absorbing elements and the adjacent parts of the working compartment from corrosion erosion, it is of the highest importance that the circulating water should be as free as possible from any mechanical impurities such as dirt and sand and from acidity. Any very soft or acid water should be treated with lime or soda ash in sufficient quantities to neutralize the acidity and keep it definitely alkaline (see General Care and Maintenance—Section 19 Water Supply).

In all cases where re-circulated water is used and where cooling is performed by an evaporative process, the entire cooling system should be emptied of water at intervals and, after being cleaned, should be refilled with clean fresh water. This operation should be repeated sufficiently frequently to prevent the solids in solution content rising above 100 parts per 100,000, and preferably much below this value. For normal conditions the frequency of cleaning should be about once per week. The foregoing applies more particularly to the larger sizes of Dynamometers, or when testing at high powers and speeds. Sea water may be used only at the risk of accelerating corrosion erosion, and although numbers of Froude Dynamometers have worked long periods of time with sea water, the life of the elements is undoubtedly shortened thereby.

The base of the Dynamometer outer casing is divided by weirs into three compartments. One forms the pump suction compartment from which the pump draws water through a foot valve and into which a supply of cooling water is fed through the temperature control valve. The middle compartment is the hot well into which the Dynamometer outlet water is discharged. The third compartment performs the function of an open flow drain outlet. The weir plate between the hot well and drain compartments is higher than the one between the hot well and pump suction compartments.

If insufficient cold water is fed to the pump suction (i.e. right-hand) compartment the water discharged from the Dynamometer into the centre compartment will flow partly over the left-hand weir to drain, and partly to the right into the suction compartment from whence it is re-circulated, together with the additional cooling water brought in through the temperature control valve. If excess cold water is fed to the pump suction compartment it will flow to the left into the central hot well compartment and be discharged over the weir into the drain compartment together with the hot water from the Dynamometer outlet.

In effect, at a constant load and speed setting, a constant volume of water is fed through the main control valve and a similar quantity is discharged through the casing orifice outlet or valve into the central compartment hot sump in the baseplate. If this casing outlet water is too cold, the temperature control valve fitted in the main feed to the pump suction compartment in the baseplate is restricted, thus allowing some of the warm casing outlet water to byepass over the weir into the pump suction compartment which then acts as a water mixing chamber by elevating the temperature of the water feed at the pump suction until a balance is obtained and the resulting water outlet temperature from the Dynamometer casing is at the figure desired. It is better to set these conditions with the engine on full power, then, unless it is absolutely necessary to conserve water, the temperature control valve setting can remain untouched for all intermediate testing at lower powers. Thus, by regulating the temperature control valve mounted on the control panel to maintain a water outlet temperature of about 140°F. (60°C.) the utmost economy of cooling water can be obtained. The Dynamometer casing outlet temperature is shown by a small thermometer mounted on the control panel.

The temperature control valve which is internal to the Dynamometer outer casing, controls the amount of water flowing; however the user should provide an inlet or isolating valve in the water feed pipe close to the Dynamometer.

To prime the pump and prevent ingress of air to the pump through the non-contact shaft seals, a small quantity of water is bled from the main Dynamometer inlet feed line through a restrictor to the pump seal compartment. Some of this seal water leaks through the shaft seals and the remainder is discharged through the overflow pipe (see Fig. 3) from the pump seal compartment. Provided some water is always being discharged from this pipe the pump will remain primed and will function correctly. The engine should be run on light load for a minute or so with the control valve closed to allow the pump to prime itself properly before the control valve is opened to load the engine.

From the same feed mentioned in the previous paragraph further holes drilled in the casing and stators lead water to a further pump seal situated in the centre of the labrynth bore of the right-hand stator. Excess water discharged from here is taken via a passage at the rear of the stator to a vent at the top of the casing which discharges through a flexible pipe to the Dynamometer sump (see Fig. 3).

If the water supply pressure is higher than 15/20 lb. per square inch (1.0/1.3 Kg. cm. ^{2}) when the required amount of water is flowing, the isolating inlet valve supplied by clients should be partly closed to reduce the feed pressure to the Dynamometer. Too high a pressure will tend to overfill the Dynamometer casing thus causing excessive load under low speed idling conditions. This is due to water under excessive pressure leaking from the stator seal compartment along the shaft clearance and into the rotor compartment.

If water is very scarce it is possible to reduce the flow by adjusting the water inlet isolating valve to maintain a constant inlet pressure of 8 lb. per square inch (0.55 Kg. cm.^{2}), the absolute minimum, regardless of the setting of the temperature control valve. This should ensure that a minimum quantity of approximately 150 gallons (700 litres) per hour is fed to the pump seals to keep the pump suction primed and in addition this pressure should ensure that sufficient water is fed to the Dynamometer itself when the main control valve is opened. The above conditions are minimum requirements, but if the pump supply pressure is higher than that stated, when testing smaller engines the water flow can be reduced by closing down the water inlet isolating valve and adjusting the water temperature control valve to suit, until under maximum power conditions the water is leaving the Dynamometer at approximately 140°F. (60°C.).

10. DRAINS

The Dynamometer casing is self draining from the orifice situated in the outlet valve at the bottom of the casing and thus there is no danger of freezing. The outlet water from the Dynamometer bedplate sump relies on gravity flow and therefore a pipe of ample dimensions and free from sharp bends should be led from the Dynamometer baseplate outlet connection to the nearest sump, drain or hot well. The outlet pipe should have a gradual fall and it should be as short in length as possible to avoid flooding back to the Dynamometer baseplate.

All other leak-offs, drains etc., from the Dynamometer casing are freely discharged into the Dynamometer baseplate. There is thus only one main outlet connection to make in order to carry all the water away to drain, sump or hotwell.

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11. ENGINE CRADLE

The cradle or stand for supporting the engine should be of rigid design, adequately bolted to suitable foundations and in correct alignment with the Dynamometer. The engine feet may be flexibly mounted if desired. In cases where there are a variety of engines to be tested, it is convenient to use an adjustable type of cradle of which we can supply several models. Whatever system is adopted for coupling the engine to the Dynamometer, the shafts of both units should be closely aligned.

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12. CARDAN SHAFTS

The Dynamometer shaft is not designed to withstand heavy bending moments, which can be caused by the use of heavy couplings, flywheels, cardan shafts etc., or by misalignment between Dynamometer and engine. For this reason self-aligning or flexible couplings should be used, of the lightest possible construction consistent with safety and in very good dynamic balance, preferably consisting of cardan shafts with two Universal joints and of a design which prevents whirling. We have special cardan shafts available to suit all G. type Dynamometers.

Flexible cardan shafts should have a centring device at each end, and it is preferable to have a telescopic joint in the centre portion to facilitate engine coupling up or disconnection.

