Part 7 Engines

Leaflet 7-2 Piston Engine Overhaul – Dynamometer Testing of Overhauled Engines

1 Introduction

1.1 After an aero-engine has received a complete overhaul, the tests prescribed in JAR-E of British Civil Airworthiness Requirements may be made with the engine either fitted with a test fan or mounted on a dynamometer test bench. This Leaflet gives guidance on testing low-power, air-cooled engines when coupled to dynamometers and includes the acceptance conditions required by the CAA when overhauled engines are tested by this method.

1.2 The Leaflet does not aim to provide a complete guide to approved inspection organisations engaged in aero-engine overhaul. The particular purpose of this Leaflet is to give students and individual engineers an outline of engine test procedure and to draw attention to a number of points of special importance. Before actual tests are attempted on engines which are to be released in accordance with CAA Requirements an approved Engine Test Schedule must be available. All overhaul work on such engines must be in accordance with the manufacturer's instructions given in the Overhaul Manual and all tests must be made as prescribed in the Engine Test Schedule for the particular type.

1.3 The Requirements relating to the testing of small air-cooled piston engines after overhaul are reprinted in Leaflet 7–1, except that the prescribed acceptance conditions are included in this Leaflet 7–2 and the prescribed formulæ for performance corrections in Leaflet 7–5. Guidance on the testing of overhauled engines by means of test fans and the prescribed acceptance conditions when engines are tested by this method, are given in Leaflet 7–3.

2 General

The tests made after overhaul consist of an Endurance Test followed by a strip examination and a Final Test during which the performance is determined. The CAA sometimes permits relaxation of the Requirements for complete strip examination, but the extent of any deviation must be approved by the CAA.

2.1 The method of testing an engine on a dynamometer test bench enables the engine output to be determined in terms of brake power, whereas this is not practicable when the engine is tested with a fan or flight propeller unless the engine incorporates a torquemeter of known accuracy or the torque reaction on the engine mounting can be measured with exactitude.

2.2 Since the engines with which this series of Leaflets is concerned are not usually fitted with torquemeters, their performance after overhaul is most often assessed by testing them when fitted with calibrated test fans, in which case, as explained in Leaflet 7–3, the corrected rpm obtained under specified conditions is taken as a measure of the engine performance. However, before an engine can be so tested, the test fan itself must be calibrated in the test cell to be used, on an engine, the performance of which has been determined on a dynamometer test bench.

3 Test Plant

A dynamometer is a heavy machine which must be rigidly mounted. This fact and the necessity of making adequate arrangements for water, electricity, fuel and oil supplies, for exhaust gas disposal, for drains, for silencing and for ventilation means that dynamometer testing is usually performed in a permanent test house. It is beyond the scope of this Leaflet to describe such a test house in detail but attention is drawn, in the following paragraphs, to a number of important features:

3.1 A dynamometer test bench consists of a mounting for the engine, a coupling shaft for interconnecting the engine to the dynamometer, a fan and the necessary ducting for cooling the engine, a starting system for the engine, the necessary controls and instruments for operating the engine and measuring its performance and systems for supplying the engine with fuel and oil and the dynamometer with water. In the case of supercharged engines a depression box should be provided for the air intake so that altitude conditions can be simulated when specified in the Engine Test Schedule.

3.2 When an engine is mounted on the test bench, care should be taken that the engine propeller shaft is in exact alignment with the shaft of the dynamometer, but the coupling should not be completed until the zero setting of the torque measuring equipment has been checked. Guidance on the procedure for this check is given in paragraph 4.

3.3 The coupling shaft between the engine and dynamometer must be specially designed. It must be light in weight, properly supported and in perfect dynamic balance. Cardan shafts incorporating two universal joints are normally used; they should be inspected before the start of the test to ensure that they have not been disturbed in any way that could upset their alignment or dynamic balance.

3.4 All test and measuring equipment must be of an approved type. All instruments should be calibrated periodically and thereafter should be checked for accuracy at regular intervals by an organisation approved for the purpose. Measuring equipment should also be checked at regular intervals, the check periods to be agreed with the CAA. Engine speed indicators should be checked with a stop watch against a revolution counter and, during tests, cross-checks should be made by measuring of the engine speed using a 'Hasler' type instrument.

3.5 Before commencing the test, the oil filter elements in the feed lines should be either cleaned or renewed. Oil tanks should be drained and flushed at intervals of approximately 100 hours’ running time.

3.6 Before checking oil consumption or oil circulation, the oil temperature must be stabilised at the check temperature specified in the appropriate test schedule. To obtain this condition, the test plant must be provided with suitable means of heating or cooling the oil as required. If the heating is accomplished with an electric immersion heater there is danger of damaging the chemical structure of the oil, since the surface temperature of this type of heater can rise to high values when the flow rate of the oil is low. It is therefore recommended that the oil is heated via a heat exchanger, using steam at a controlled pressure if a source is available but otherwise using a circulating water supply as a means of conveying heat from an immersion heater to the oil.

3.7 Engine oil consumption can be checked by either of the following methods:

a) Readings of oil volume should be taken from a graduated sight glass fitted externally to the oil tank. The readings should be recorded each 15 minutes during the prescribed stages of the test schedule and the difference between the initial and final readings can be used to calculate oil consumption in litre/h (pint/h).

b) On an engine which has a 'wet sump' lubrication system, the oil should be drained out and weighed at the end of the running-in period, replaced in the engine, then drained out and weighed again after the Endurance Test. The difference between these weights will enable the oil consumption to be calculated.

3.8 The fuel pressure gauge connection should be made at the inlet to the carburettor or fuel injector. A fuel flowmeter calibrated in litre/h or kg/h (pints/h or lb/h) must be tapped into the fuel supply line and readings must be taken as called for in the test schedule appropriate to the engine.

3.9 To avoid unscheduled stoppages during the test, all pipe connections should be properly made and all pipes should be adequately supported. The test bench controls should be checked for alignment and range of movement and the engine baffles and cowlings should be firmly secured.

3.10 Measurements of the exhaust back pressure should be made as close to the engine as possible but, where more than one manifold is provided because of the cylinder configuration, the pressure at each silencer connection should be checked and the mean reading obtained. If it is inconvenient to measure the pressure from each connection throughout the test, the pressure tapping with the value closest to the mean reading may be used.