If a single flexible joint is used instead of a cardan shaft, it should not be fitted with a centring device, and the design should be such as to maintain dynamic balance while running. In the absence of a cardan shaft, alignment between engine and Dynamometer must be carried out with exactitude. Cardan shafts or flexible couplings should be mounted in such a way as to avoid overhang from the bearings of the Dynamometer shaft. Heavy or long face to face adapters should not be used; in cases where such connections are necessary they should be of the smallest possible diameter. In case of doubt as to the permissibility of individual arrangements, do not hesitate to consult us.

Any shaft, such as an in-line starting shaft, driving the Dynamometer should be supported in its own independent bearings and a flexible joint or disengaging clutch should be used to connect it to the Dynamometer. It is inadvisable to support such a shaft by a single outer bearing while relying solely upon the Dynamometer bearing at the inner end; in such cases misalignment may be present to an extent which, while not preventing the outer bearing from running cool, will impose a heavy bending movement on the Dynamometer shaft.

Heavy steel guards should be provided around cardan shafts and couplings. Facings are provided on the end face of the Dynamometer outer casing to facilitate the adequate and centralized fitting of a cardan shaft guard.

It is preferable that the inside of the guard is made perfectly concentric and close fitting to the outside diameter of the cardan shaft to prevent whirling in the event of breakage. The guard should be split along the horizontal centre to facilitate examination and removal of the cardan shaft.

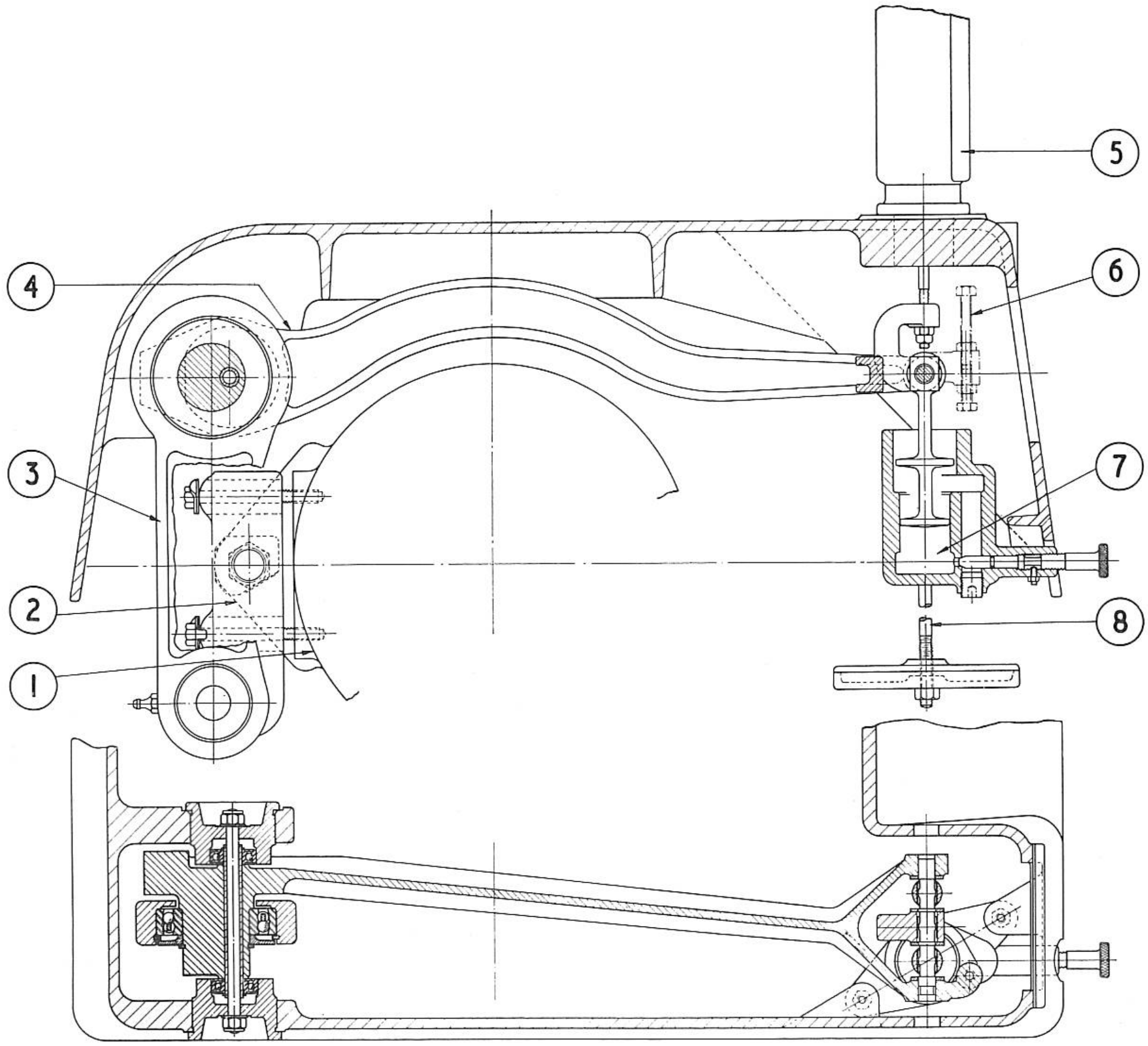

Fig. 5. Arrangement of Weighing Gear,
Froude G. Type Dynamometer.

1. Dynamometer Casing
2. Balance Arm
3. Connecting Link
4. Reducing Lever
5. Spring Balance
6. Lever Motion Stops
7. Dashpot
8. Balance Weight Bolt

13. DASHPOT

The extremity of the reducing lever of the weighing gear is fitted with a rigid pin which has three connections—(1) to the spring balance, (2) to the balance weight bolt and (3) to the dashpot—all with self-aligning bushes. The body of the dashpot is mounted rigidly inside the top half of the Dynamometer outer casing underneath the reducing lever. The function of the dashpot is to damp out any inequalities of torque so as to obtain a steady reading on the spring balance. The dashpot should be filled with a light grade of oil (see General Care and Maintenance, Section 21), and it is important to ensure that the dashpot is completely filled and all air ejected from the underside of the piston (see Item 7, Fig. 5).

Access for this purpose is obtainable by removing the small detachable cover or nameplate in the Dynamometer outer casing immediately under the spring balance. The dashpot is fitted with a byepass needle valve to adjust the amount of damping to suit any particular running condition and this adjustment is obtained by a small knurled nut which projects outwards through a hole in the side of the Dynamometer casing. To increase the amount of damping the needle valve is rotated in a clockwise direction.

If it is desired to remove the needle valve, first unscrew the locating peg on the underside and drain the oil. The drain plug is situated at the base of the dashpot body (see Fig. 5).

WORKING INSTRUCTIONS

14. STATIC BALANCE

Before commencing a test it is important that the Dynamometer should be checked to ensure that the static balance of the weighing gear is correct. The procedure is as follows:

(1) It is immaterial whether or not the Dynamometer is coupled up to the engine.

(2) Partly open the water inlet isolating valve, which should be fitted when the water supply is connected to the front of the Dynamometer at a point between the spring balance weight pan and the parked balance weights; alternatively at the other connection on the opposite side of the machine (see Fig. 2).

(3) Make sure that the load control valve and the water temperature control valve on the control panel are fully closed, i.e. minimum load (see Fig. 2).

(4) Make sure that the rotatable sleeve embracing load control valve is set to correct position for loading, i.e. not to "Load Off" position (see Section 6).

(5) Make sure that the removable static weight (painted RED) is on or off the balance weight bolt according to whether 'A' or 'B' direction of rotation is required (see Section 16 and Fig. 6), and that all other loose balance weights are removed.

(6) Adjust dashpot byepass to zero or free setting (see Section 13) by unscrewing the knurled nut (anti-clockwise).

(7) Check that the Dynamometer spring balance indicates zero by depressing and lifting the balance weight bolt to ensure that the spring balance pointer returns to zero or to a position equidistant each side of zero.

(8) If the spring balance pointer does not indicate zero, rotate the small screw (in the appropriate direction) which can be found underneath the small plate marked "Adjust" situated on the top of the spring balance casing. If the zero setting for some reason is considerably out, then the value of the static weight must be adjusted.

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15. RUNNING CONDITIONS

(1) The Dynamometer is then ready for running and the engine can be started up under light load and low speed conditions, i.e. with the control valve at MINIMUM setting.
After starting up the engine allow it to idle for a few minutes to allow the Dynamometer pump suction to prime itself before the control valve is opened to pass large quantities of water through the Dynamometer.

(2) The load control handwheel at the Dynamometer should then be rotated in a clockwise direction (i.e. screwing outwards) to increase the load, while at the same time opening the engine throttle until the desired conditions of load and speed are obtained. Alternatively, after the engine is on full throttle, the load and speed can be adjusted entirely by means of the Dynamometer load control handwheel.

NOTE. If valve tends to become slack or to rotate under vibration, gently tighten the thumb screw which operates a friction lock against the threaded valve spindle.

(3) When running at the desired conditions of load and speed, the required degree of weighing gear damping can be obtained by adjusting the dashpot needle valve situated immediately below the spring balance. Damping is increased by rotating the needle valve in a clockwise direction (see Section 13).

(4) Add extra balance weights to the balance weight bolt as required, when the engine torque exceeds the capacity of the spring balance.

(5) When the engine has been set to the required running condition, the Dyanmometer temperature control valve should be adjusted to obtain a water outlet temperature of between 130° and 140°F. (55° to 60°C.) as shown by the dial thermometer provided (see Water Supply, Section 9).

(6) Normally the orifice in the outlet valve is capable of passing sufficient water from the Dynamometer casing to keep it cool. However, if the casing tends to overheat, the valve may be opened very slightly to reduce the temperature, followed if necessary by re-adjustment of the inlet control valve to restore the original load. In addition, if the Dynamometer load in any way tends to become unstable, this may be improved by careful adjustment to the outlet valve, with a corresponding adjustment to the control valve if necessary.

(7) Governor tests can be conducted, if required (see Section 6), by operating the load throw-off device.

(8) At the conclusion of a test the engine can be shut down on its own, or alternatively, if desired, by reducing the Dynamometer load simultaneously with the closing of the engine throttle.

Leave all other valves as set if desired to start up again; if not, simply close isolating inlet valve in water feed pipe close to the Dynamometer.

16. TORQUE MEASUREMENT

The torque absorbed by the Dynamometer is indicated on the spring balance dial mounted on top of the outer casing of the Dynamometer and this is supplemented by small balance weights of known value which can be added as desired to the balance weight bolt under the spring balance. The sum total of these two items represents the total torque input to the Dynamometer (see Section 17).

A loose static weight (painted RED) is provided equivalent to a full scale reading on the spring balance. For the forward or 'A' direction of rotation this static weight should be in position on the balance weight bolt. This converts the spring balance into a relieved load type, i.e. the pointer rotates in an anti-clockwise direction when torque is applied, and its range is extended by adding the balance weights to the balance weight bolt.

For the reverse or 'B' direction of rotation, the loose static weight (painted RED) is removed, and this converts the spring balance to a direct reading type, i.e. the pointer rotates in a clockwise direction when load is applied. For this direction of rotation ('B') the spring balance is capable of measuring the maximum torque shown on the capacity curve without the use of extra balance weights.

The arrangement of the torque weighing gear is shown in Fig. 5. The Dynamometer is adjusted and calibrated by Heenan & Froude Ltd. before despatch to ensure accuracy of torque weighing.

17. CALCULATION OF B.H.P.

The length of the balance arm of the Dynamometer combined with the ratio of the weighing lever is such that a very convenient formula is used for calculating the horse power absorbed by the Dynamometer.

If W = Nett weight lifted by the Dynamometer, i.e. spring balance reading plus amount of extra balanceweights in use,

N = Dynamometer shaft speed in revolutions per mintute,

K = A constant, the value of which is stamped on the Dynamometer nameplate,

$$\text{Then B.H.P.} = \frac{WN}{K} \text{ or C.V.} = \frac{WN}{K}$$

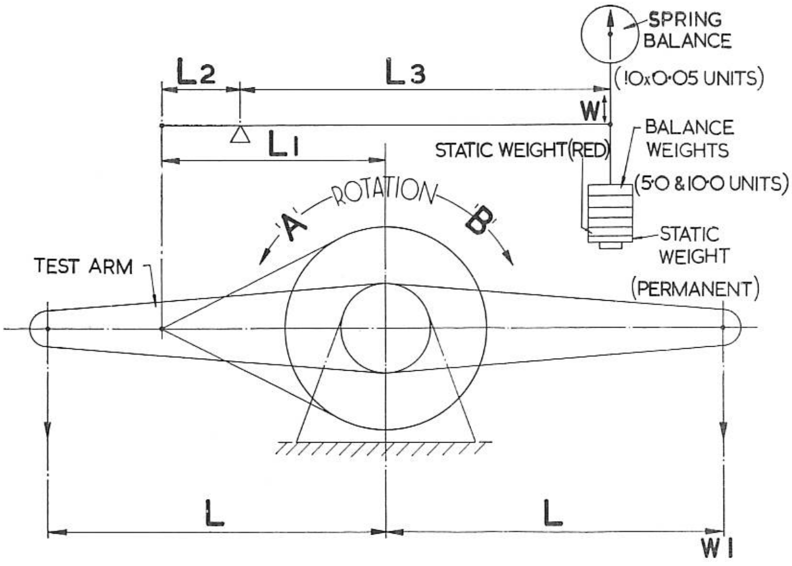

Fig. 6. Lever Lengths, Arm Ratios and Constants for Froude G. Type Dynamometers.