4 Types of Dynamometer

There are three principal types of dynamometer commonly used for the testing of aero-engines, the hydraulic type, the electrical (direct-current) type and the eddy-current type. With all types, the engine under test is directly coupled to the rotor shaft of the dynamometer, which can be loaded to obtain the desired engine speed. The dynamometer absorbs the power output of the engine and, in doing so, experiences a torque reaction on its own casing. It is by measurement of this torque reaction that the brake power of the engine is determined; it can be calculated from a simple formula which takes into account the torque reaction and the rpm of the dynamometer rotor.

$$\text{Brake Power} = \frac{\text{torque (Nm)} \times 2\pi \times \text{rpm}}{60\,000}\ \text{kW or}\ \frac{\text{torque (lb ft)} \times 2\pi \times \text{rpm}}{33\,000}\ \text{BHP}$$

4.1 Hydraulic Dynamometers

A part sectioned view of a typical hydraulic dynamometer is illustrated in Figure 1. The shaft of this machine carries a rotor which has a series of semi-elliptical cups separated by vanes; the rotor runs between two sets of similar cups formed in the casing. Water at constant pressure is fed into the casing. Rotation of the shaft circulates this water by centrifugal force around the orbits formed by the opposing pairs of moving and static cups, the water thus absorbing the power fed into the machine by the engine under test. The shaft is supported in the casing by ball bearings and the casing itself is mounted on trunnion bearings which allow it to rotate in response to torque reaction. The reaction on the casing is balanced and the rotation of it constrained, by a system of weights and levers and a spring balance which, when correctly preset, indicates the load due to torque.

The loading on the engine can be reduced by adjusting a pair of shrouds, known as sluice gates, so that they progressively mask the rotor cups from the cups in the casing and can be increased by the reverse process. The type illustrated is a non-reversible dynamometer but reversible types are also made. The latter have two rotors and two sets of casing vanes, one to work clockwise and the other anti-clockwise.

NOTE: The following instructions are applicable when the testing is done with a Non-reversible Froude Type D.P.Y. dynamometer. Since this dynamometer is the type most widely used for testing small aero engines, these instructions have been included as an example. Should any other types of hydraulic dynamometer be employed, instructions for its use must be obtained from the manufacturer.

4.1.1 Before coupling an engine to the dynamometer, the static balance of the weighing apparatus should be checked. This is done in the following way:

a) Adjust the inlet and outlet water valves so that there is a steady flow of water through the dynamometer.

b) A dashpot prevents oscillations of the torque lever arm from being transmitted to the spring balance. When the spring balance is being checked the dashpot should be freed by setting its adjusting nut to zero.

c) Remove all loose balance weights from the end of the lever arm, leaving the fixed static weight in place.

d) If the lever arm is not in a position slightly above the bottom stop on the bedplate, the adjustment on the interconnection to the spring balance should be reset. The adjustment should be checked by raising the lever arm which should cause the pointer of the spring balance to make one revolution before the lever arm touches the top stop in the spring balance column.

e) By moving and locking the small sliding weight on the lever arm, the pointer of the spring balance should then be reset to zero. The dynamometer is then ready for the test and the engine should be coupled to it, care being taken to ensure exact alignment of the engine and dynamometer shafts.

f) A final check should be made by alternately lifting and depressing the lever arm by hand, when the pointer should settle down to zero and it should be possible by depressing the lever arm to move the pointer a few degrees to the minus side of zero, without causing stiffness or binding. The adjusting nut of the dashpot should then be screwed down so that the by-pass will be partially closed, although final adjustments must be made when the engine is running.

NOTE: If the spring balance does not register sufficient load to balance the output of the engine under test, the load may be increased by adding extra balance weights. These are marked with figures representing the correct weight which must be added to the load registered on the spring balance and the sum of weights and registered load will then represent the factor W in the formula given in paragraph 4.1.3 for calculating Brake Power.

4.1.2 Before starting an engine coupled to a non-reversible dynamometer, the water inlet valve should be fully opened but the outlet valve should only be opened slightly. As prescribed in the Requirements, the Engine Test Schedules (Leaflet 7–1) specify that engines under test should be run-in under their own power with an initial light load. For starting purposes it is advisable to close the sluice gates to minimise the load on the engine; afterwards, as the engine is opened up in incremental stages, the load should be progressively increased by opening the sluice gates, to maintain the operating conditions to those agreed for each stage by the CAA. As the engine power is increased the water outlet valves should be adjusted so that they pass sufficient water to keep the water temperature at a reasonable level; about 60°C is satisfactory.

4.1.3 It has been stated that the power of the engine can be found if the torque and the rpm of the rotor are known. The torque is calculated by multiplying the length of the lever arm by the effective weight lifted. Since the lever length, the value of π and the power conversion factor are all constant, the simplified formula given below can be used. The formula introduces a constant K known as the dynamometer constant, which has a value determined for each type of dynamometer by its manufacturer. The value of K, which varies with the length of the lever arm, is stamped on the nameplate of each dynamometer. The formula is therefore:

$$\text{Brake Power} = \frac{W \times N}{K}$$

where W = net weight lifted by dynamometer

N = rpm of rotor

K = dynamometer constant

4.2 Electrical Dynamometers

The type of electrical dynamometer usually supplied for the testing of small engines consists of a generator designed so that it will also function as an electric motor. Thus when supplied with electrical power it can be used for running-in a newly-assembled engine or when driven by an engine under test it generates electrical energy. The first of these functions is not normally applicable to overhauled aero-engines, which are run-in under their own power, but it does provide a means of measuring the power required to overcome the internal resistance of an engine when this information is required. The armature shaft of a typical electrical dynamometer is carried by bearings in the casing of the machine and the casing is itself carried in co-axial bearings which allow it to swivel in the same direction of rotation as the shaft. When an engine is driving the armature shaft with the dynamometer connected to an electric circuit, the turning moment is resisted by a combination of bearing friction, electro-magnetic reaction and air resistance. These three loads each tend to rotate the casing, to which is attached a lever arm and weighing apparatus similar to that of a hydraulic dynamometer. The magnitude of the total force acting on the casing is indicated on a spring-balance dial, which enables the engine power to be found by the method given in paragraph 4.1.3.

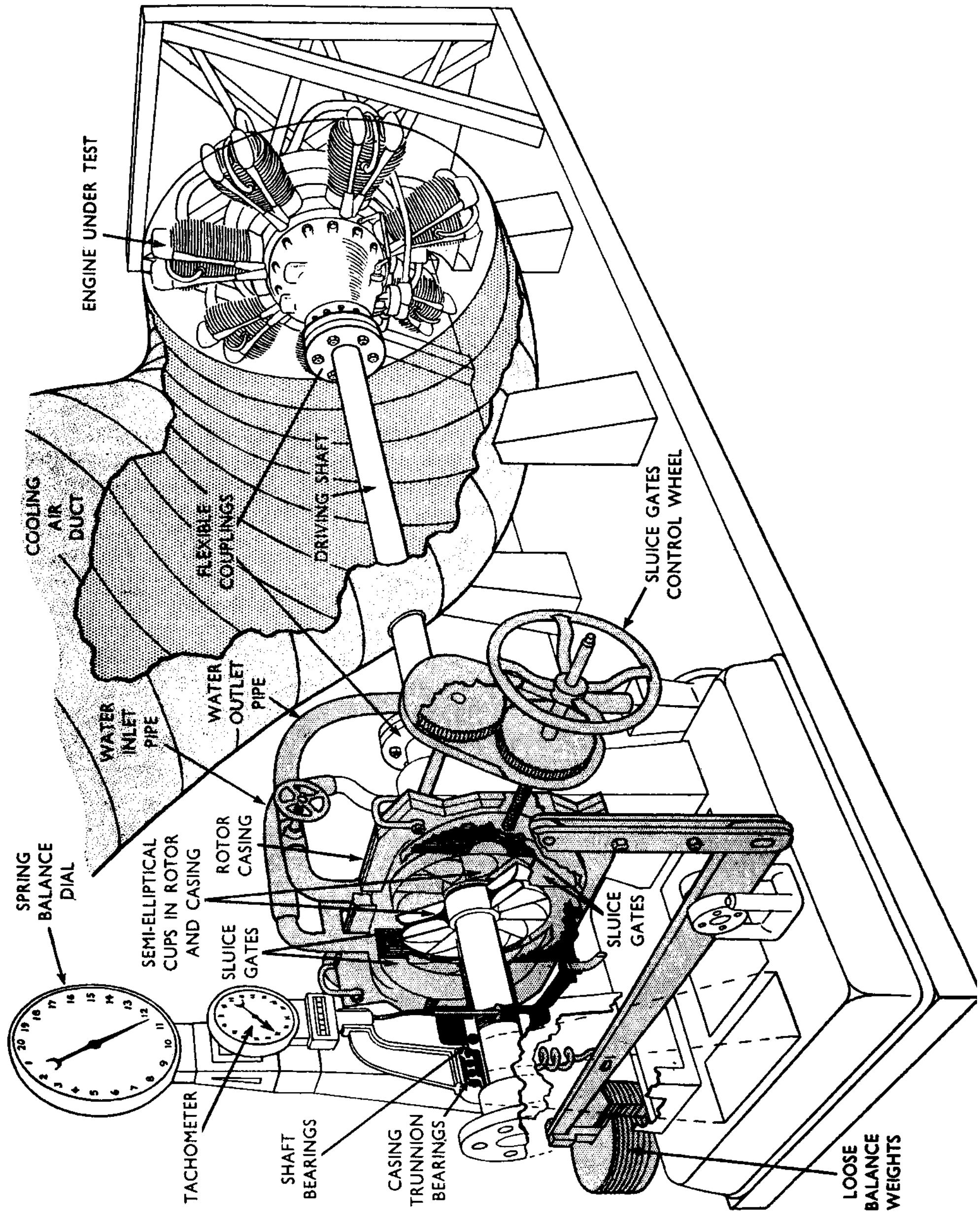

Figure 1 Radial Engine Coupled to Froude Hydraulic Dynamometer

4.3 Eddy-current Dynamometers

The single frame electrical dynamometer described in paragraph 4.2 is not designed to absorb high powers and therefore an eddy-current dynamometer is more often used for testing engines which develop over 150 kW (200 BHP). An eddy-current dynamometer is an electrical machine in which the rotor is manufactured with a number of coarse teeth which act as magnetic poles. The rotor turns inside a stator which incorporates one or more field coils excited by a small amount of direct current, so that during rotation concentrations of magnetic flux are produced at each pole of the rotor. The flux concentrations induce eddy-currents in the stator and it is these which resist the rotation of the rotor and therefore load the engine under test. The degree of power absorption is controlled by regulating the amount of excitation of the main field coils. The engine power is converted into heat by the braking effect of the machine and cooling water has therefore to be circulated to conduct the heat away. In this type of dynamometer the water outlet temperature should not exceed 60°C but if possible it should be limited to 50°C as this will help to reduce the possibility of internal scale formation. As with the hydraulic and electric types of dynamometer, the engine power is found by measuring the torque reaction exerted on the stator casing. The casing is mounted on trunnion bearings which allow some freedom of oscillation and attached to the casing is a lever arm which operates weighing gear. The engine power is found by the method given in paragraph 4.1.3.

4.4 Dynamometer Plant for Helicopter Engines

British Civil Airworthiness Requirements prescribe that engines intended to be installed in helicopters should be tested in the attitude in which they will be mounted in the airframe (Leaflet 7–1). Thus when the axis of rotation of the crankshaft is to be vertical in service, one solution is to provide a right-angled gearbox to couple the engine to the dynamometer. The dynamometer itself can be of any type capable of absorbing the power output of the engine but the brake power readings obtained from it must be corrected for the power absorbed by the gearbox. (This information is usually obtainable from the manufacturer of the gearbox). Since helicopter engines are not always provided with integral reduction gears, a right-angled gearbox may be designed with a reduction ratio to assist in matching the engine speed to the characteristics of the dynamometer. If required, hydraulic dynamometers can be made to run directly coupled to helicopter engines without the introduction of a gearbox and in addition special dynamometers can be made to suit vertical or any other shaft inclination desired. In some special cases both dynamometer and engine can be arranged on a swivel to give variable adjustment of shaft inclination. The test bench may also be designed so that the engine is provided with an external source of cooling air since, if it drives its own cooling fan, it may be necessary to make allowance for the power absorbed by the fan.

5 Test Running and Observations

After the engine has been coupled to the dynamometer and the preparations for starting and running have been completed, the engine should be tested strictly in accordance with the approved Test Schedule appropriate to the type. The observations made during the tests should be recorded on properly prepared test log sheets. During the tests attention should be given to the following points:

5.1 The engine should be tuned according to the instructions in the approved Test Schedule. The observed fuel flowmeter readings must be corrected to standard conditions; formulae and/or charts for this purpose are normally provided with the schedules supplied by engine manufacturers. Likewise, the fuel flow acceptance limits (see paragraph 6.1.2) are normally quoted in the same source.