L1, L2, L3 — Weighing Gear Lever Lengths

W (a) Spring Balance
(b) Loose Balance Weights (Total)

R Effective Balance Arm Length

K Constant for Power Calculation

L Test Arm Length

$\frac{R}{L}$ Test Arm Ratio

$\frac{W1}{W}$ Test Weight Ratio

Symbol		ENGLISH MACHINES			METRIC MACHINES		
		G.3	G.4	G.5	G.3	G.4	G.5
L1		9.633″	8.285″	11.4592″	.241348 m.	.207568 m.	.287087 m.
L2		1.88″	0.539″	0.50″	.047752 m.	.01369 m.	.0127 m.
L3		20.50″	20.50″	27.50″	.5207 m.	.5207 m.	.6985 m.
W	(a)	10 units	10 units	10 units	10 units	10 units	10 units
	(b)	45 units	30 units	40 units	45 units	30 units	40 units
R		105.042″	315.127″	630.254″	2.63159 m.	7.89445 m.	15.7895 m.
K		600	200	100	600	200	100
L		31.5127″	31.5127″	37.815″	0.71619 m.	0.71619 m.	0.85918 m.
$\frac{R}{L}$		3.33:1	10:1	16.66:1	3.6744:1	11.0227:1	18.377:1
$\frac{W1}{W}$		$3.33:1\left(\frac{lb.}{units}\right)$	$10:1\left(\frac{lb.}{units}\right)$	$16.66:1\left(\frac{lb.}{units}\right)$	$\frac{3.6744}{2.2046}=1.66:1\left(\frac{kg.}{units}\right)$	$\frac{11.0227}{2.2046}=5:1\left(\frac{kg.}{units}\right)$	$\frac{18.377}{2.2046}=8.33:1\left(\frac{kg.}{units}\right)$

In both English and Metric Machines the spring balance and loose weights are actually in English pound units.

Effective balance arm length $= R = \frac{L1 \times L3}{L2}$ (English in inches; Metric in metres)

$$\text{English B.H.P.} = \frac{2\pi WRN}{12 \times 33000}$$

$$\therefore \text{English B.H.P.} = \frac{WN}{K}$$

Where $K = \frac{33000 \times 12}{2\pi R}$ (R in inches; W in units—pounds actual)

Test Arm Ratio $= \frac{R}{L}$ (i.e. 10 units at spring balance (W) $= \frac{10 \times R}{L}$ lb. at W1 and $\frac{W1}{W}\left(\frac{lb.}{units}\right) = \frac{R}{L}$)

$$\text{Metric C.V.} = \frac{2\pi WRN}{4500}$$

$$\therefore \text{Metric C.V.} = \frac{WN}{K}$$

Where $K = \frac{4500}{2\pi R}$ (R in metres; W in units—pounds actual)

Test Arm Ratio $= \frac{R}{L \times 2.2046}$ because W units $= \frac{W}{2.2046}$ actual

(i.e. 10 units at spring balance (W) $= \frac{10 \times R}{2.2046L}$ kg. at W1 and $\frac{W1}{W}\left(\frac{kg.}{units}\right) = \frac{R}{L \times 2.2046}$)

In the G. type Dynamometer the marked values on the spring balance dial and the balance weights are referred to simply as units. In actual fact the calibrations are in English lb. weight. However, the reason for this is the fact that the Dynamometers can then be used for calculating both English B.H.P. and Metric C.V., while at the same time using the same horse power calculation constant K. To accomplish this end it is only necessary to make a slight adjustment in the ratio of the weighing gear to account for the small difference between English and Metric H.P., i.e. 0.9863 to 1.0. This adjustment is made at Heenan & Froude's Works before despatch, according to whether the machine is desired to conform to English or Metric standards. In this connection please refer to the weighing gear diagram, Fig. 6.

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18. CHECKING FOR ACCURACY

All Dynamometers are calibrated for accuracy before despatch by means of a static test arm. The test arm is located on and set-screwed to the bearing end cover at one end of the Dynamometer by threading it over the half coupling on the shaft. The test arm is a double arm which can be used for checking the accuracy of torque measurement in both directions of rotation. In the reverse direction of rotation it is only necessary to check the range of the spring balance. The test arm is provided at each extremity with two holes, which are jig-drilled to an accurate distance from the shaft centre-line. The inner of the two holes is utilized for testing Dynamometers to Metric standards and the outer hole is used for testing machines to English standards.

The Dynamometer itself should be set in static balance; the test arm is then attached and fitted with a weight bolt at either end. If necessary, a small temporary weight should be added to either side of the test arm to re-balance the Dynamometer to zero when the test arm is fitted. It is then possible to apply known weights to the end of the test arm, either in English lb. or Metric Kgs., to observe the readings given by the weighing gear. The records of such periodic check tests should be preserved for inspection in the event of any query concerning the accuracy of the Dynamometer. The test arm is a standard unit which can be supplied as an accessory with Dynamometer, or alternatively particulars for the manufacture of the unit can be supplied. In this connection please also refer to the weighing gear diagram, Fig. 6.

GENERAL CARE AND MAINTENANCE

19. WATER SUPPLY

The attention of Dynamometer users is drawn to the following points which have a great influence on the durability of the Dynamometer power absorbing elements:

(*1*) Cleanliness of circulating water.

(2) Maintenance of pH value between certain limits.

It is imperative that the circulating water which passes through the Dynamometer and the cooling plant should be free from abrasives such as sand, gravel, concrete, chips and dust etc., which are liable to be present on any site where building operations, road-making, etc., may have been in progress.

The life of the power absorbing elements will be increased by periodic attention to the circulating water, including the following:

(*a*) In the case of a new installation, before starting up the Dynamometer, the entire system should be thoroughly scraped as far as possible and flushed out with circulating water, replaced twice before it is admitted to the Dynamometer.

(*b*) The make-up water supply to the cooling plant should be entirely free from abrasives and should be treated suitably to raise its pH value to between 8 and 8.4.

(*c*) The whole of the circulating water should be tested at frequent intervals and the treatment regulated to maintain the pH value within the above mentioned limits.

(*d*) In order to economise in the use of soda ash and like additives, users at one site have found that a small quantity of borax (4 parts) and boric acid (1 part) dissolved together in a bucket is capable of raising the pH value effectively. In their case they add about 25 lb. of the mixture to each cooler whenever replacing with fresh water and about half this quantity once weekly.