5.2 At each stage of test running, a careful watch should be kept for signs of defects and such undesirable behaviour as excessive oiling, vibration, breather discharge or detonation.

5.3 Single ignition checks should be made and the power drop measured. As each magneto is switched OFF, the engine load should be reduced, e.g. by opening the sluice gates on a hydraulic dynamometer, so that the rpm is restored to that obtained with both magnetos operating. The differences in power output between operation with single and duel ignition should be recorded on the log sheets.

5.4 Stage 11 of the Final Test calls for a power/rpm curve to be drawn at the Maximum Weak-mixture Power manifold pressure. To obtain this curve the engine should be run over the range of rpm specified in the Test Schedule. The resultant curve should be smooth; if it is not so and any of the points plotted diverge to any appreciable extent, the readings should be rechecked.

5.5 If, after rechecking, it is necessary to adjust or replace any component or part, the test, or portions of it, will have to be repeated, unless otherwise agreed by the CAA.

6 Acceptance Conditions

The acceptance conditions for overhauled engines tested on a dynamometer test bench are prescribed in JAR–E of British Civil Airworthiness Requirements and are repeated in the following paragraphs. Apart from the general running standard of each engine and its ability to satisfactorily complete the tests detailed in the relevant schedule, the specific standards of performance of 6.1 or 6.2, as appropriate, must be obtained to the satisfaction of the CAA.

6.1 Engines Rated in accordance with the Requirements in force on and after 18th November, 1946 (ICAO Ratings)

6.1.1 Power

The corrected Maximum Take-off Power shall be not less than 96% of the declared Maximum Take-off Power. Also, in the case of a supercharged engine, the corrected power at the declared full throttle altitude at Maximum Take-off Power and Maximum Continuous Power conditions, as derived from the tests of Stages 7, 8, 9 and 10 of the Final Test, shall be not less than 96% of the declared power. Alternatively, the sum of the ratios of the corrected sea-level power and the corrected supercharger compression ratio (at 15°C) at Maximum Take-off and Maximum Continuous conditions to the established values for the prototype engine shall be not less than 1·96. These conditions shall be met in each supercharger gear.

NOTE: For the assessment of the supercharger performance, it is recommended that a chart should be prepared, for each supercharger gear, showing the absolute pressure which would be required at the air intake of the engine, with a supercharger compression ratio at 15°C equal to that quoted in the Engine Technical Certificate, when running at full throttle at the Take-off and Maximum Continuous manifold pressures (Takeoff and Maximum Climbing for engines with pre-ICAO ratings). The chart, a specimen of which is reproduced in Leaflet 7–5, should cover a suitable range of rpm and air intake temperatures. The performance of the supercharger under test will be measured by comparing the observed air intake pressure with that determined from the chart.

6.1.2 Fuel Consumption

The fuel consumption at all sea-level rating conditions shall be within the limits quoted in the engine specification or technical certificate.

6.1.3 Oil Consumption

The mean oil consumption obtained from the tests of Stages 3 and 4 of the Endurance Test and Stage 4 of the Final Test, shall be within the declared limits. In the event of the engine not being able to comply with this requirement during the tests of Stages 3 and 4 of the Endurance Test, it shall be rejected for rectification and re-submission to the Endurance Test. Alternatively, the endurance running of Stages 3 and 4 of the Endurance Test may be extended up to a maximum of an additional 2 hours, until the consumption falls within the required limits over a period of at least 30 minutes duration. The consumption shall be checked in each supercharger gear.

As a further alternative, where the applicant is of the opinion that the oil consumption can be improved by adjustment during strip examination, the endurance portion of the Final Test may be extended by the addition of a run limited to a minimum of 1 hour at the declared Maximum Continuous Power conditions. The running shall be equally divided between the supercharger gears. During the period of oil consumption measurement, ignition checks, or operation of any accessory or any other test or adjustment which may affect consumption, shall be avoided. The oil consumption in each supercharger gear shall be reasonably consistent.

6.1.4 Accelerations

Accelerations shall be smooth and free from hesitation or other signs of fuelmetering trouble.

6.1.5 Single Ignition Check

The power drop when running with single ignition shall not exceed the declared maximum.

6.1.6 Cleanliness

The engine shall be free from leaks at all joints and connections, etc.

6.2 Engines Rated in accordance with the Requirements in force before 18th November, 1946 (pre-ICAO Ratings)

The acceptance conditions for these engines are the same as those in paragraph 6.1 except that Maximum Climbing Power should be substituted wherever reference is made to Maximum Continuous Power.

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Leaflet 7-3 Piston Engine Overhaul – Fan Testing of Overhauled Engines

1 Introduction

1.1 After an aero-engine has received a complete overhaul, the tests prescribed in JAR-E of British Civil Airworthiness Requirements may be made with the engine either fitted with a test fan or mounted on a dynamometer test bench. This Leaflet gives guidance on testing low-power, air-cooled piston engines by means of test fans and includes the acceptance conditions required by the CAA when overhauled engines are tested by this method.

1.2 Since the engines with which the series is concerned are more often tested by the fan method than on a dynamometer test bench, this Leaflet gives fairly detailed information on the methods used for choosing test fans to suit particular engines and for calibrating test fans. It also draws attention to a number of other points of special importance. Before tests are attempted on engines which are to be released in accordance with CAA Requirements, an approved Engine Test Schedule (see paragraph 2) must be available. All overhaul work on engines must be in accordance with the manufacturer's instructions given in the Overhaul Manual and all tests must be made as prescribed in the Engine Test Schedule for the particular type.

1.3 The Requirements relating to the testing of small air-cooled piston engines after overhaul are reprinted in Leaflet 7–1, except that the prescribed acceptance conditions are included in this Leaflet and the prescribed formulae for performance corrections in Leaflet 7–5. Guidance on the testing of overhauled engines on dynamometer test benches and the acceptance conditions prescribed when engines are tested by this method, are given in Leaflet 7–2.

2 General

The test procedure prescribed for piston engines after overhaul includes an Endurance Test followed by a strip examination and a Final Test during which the performance is determined. Engine manufacturers in the United Kingdom prepare Test Schedules and instructions which are approved by the CAA for use when testing particular engine types. As explained in Leaflet 7–1, these schedules are based on the appropriate basic schedule from JAR–E of the Requirements and the Engine Technical Certificate.

2.1 Although the Requirements recognise two basic methods of testing piston engines after overhaul, the test fan method, because of its lower cost, is most frequently used for testing the smaller engines. This method entails fitting the engine with an approved type of test fan which is calibrated to absorb the power output of the engine at a specified rpm. Since torquemeters are not usually fitted to the small engines with which this Leaflet is concerned, the rpm obtained when running with a calibrated fan is used to indicate the engine power. However, the results obtained can be grossly inaccurate unless exceptional care is exercised in the application of the method.

2.2 Since it is a requirement that helicopter engines be tested in the attitude in which they will be installed in the helicopter, engines which are intended to be installed with the axis of rotation either vertical or inclined from the horizontal may be tested on a dynamometer test bench specially designed for the purpose (Leaflet 7–2). However, tests on such engines are often run with the engine loaded by a paddle-bladed fan, in which case it is sometimes necessary to change the paddles to suit conditions at the various stages of the test run. Thus paddles of one diameter ('A' plates) may be specified for running at Maximum Continuous Power conditions and paddles of a different diameter ('B' plates) for running at Maximum Take-off Power conditions. Whilst paddle-bladed fans are calibrated in a similar manner to aerofoil-bladed fans, the technique of rendering them 'heavy' or 'light' is of course different.

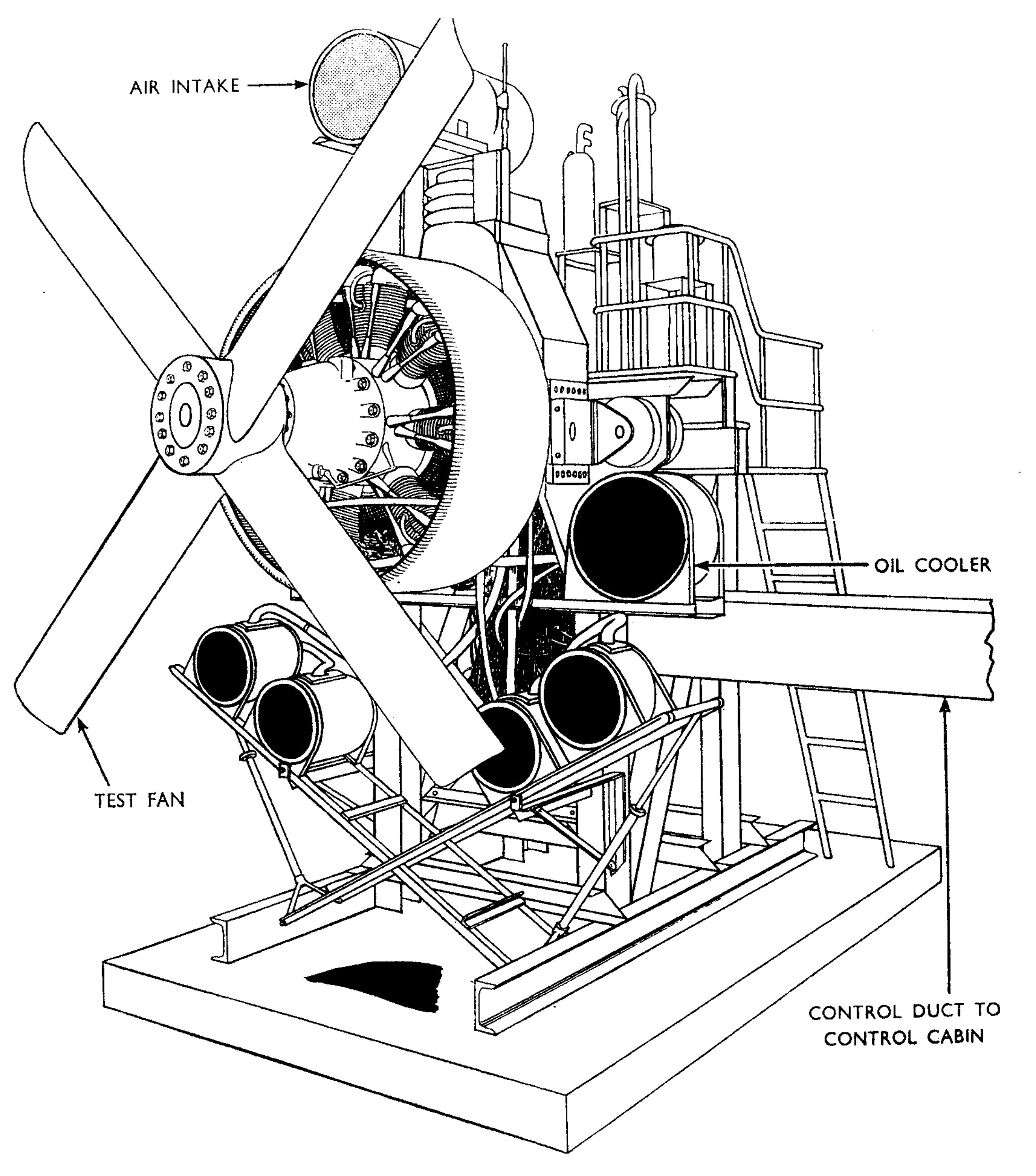


Figure 1 Aero-engine Test Bench For Fan Testing

3 Fan Testing

The fan method of testing an aero-engine consists of running the engine on a test bench with a calibrated test fan fitted instead of a flight propeller, the fan providing the means of loading the engine during the test. To assess the engine power output, the rpm of the overhauled engine when loaded with the test fan must be compared with the rpm which would be developed by the type engine loaded with the same fan and run on the same test bed under the same conditions.

3.1 Test Plant

The engine to be tested should be mounted on a test bench which should be provided with the complete oil, fuel and electrical systems required for starting and running the engine and, in the case of supercharged engines, with equipment for reducing the pressure of the air supplied to the engine intake so that altitude conditions can be simulated when specified in the engine test schedule. A suitable type of test bench for small engines is shown in Figure 1; it can be adapted for either radial or in-line engines. Whichever type of engine is fitted, adequate provision must be made for cooling it. This may necessitate fitting an oversize cooling scoop to in-line engines. Testing should normally be done in a specially designed building, preferably located so that the engines under test inhale air which is free from excess moisture or industrial contaminants. However, some test stands for the testing of small engines are of a mobile type and, in favourable atmospheric conditions, may be used in the open air. In all cases the test bench must be approved by the CAA.