(*e*) Once monthly each cooler should be drained and the tank scraped free of sediment and finally flushed with clean water. On re-filling the system the pH value should be raised to approximately 8.4 in readiness for the ensuing month's run, during which the pH value should not be allowed to fall below 8.0.

(*f*) The use of fine strainers in the inlet tank of the water coolers notably helps to extract harmful mechanical impurities from the water and these strainers should be examined and cleaned regularly.

(*g*) Once every twelve months the interior of the cooler casing and screen frames should be scraped and painted with Bitumastic paint.

(*h*) The strainer at the water inlet inside the sump of the baseplate should be periodically removed for examination and cleaning if necessary. Any restriction here will possibly cause overheating.

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20. BEARINGS

The Dynamometer shaft bearings are grease lubricated and should be lightly charged with Shell Alvania No. 3 Grease, or equivalent, at approximately one monthly intervals. The Dynamometer shaft is carried on a locating ball bearing at the tachometer drive end and a roller bearing at the opposite end.

The casing trunnion bearings and weigher lever bearings are also grease lubricated but only require lightly charging with grease at approximately six monthly intervals. The recommended grease is Shell Alvania No. 3 Grease, or equivalent.

It is highly important never to let any water or moisture reach the bearings, and the housings should not be grease packed too tightly as overheating in the case of shaft bearings and stiffness in the case of trunnion and weighing gear bearings may result from this condition.

Removal of Bearings.

(1) Do not remove bearings from the shaft unless absolutely necessary.

(2) If removed, the bearings must be washed out thoroughly with clean petrol before replacing.

(3) When separating the two half casings extreme care is necessary to avoid damaging the righ-hand liner seal by the pump impeller key. The following method must be adopted :

First of all the Dynamometer carcase must be removed from the outer baseplate.

Referring to the cross sectional arrangement, Fig. 3, with the casing assembly vertical and the left-hand casing on the bottom, remove the seven $\frac{3}{8}'' \times 2\frac{1}{2}''$ capscrews and the one $\frac{3}{8}'' \times 1\frac{1}{2}''$ capscrew, thus freeing the casing joint.

Remove the locking plate, half coupling, tachometer housing and worm from the shaft and casing. Remove four only of the $\frac{7}{16}'' \times 4''$ capscrews securing the liner, unscrewing the remaining two about $\frac{1}{2}''$. The casing is then drawn slowly off the shaft unit while these two screws are tapped down, ensuring that the liner remains with the lower casing and the shaft. Then release these two screws and withdraw the casing without the liner but complete with ball bearing shaft throwers and seals.

Once the top casing is removed the pump impeller can then be extracted. Removal of the impeller key will permit withdrawal of the liner.

If it is desired to remove roller bearings, remove bottom half coupling, locking plate and end cover, then draw shaft upwards through bottom casing, thus releasing inner race and rollers of bearing. Outer race of bearing can then be prized out of its housing.

(4) Do not strike any part of a ball or roller bearing with a hammer.

Fitting Bearings.

(1) The inner race must be a tapping fit on the shaft; if too tight, damage would result from expansion of the race, and if slack, as an ordinary hand-push fit, the bearing would turn on the shaft.

(2) The shoulder against which the bearing would rest must be perfectly square and free from bruises.

(3) To fit a bearing, the use of a tube to pass over the shaft is most suitable, but the alternative of a flat-ended chisel of soft material and tapping round the bearing close to the surface of the shaft, avoiding too much of a zigzag motion, would be suitable.

(4) The outer race requires to be a snug hand-push fit in the housing.

(5) When fitting the inner or outer race, see that the parts are first lubricated with a little oil.

(6) When fitting a coupling, support the extreme end of the shaft to relieve the bearing of shock due to the hammer action.

(7) To avoid possibility of leakage of water into the shaft bearings, check that at the pump end of the shaft the water drain holes from the atmospheric leak-off compartment adjacent to the pump seal feed compartment are not blocked with scale or foreign matter (see Fig. 3). The inlet pressure to the Dynamometer must not be excessively high. If a possible leak into the bearing occurs at the other end of the Dynamometer, this is usually caused by the shaft thrower not being in correct axial relationship to the outer edge of the annulus compartment in which it works due to wrong assembly (see Fig. 3). It can also be due to the drain holes from the leak-off compartment being partially blocked with scale or foreign matter.

We have a standard set of instructions concerning the method of dismantling and erecting the Dynamometer which can be supplied on request.

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21. DASHPOT

The weighing gear dashpot should always be kept full with a light grade of oil such as Esso Norpol 35 or Vacuum Velocite No. 6. If the oil becomes thick or dirty, the dashpot should be dismantled, cleaned and re-filled with fresh oil. Access to the dashpot is obtainable through the small detachable cover in the Dynamometer outer casing immediately below the spring balance. The dashpot and its connections to the weighing lever should be kept clean and free from all suspicion of stiffness. Undue play should not be allowed to develop and the bush in the top of the dashpot rod should be replaced if necessary.

If the piston is sticking, remove the dashpot and thoroughly clean with petrol or paraffin. Ensure that piston and back of cylinder are free from rust; if not, clean with very fine emery or a hone.

To dismantle the dashpot first of all remove the retaining grubscrew and then the damping adjuster screw (see Fig. 5) and drain off the oil. Then unscrew the two stud nuts and lower the dashpot body downwards off the piston and rod.

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22. WEIGHING GEAR

The link gear in this part of the Dynamometer should be periodically examined and protected against rust, especially in the pin joints. Whenever setting up for a test carefully examine the joints to see that binding does not take place. The bottom bearings of the weighing lever link should be grease lubricated at six monthly intervals but only lightly so that sensitivity is not affected. The weighing lever bearings are charged on erection and require no further attention.

Keep the small Dynamometer balance weights in a clean unchipped condition and occasionally check for accuracy. When not in use the weights should be placed on the stand provided for this purpose. Occasionally check the setting of the stops at the end of the weighing lever to ensure that undue overtravel in either direction does not damage the spring balance. The spring balance does not require any attention but in no circumstances should oil or grease be put on to the rack and pinion. If necessary, the accuracy of the weighing gear can be checked periodically (see Section 18).

The spring balance can be removed, if necessary, and independently checked for accuracy by mounting on a suitable support, fitting a weight pan and applying a dead weight check. The spring balance indicates a relieving load (black figures) and weights should be removed from the pan when taking readings noting that the ratio is 1 : 1. If there is a linear error, this can be corrected by removing the dial and adjusting the length of the calibrating spring.