3.2 Test Instruments

The test bench should be equipped with an approved range of instruments to enable accurate indication of the relevant test data specified in the test schedule appropriate to the engine. The instruments and all measuring equipment should be calibrated prior to fan calibration and should afterwards be checked for accuracy at regular intervals, as agreed with the CAA. An additional revolution counter which will serve as a master for checking the continuous reading rpm indicator must also be available; an instrument approved for this purpose is the 'Hasler', which is a hand-held indicator of great accuracy incorporating its own chronometer. In accordance with the Test Observations Code given in the Requirements (See Leaflet 7–1), the following continuous reading instruments are required for the testing of small air-cooled engines:

	Instrument	**Calibration**
1	Engine speed indicator	rpm
2	Manifold pressure gauge	kN/m^2 or kPa (inHg)
3	Main oil pressure gauge	kN/m^2 or kPa (lbf/in^2)
4	Auxiliary oil pressure gauge	kN/m^2 or kPa (lbf/in^2)
5	Pump inlet oil pressure gauge	kN/m^2 or kPa (lbf/in^2)
6	Fuel pressure gauge	kN/m^2 or kPa (lbf/in^2)
7	Oil temperature gauges (inlet and outlet temperatures)	°C
8	Cooling air temperature gauge	°C

9	Cooling air speed indicator (or cooling air differential pressure gauge)	m/s or kN/m^2 (mile/h or inH$_2$O)
10	Stop watch for checking oil circulation rate	Seconds
11	Cylinder head temperature gauge	°C
12	Fuel flowmeter	kg/h or litre/h (lb/h or pints/h)
13	Air intake temperature gauge	°C
14	Exhaust back pressure gauge	kN/m^2 or kPa (lbf/in^2)
15	Test house barometer	kN/m^2 or kPa (inHg)
16	Air intake pressure gauge	kN/m^2 or kPa (inHg)
17	Fan air temperature gauge	°C

3.3 Test Plant Oil System

The instructions given in Leaflet 7–2 for cleaning and heating test bench oil systems and for measuring oil consumption and oil circulation are also applicable when an engine is to be tested with a fan.

3.4 Instrument and Pipe Connections

The provisions of paragraphs 3.8, 3.9 and 3.10 of Leaflet 7–2 are also applicable when an engine is to be tested with a fan.

4 Choice of Test Fan

The type of test fan to be used when testing a particular type of engine must have been agreed with the engine manufacturer and approved by the CAA; the criteria determining the choice include the power dispersal characteristics of the fan, the ability to withstand the blade stresses imposed during prolonged bench running and the cooling requirements of the engine. There are two main groups of fans: fixed-pitch fans and variable-pitch fans controlled by a constant-speed governor.

4.1 Fixed-pitch Test Fans

Fixed-pitch fans may be sub-divided into two types: those which have one pitch that cannot be altered and those which have an adjustable pitch which can be locked at predetermined pitch settings. These two types of fans are usually designed and calibrated to absorb the Maximum Continuous Power of the engine when it is running at Maximum Continuous rpm under standard sea-level conditions and it is also essential that they should not allow the engine to overspeed at the Maximum Take-off manifold pressure.

4.1.1 Fans with unalterable pitch settings are specially made with square-tipped blades of laminated wood manufacture. The blades are made wide to provide maximum power absorption and maximum engine cooling with minimum blade tip diameter. Because design limitations and variations in test conditions make it impossible to predetermine the exact diameter required to absorb a given power, the blades are supplied oversize and have to be individually calibrated by successively removing material from the blade tips until the required power absorption is obtained. This operation is known as 'cropping'.

4.1.2 To crop a fan, thin slices are sawn from the tips of each wooden blade, care being taken to ensure that equal amounts are removed from each tip and that all sharp corners are rounded off. After each cropping, the fan must be rebalanced before it is replaced on the engine. On completion of cropping, the cropped blades should be protected against deterioration by applying the approved finish to the bare ends. If the blades are overcropped by a small amount, or are found to be absorbing too little power for any other reason, it may be permissible to make the fan 'heavy' by adding spoilers to the blades. The advice of the fan manufacturer should be sought on the method of spoiling appropriate to a particular type of fan.

4.1.3 The power absorption characteristics of a fixed-pitch fan with adjustable-pitch settings are varied by altering the pitch of the blades. The blade pitch is usually altered by resetting stops incorporated in the hub of the fan and these should be adjusted in accordance with the instructions of the manufacturer of the fan. If the rpm obtained during calibration are too high, the blades should be moved towards coarse pitch; if the rpm are too low, they should be moved towards fine pitch.

4.2 Variable-pitch Test Fans

Variable-pitch test fans controlled by a constant-speed governor can be operated at a fixed, predetermined position, e.g. on the fine or coarse pitch stop and also at variable settings under the control of the governor. Fans of this type are calibrated by adjusting their pitch stops so that the power of the engine at Maximum Take-off manifold pressure is absorbed without over- speeding when the engine is running under standard sea-level conditions. Such fans must also be able to absorb the Maximum Continuous engine power when constant speeding or running against a stop with the engine running under Maximum Continuous conditions.

4.3 Flight Propellers

A flight propeller may be approved as a test fan if the engine cooling provided is adequate and the propeller is able to withstand the more severe stresses which occur in the blades when operated under static instead of flight conditions. Once a metal flight propeller has been used as a test fan it must not again be used for flight purposes.

NOTE: Experience has shown that, unless a cable-suspended test rig is used, metal flight propellers are seldom satisfactory for prolonged test bed running.

4.4 Method of Determining Fan Type Required

If doubt exists as to whether a fixed-pitch or variable-pitch fan should be used for a particular engine type, the following method of determination may be used.

4.4.1 Unsupercharged Engines

The power/rpm curve at full throttle under standard sea-level conditions should be copied from the Engine Technical Certificate and marked at points corresponding to 90% and 97% of the maximum rpm. As shown in Figure 2, the point of Maximum Continuous power and rpm (the calibration point) should also be marked and a fan power absorption curve should be drawn through it to cut the full throttle curve. The fan power absorption curve is drawn on the assumption that the power varies with the cube of the rpm. The rpm indicated at the point of intersection of the two curves should lie between 90% to 97% of the maximum rpm. If it fails to do so, the point of Maximum Continuous power and rpm may be adjusted by ±2% of the rpm value and a cube law curve may be drawn through this adjusted point. If it is possible to bring the absorption curve to intersect the full throttle curve between the 90% to 97% rpm range by the ±2% adjustment, the engine may be tested with a fixed-pitch fan; if not, a variable-pitch fan should be used.