If errors or stiffness occur during a calibration test, examine the trunnion bearings for possible brinelling and rotate the outer race slightly so that the balls rest in a fresh place. If the trunnion bearings have been subjected to heavy vibration and show signs of brinelling all round the ball tracks, they should be replaced. Do not over-grease trunnion bearings. The bedplate must be set down on a level underframe or foundation otherwise distortion of trunnions can occur with consequent weighing gear stiffness.

The reducing lever and connecting link bearings must be free, uncontaminated with moisture, not brinelled or over-greased. Only examine if the weighing gear is troublesome and thoroughly clean or replace before re-assembly.

If the lever is raised and depressed and sticking of the spring balance pointer indicates stiffness, it should be removed for examination. First of all remove the top cover of the Dynamometer casing by disconnecting the lower link pin and the outer casing joint bolts. Then remove the lever from the top half of the casing in the following manner:

Remove the Simmonds nuts from the lever support pin and tap out the cast bearing housings; clean the bearings and examine for signs of brinelling; if they are brinelled badly, replace with new ones, otherwise lightly grease them and re-assemble, taking special care not to overtighten the Simmonds nuts.

If the connecting link bearings are suspected, remove them from the link, clean in petrol and examine for signs of brinelling as with any of the bearings in the weighing system. If they are heavily marked, renew them. If over-greased, or if the grease is old and has become hard, clean and re-grease, taking care not to over-grease.

When the foregoing operations have been checked or completed, the weighing gear should be restored to its original standard of sensitivity and zero setting and, if necessary, the Dynamometer can be re-calibrated with the aid of a jig bored test arm and dead weights (see Calibrating Instructions, Section 18).

If there is resistance to weighing gear motion, check that the pump seal feed hosepipe is free, flexible and lined up; also that no parts attached to the moving carcase are fouling or rubbing against fixed portions of the outer casing, such as the control valve against the nameplate.

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23. TACHOMETER

The pinion on the tachometer driving spindle should occasionally be examined for wear by removing the housing. Before removing the housing uncouple the tachometer driving spring, remove the tachometer from its support in the top half of the casing and draw off the shaft coupling.

The tachometer gear drive fitted around the coupling boss at the one end of the Dynamometer is lubricated by the same grade of grease as the adjacent bearing housing, i.e. Shell Alvania No. 3. The gear housing should be grease gun lubricated at monthly intervals. The gear housing is dowelled to the casing so that when replaced the gears should mesh correctly as before removal. The bearings for the driving spindle consist of Oilite bushes which need no maintenance.

As regards the tachometer, the small grease cup on top of the gear housing should be re-filled every 2,000 hours by the grade of lubricant stated on the adjacent nameplate, or alternatively use Shell Alvania No. 3. It is not wise to interfere with the mechanism in the dial itself, and any trouble such as stiffness or inaccuracy should be reported to Heenan & Froude Ltd. for a decision as to the action to be taken.

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24. HYDRAULIC CONTROLS ETC.

If the main control valve or load throw-off device tends to become stiff in operation, it should be removed from the casing, dismantled and cleaned (see Fig. 4). The complete valve and body can be removed by taking off the nameplate and then detaching the valve from the side of the Dynamometer casing. Foreign matter and scale, if deposited by water, should be gently removed without scoring or damaging the surfaces of the sleeve and valve and the control rod threads should be cleaned if necessary.

The foot valve (see Fig. 3) at the bottom of the pump suction in the bedplate sump should occasionally be checked to make sure that it opens and closes freely. The flap should be replaced if it fails to seal properly.

The gauze strainer (see Fig. 2) at the termination of the inlet pipe into the baseplate sump should occasionally be removed for cleaning by unscrewing cap head screw, and replaced if necessary. The various air vents and leak-offs at the base of the casing (see sectional arrangement, Fig. 2) should be examined to see that no blockage has occurred. The baseplate sump should be drained occasionally by removal of the small plug at the side. Remove accumulated sediment and flush until clean.

Flexible air vent and drain pipes should be led into the water outlet compartment of the baseplate to avoid any turbulence which may be caused in the pump suction compartment. All air vent pipes should be clear and not partly submerged in the water in the baseplate.

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25. RECTIFICATION OF POSSIBLE PERFORMANCE TROUBLES

Air Vents to Rotor Compartment.

The air vent system, which must be completely unrestricted for satisfactory Dynamometer operation, consists of air vent holes in each stator drilled from the vortex centres and communicating with atmosphere by means of holes in the Dynamometer carcase. There are three holes per stator, two stators per Dynamometer, i.e. a total of six holes. The four holes at the top of the carcase are fitted with vent pipes, which must *terminate well above the maximum water level* in the baseplate sump, while the two holes at the bottom of the carcase remain unpiped.

N.B. Do not confuse these vent pipes with those from the right-hand stator seal, pump and pump seal compartment (see Fig. 3).

There are a number of external observations which can be made to check that the vents are operating correctly and these are listed below:

(*1*) When the Dynamometer is running under maximum capacity conditions at speeds of 500 r.p.m. or above, there should be a small and continuous leakage from all these vents.

(*2*) If these vents are plugged there should be a definite increase in Dynamometer torque together with a corresponding reduction in Dynamometer speed. If this does not occur, a restriction in the venting is indicated.

(*3*) On operating the load throw-off lever, the load should fall off in a reasonable time; if it does not, a restriction in the venting is indicated.

(*4*) A small but continuous leakage from any of these vents under partial capacity conditions indicates a probable breakdown of the 'O' ring sealing arrangements between a stator and the carcase.

Low Maximum Capacity.

(*1*) Outlet valve not closed—Close valve.

(*2*) Low Inlet Pressure—Fit 30 p.s.i. gauge to water inlet connection at bedplate on opposite side to inlet in use. (Drill and tap blanking cap to suit gauge.) Minimum pressure of 10 p.s.i. is required to ensure satisfactory pump prime.

(*3*) Blocked inlet manifold upstream of seal feed—Open water temperature control valve fully. Provided inlet pressure is not less than 10 p.s.i. there should be at least 2000 g.p.h. flowing from bedplate outlet pipe. If quantity is low, manifold and inlet strainer should be inspected and cleaned if necessary.

(*4*) Pump failure—see later paragraph.

(*5*) High flow resistance after pump outlet—If pump is found to be satisfactory, then undue resistance to flow after pump outlet should be suspected from either or both the following:

- (*a*) Blockage in water passages between pump and centre of vortex. This includes stator inlet holes and control valve porting. A strip will be necessary; also remove and examine the main control valve.
- (*b*) Inadequate air venting—see first paragraph of this Section.

High Minimum Capacity.

(*1*) Too large a clearance in stator seal adjacent to pump. This may also have the effect of making it difficult to fill pump compartment when starting up. The only cure is to strip and check clearance. (Not likely to occur if originally satisfactory unless damaged when dismantling or re-assembling carcase).

(*2*) Outlet valve not fully open—Open valve.

(*3*) Orifice in outlet valve partially blocked—Dismantle and clean.

(*4*) Excessive leakage past load control valve—Check clearances.

(*5*) Restricted or blocked venting—This will probably also be recognised by high water temperature rise. For other symptoms of blocked vents see first paragraph of this Section.

(*6*) Breakdown of seal on outside diameter of stators between seal feed passage to stator bore and inlet compartment. This fault may also cause failure of pump prime.—The only remedy is to strip and check seal.

Unstable Load.

(*1*) Partial blockage or restriction of air vents to vortex centre—The external observations which can be made to check this point are given in the first paragraph of this Section dealing with air venting. In this connection particular attention is drawn to the fact that the top air vent pipe must not be immersed below the level of the water in the bedplate sump.

(2) Partial failure of pump prime—Check for blockage or partial restriction of the air vent from the top of the pump compartment. If this is not the cause then see items under later paragraph entitled "Pump Failure"; also, bleed air by opening the air cock on the pump discharge near the control valve.

(3) Dashpot not working satisfactorily—Check that dashpot is properly filled with oil and that needle valve is seating properly so that efficient torque damping is available.

Partial Loss of Load Capacity.

(*1*) The most usual cause is partial or complete restriction of the air vents—See first paragraph of this Section.

(2) A slow leakage of air into the suction side of the pump—See later paragraph entitled "Pump Failure".

(3) Partial restriction of the air vent from the pump compartment—Remove vent pipe and clean out vent hole with a $\frac{1}{16}$" diameter wire.

Complete Loss of Load.

(*1*) No water inlet pressure available or blocked inlet manifold—Check source.

(2) Load control valve not fully closed before starting up—Check position of load control valve and close if necessary.

(3) Burst seal feed hose—Check hose pipe and if necessary replace.

(*4*) Failure of Pump—See next paragraph.

Pump Failure.

(*1*) Blockage in pump seal feed—Assuming adequate water inlet pressure, there should be a full bore flow of water from the seal feed overflow (see Fig. 1). If not, a restriction in the seal feed should be suspected. This can be caused by (*a*) blocked orifice, (*b*) strangled or burst flexible hose, (*c*) blocked hole in half casing which interconnects flexible hose with seal feed compartment.

(2) Insufficient flow of water from seal feed compartment into pump inlet compartment—Fit gauge glass not less than 3 ft. long to pressure tapping on pump foot valve and fit 30 p.s.i. gauge to pressure tapping between pump outlet and load control valve. With the Dynamometer stationary, an inlet pressure of not less than 10 p.s.i. and with the *load control valve fully closed*, there should be full bore flow from the air vent pipe at the top of the pump compartment. If there is no flow from this pipe but the gauge glass indicates that this compartment is full, then a blocked or undrilled vent hole is indicated and can be checked by dismantling the pipe and inserting a $\frac{1}{16}$" diameter wire into the vent hole.

If the level of water indicated on the gauge glass shows that the pump compartment is not full, the following faults should be suspected—(*a*) An excessive leak through the pump foot valve. The foot valve should be removed and checked by filling up with water, bearing in mind that a 100% leakproof joint is not necessary. (*b*) Too small a clearance between seal feed and pump inlet compartments. (*c*) Too large a clearance in stator labrynth seal adjacent to pump. In this case the Dynamometer will probably have a high minimum capacity.

Faults (*b*) and (*c*) can be overcome without stripping the machine by drilling two holes in the lower half of the pump half casing, one into the seal feed compartment and the other into the inlet compartment. The two holes should be externally connected by a pipe not larger than $\frac{1}{4}''$ diameter bore.

(*3*) Air leak on suction side of pump—With an inlet pressure of not less than 10 p.s.i., the load control valve fully closed and the Dynamometer running at a speed of 1000 r.p.m., there should be a suction of not less than 12″ water gauge in the foot valve. If this minimum figure is not obtained an air leak on the suction side of the pump should be suspected and the two known causes are:

(*a*) Breakdown of the 'O' ring joint between the foot valve and half casing.

(*b*) Poor foot valve casting.

(*4*) Insufficient pump outlet pressure—With an inlet pressure of not less than 10 p.s.i., the load control valve fully closed and the Dynamometer running at 1000 r.p.m., and assuming the other faults listed above do not exist, then the pressure at the pump outlet should be not less than 7 p.s.i. If it is, a restriction in the pump outlet is indicated. A pressure gauge for this purpose can be fitted in place of the air cock on the pump discharge.

If the above exercise shows the pump to be perfectly satisfactory then Item 5 "Low Maximum Capacity" is indicated and the necessary examination should be carried out.

26. LUBRICANTS

To simplify maintenance we have used the same grade of lubricant for all purposes throughout the Dynamometer (except dashpot) and the recommendations given are for grades supplied by the Shell Company but the alternative grades of other manufacturers are shown in the table below.

LIST OF ALTERNATIVE GRADES OF RECOMMENDED LUBRICANTS.

APPLICATION	*Lubricant*	*Shell Mex and B.P. Ltd.*	*The Mobil Oil Company Ltd.*	*Castrol Companies*	*Power Petroleum Company Ltd.*	*Esso Petroleum Company Ltd.*	*Lubricate at intervals of:*
Main Shaft Bearings	Grease . (Nipples)	Alvania Grease 2	Mobilux Grease No. 2	Spheerol A.P. 2	Energrease L.S. 2	Beacon 2	1 month (or as required)
Casing Trunnion and Weighing Gear Bearings	Grease (Stauffer or nipples)	Alvania Grease 2	Mobilux Grease No 2	Spheerol A.P. 2	Energrease L.S. 2	Beacon 2	3 months (lightly)
Tachometer Drive Gears	Grease (Hand insertion)	Alvania Grease 2	Mobilux Grease No. 2	Spheerol A.P. 2	Energrease L.S. 2	Beacon 2	1 month
Tachometer Drive Spindle	Grease (Nipples)	Alvania Grease 2	Mobilux Grease No. 2	Spheerol A.P. 2	Energrease L.S. 2	Beacon 2	1 week
Weighing Gear Dashpot	Oil (Refill)	Tellus Oil 15	Gargoyle Arctic Oil Light	Hyspin 40	Energol HL 40	Nuto H-44	Keep full. Replace when dirty
All Operating links, forks, pins, and sluice gear bushes	Oil (Can)	Talpa oil 20	Vactra Oil Heavy Medium	Perfecto NN	Energol O.E.125	Coray 50	2 weeks

FROUDE HYDRAULIC DYNAMOMETER — TYPE GB.
ADDITIONAL INSTRUCTIONS

1. PRINCIPLE AND CONSTRUCTION (see also page 5)

The GB. type Dynamometer is practically identical with the G. type machine, but with the following alterations:

(*1*) The rotor, stators and pump impeller are made in high duty bronze instead of cast iron.