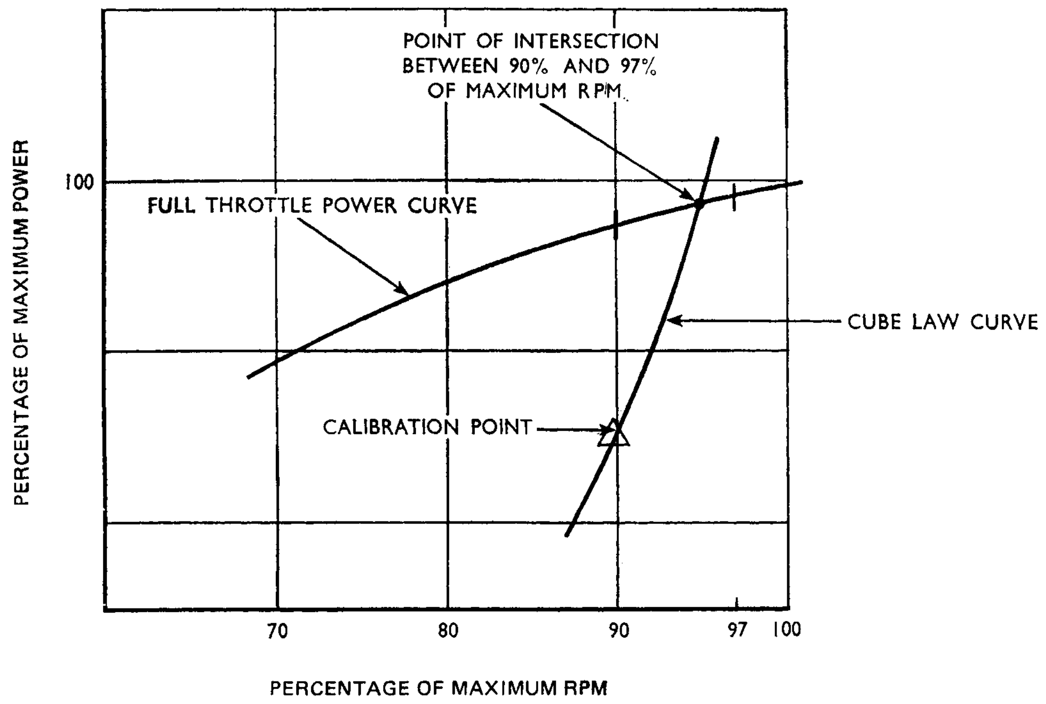


Figure 2 Determination of Type of Test Fan Required for an Unsupercharged Engine

4.4.2 Supercharged Engines

The procedure for supercharged engines with single speed superchargers is similar to that given in paragraph 4.4.1, except that the power/rpm curve at Maximum Take-off manifold pressure should be the curve obtained from the Engine Technical Certificate. Points corresponding to 90% and 97% of the maximum rpm should be marked on the Take-off power curve and the power absorption curve, originating from the point of Maximum Continuous Power and rpm (the calibration point) should be drawn to intersect this power curve. If, after an adjustment of ±2% of the rpm value, the intersection of the two curves fails to be between 90% and 97% of the maximum rpm, a fixed-pitch fan would be unsuitable for the test.

4.4.3 Variable-Pitch Fan Settings

If the procedure given in paragraph 4.4.1 or 4.4.2, as appropriate, indicates that a fixed-pitch fan is unsuitable, a variable-pitch fan should be used. For the power check, one pitch stop of the variable-pitch fan should be set so that 97% of the Maximum Take-off rpm is obtained when running against this stop at Maximum Take-off manifold pressure (see Figure 3). To achieve this, separate engine runs should be made at Maximum Take-off manifold pressure to establish the speeds obtainable with the fan on its fine and coarse pitch stops respectively. The rpm obtained on each run should be marked on the Take-off power curve as an indication as to which stop, after adjustment, will give the fan pitch resulting in a fan power absorption curve passing through the 97% rpm point on the power curve. If the coarse pitch stop is used, the constant-speed unit (CSU) is set to the minimum rpm position and the fan will constant speed for a point below the absorption curve. If the fine pitch stop is used, the CSU control is set to the maximum rpm position and the fan will then constant speed for a point above the curve.

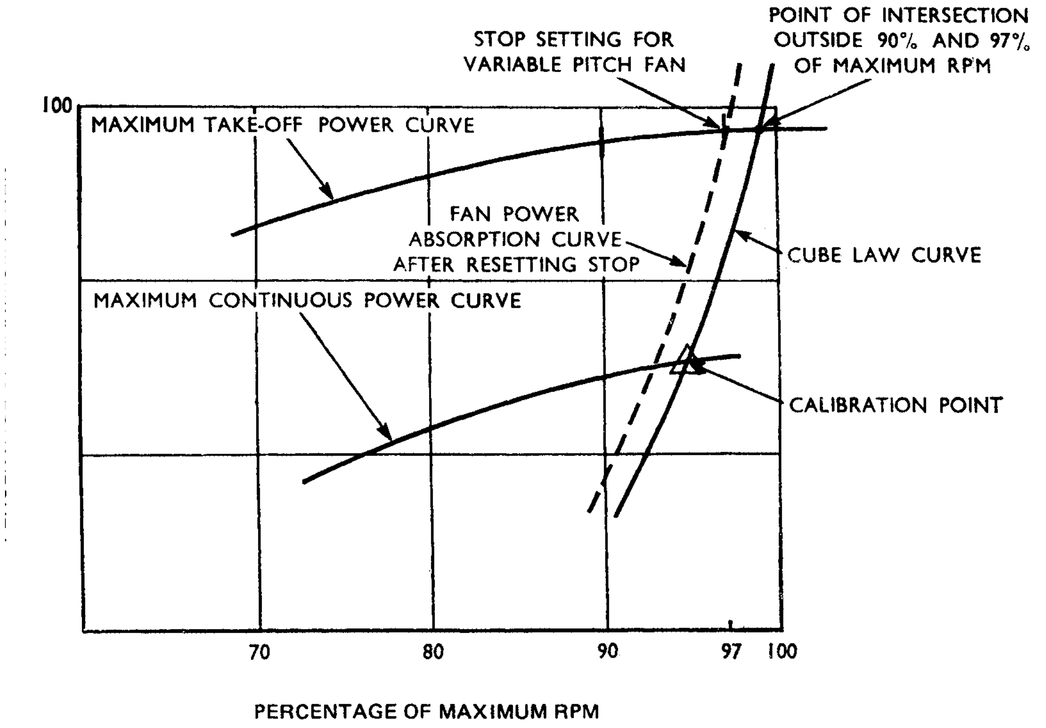


Figure 3 Determination of Type of Test Fan and Pitch Setting Required for a Supercharged Engine