(2) As the result of (*1*) the maximum B.H.P. absorbed and the maximum permissible r.p.m. are both considerably increased above that of the G. type machine, in accordance with the capacity curve.

(3) High speed bearings are fitted and grease lubrication is dispensed with in favour of oil mist lubrication.

The preceding instructions for G. type Dynamometers also apply to the GB. type machines with the exception of the following:

Shaft Bearings.

The Dynamometer shaft is carried upon a high speed anti-friction ball bearing at the tachometer end and a high speed roller bearing at the opposite end. The ball bearing is locked in position for locating the rotating components on the shaft and the outer race of the roller bearing allows float for expansion.

Both bearings are lubricated with oil mist obtained from a Lubro-Control unit mounted on the side of the Dynamometer outer casing. The unit comprises an air filter, regulator and lubricator unit with pressure gauge. An air line capable of supplying reasonably dry air at a pressure of 30/40 lb. per square inch should be connected up to the air filter.

A line diagram of the units which are usually incorporated in the oil mist lubrication system is shown in Fig. 7. The solenoid valve (if supplied) is operated by a manual switch "On" and "Off" at the discretion of the operator so that air and lubrication supply can be conserved when the machine is not running. The pressure switch is usually set at 20 lb. per square inch for safety purposes and this should be connected into the engine or turbine control so as to stop rotation in the event of lubrication failure to the Dynamometer. In all cases, as an extra, a low level oil switch can be supplied for the oil reservoir, to indicate the necessity for refilling. In any case, however, a visual sight gauge is provided to indicate oil level.

The pressure regulating valve should be adjusted to give the required air pressure, i.e. between 30/40 lb. per square inch, as shown on the gauge provided. The flow of oil can be observed in the glass dome on the top of the oil reservoir. The adjusting screw on the inlet side of the oil reservoir increases or decreases the rate of oil flow as observable in the glass dome. The adjusting screw on the right-hand side of the oil reservoir increases or decreases the air supply. Both screws are turned in an anti-clockwise direction to increase flow. It is usual to start up the oil system some two or three minutes before the Dynamometer is due to run. The correct grade of oil should be used for the oil mist lubrication system as this is important (see Section 20 below). For additional information concerning the oil mist lubrication unit, see Forms No. E757B.2-59, 738/250. 1-59 and 287 issued by C. A. Norgren Ltd.

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9 and 19. WATER SUPPLY (see also pages 11 and 19)

Naturally more water is required than for the G. type machine if the GB. machine is tested up to its maximum B.H.P. absorption capacity, although the recommended inlet pressure of 15/20 lb. per square inch should be sufficient. However, spare pressure up to a higher value should be available. In view of the

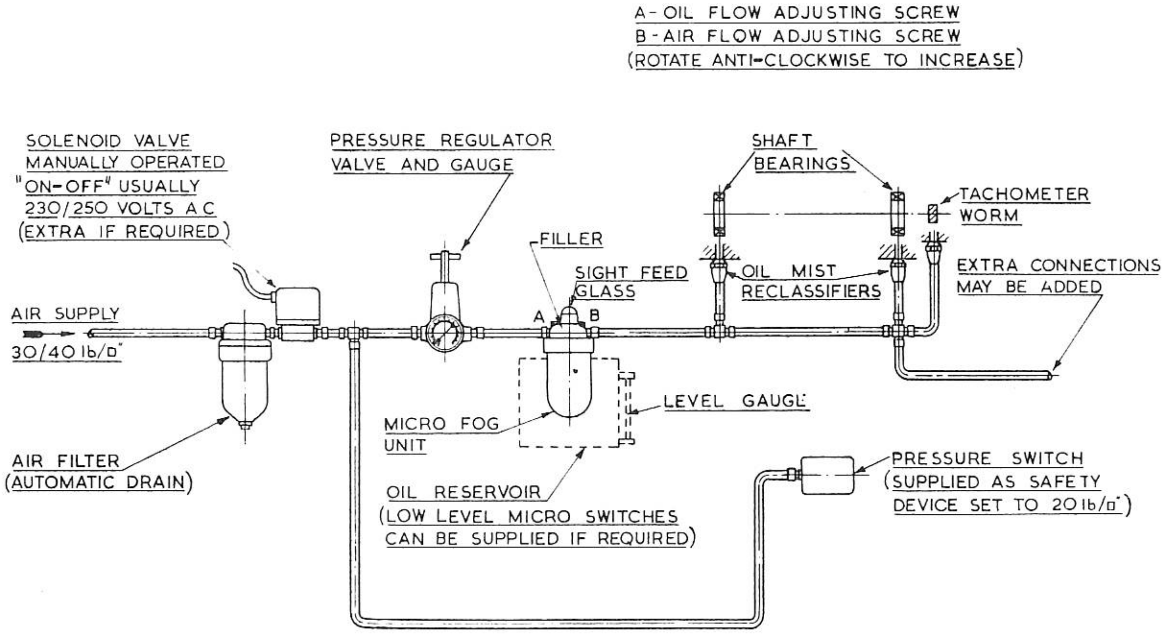

Fig. 7. Diagram of Oil Mist Lubrication System for Froude GB. Type Dynamometers.

increased duty, particularly in speed, further stress is laid on the cleanliness of water supply, for which see appropriate sections above mentioned.

15. RUNNING CONDITIONS (see also page 15)

The operation of the GB. type Dynamometer is the same as for the G. type machine with the exception that possibly at high speeds it may be necessary to open the outlet valve a little more in order to maintain the water outlet temperature at the correct figure. X

20. BEARINGS

The Dynamometer shaft bearings are oil-mist lubricated and require no attention other than keeping the oil lubrication reservoirs filled with the correct grade of oil which is as follows:

MOBIL OIL COMPANY LIMITED—Mobil Almo No. 1.

SHELL MEX & B.P. LIMITED—Shell Rotella Oil 30.

or the exact equivalent of other manufacturers.

23. TACHOMETER (see also page 22)

The tachometer usually supplied with the GB. Dynamometer is of the same magnetic type as with the G. machine and has the same type of gear drive. However, the drive gears are lubricated by the same oil mist system as the shaft bearings by means of an extension pipe from the bearing feed lines.

Electrical tachometers can be supplied if required, but if the machine is to be used continuously at its maximum speed it is preferable to utilize a pulse unit such as a Sunbury head operating a frequency meter which in turn feeds a revolution indicator.

Sole Patentees and Manufacturers :

Dynamometers by –	HEENAN & FROUDE Ltd.

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