5 Fan Calibration

Before being used for testing overhauled engines, each test fan on each site must be calibrated on a new or recently reconditioned engine (hereinafter referred to as the 'calibrated engine') which has not been run to any extent since its power output was last determined, for the purpose of fan calibration, on a dynamometer test bench. The calibration of the fan must be performed in the test cell in which the overhauled engines are to be tested and unless it can be shown that changing from one test bench to another has no effect on fan performance, a separate calibration should be made each time the fan is used on a different bench. For preference the fan should be calibrated when the wind is unlikely to have any appreciable effect on results, but, if tests must be made when a strong wind is blowing, appropriate corrections may be made. The correction factors applied must be agreed by the CAA.

5.1 For an unsupercharged engine, the Full Throttle power curve of the calibrated engine must be available. In the case of a supercharged engine, the Maximum Take-off and Maximum Continuous constant manifold pressure curves, at standard sea-level atmospheric conditions, are required. An approved Test Fan Calibration Schedule for the engine type (obtainable from the engine manufacturers and normally included in the Engine Test Schedule), the power curves for the engine type (obtainable from the Engine Technical Certificate) and the appropriate correction curves (see Leaflet 7–5), must also be available.

5.2 Before commencing fan calibration, it is advisable to use an old engine to enable the test bed to be correctly set up. The calibrated engine should then be mounted on the test bench and primed with warm engine oil (see paragraph 7.1). The manufacturer may specify that a special cooling airscoop should be fitted for test bed running.

5.3 When a test fan is being calibrated, the engine temperatures and pressures should be as near as possible to those recorded when the engine was calibrated on the dynamometer.

5.4 The test fan power absorption characteristics are presented in the form of a cube law curve drawn on the assumption that, under constant atmospheric conditions, the power absorbed varies as the cube of the rpm. Consequently, if the power to be absorbed by the fan at one particular engine speed is known, a cube law curve showing the power/rpm relationship over a range of speeds may be drawn from calculated data. If such a curve is drawn through the power it should absorb at a particular speed so as to intersect the appropriate power curve for the calibrated engine, the value of rpm at the intersection is the rpm to be obtained from the fan after its blades have been cropped or its pitch stop finally adjusted.

5.5 In practice a tolerance of not more than ±20 rpm has to be allowed, which necessitates drawing a cube law curve for the fan, after cropping or pitch adjustment, which is based on rpm values derived from the observed results corrected to standard sea-level conditions. The intersection of the actual fan power absorption curve and the appropriate engine power curve for the type engine then gives the 'acceptance rpm' value for the test fan. The corrected values subsequently attained when overhauled engines are tested with the same fan on the same test bed should not be less than 98% of these values.

5.6 The acceptance rpm of the test fan on the particular test bed should be recorded and used as a reference whenever the fan is used for testing. At periods agreed with the CAA, each test fan should be weighed, its static balance should be checked, the blade angles should be measured at specified stations and the general condition of the fan should be assessed. At longer agreed periods and whenever any change in the environment of the test cell is made or whenever distortion of the fan blades is suspected, the acceptance rpm should be re-checked by a repeat calibration.

6 Fan Calibration Procedure

The procedure for calibrating a test fan for use in testing a particular type of engine varies according to whether the engine is supercharged or unsupercharged. In practice a specific method to suit the characteristics of each type of engine is recommended by the engine manufacturer and is included in the approved Engine Test Fan Calibration Schedule. The approved method must be used at all times, but an outline of the general principles of calibration procedure is given in the following paragraphs. Whilst the specimen procedures given are typical, they are not necessarily generally applicable to all engine types.

6.1 Unsupercharged Engines

Unsupercharged engines are generally tested with fixed-pitch fans and a typical calibration procedure is as follows:

6.1.1 Draw the power/rpm curves at full throttle for the calibrated engine and for the type engine, as shown in Figure 4.

6.1.2 Plot on the graph the test fan calibration point (obtained from data supplied by the engine manufacturer) and through it draw a cube law curve representing the power absorption characteristics of the fan. Extend this curve as necessary to intersect the full throttle curve for the calibrated engine. The point of intersection gives the corrected rpm to be attained, subject to a tolerance of ±20 rpm, when the test fan has been adjusted and the calibrated engine is running at full throttle.

EXAMPLE: If the calibration point is 142 kW at 2100 rpm, mark this point on the graph and then plot further points obtained by incremental increases of power and rpm. Since the power absorbed by the fan is assumed to increase with the cube of the rpm, the increments of power increase should be cubed thus:

$142 \times 1{\cdot}1^3$ against $2100 \times 1{\cdot}1 = 189$ kW/2310 rpm

and $142 \times 1{\cdot}2^3$ against $2100 \times 1{\cdot}2 = 245{\cdot}4$ kW/2520 rpm

The cube law curve is a line drawn from the calibration point through the points plotted to the full throttle curve of the calibrated engine.

6.1.3 The temperature correction chart (Leaflet 7–5) should now be used to find the corresponding value of rpm which should be obtained in the actual conditions of fan air temperature prevailing at the site.

6.1.4 With the calibrated engine fitted with the test fan and installed on the test bench in the cell for which the calibration is required, the engine should be run until normal running conditions have stabilised. It should then be opened up to full throttle and careful note taken of the rpm obtained. The rpm observed on the continuous reading rpm indicator should be cross-checked by means of the 'Hasler' indicator.

6.1.5 To obtain the value of rpm determined by the method given in paragraph 6.1.3 (within ±20 rpm), the fan should be removed and the blades cropped or the pitch adjusted as necessary. This should be done in successive stages with trial runs and, in the case of cropped propellers, rebalancing between each stage. If a cropped test fan gives a higher speed than that aimed at, it should be made 'heavy' in the manner approved by the fan manufacturer.

6.1.6 The fan should then be remounted on the engine and the engine should again be run at full throttle. When the required rpm are obtained, the observed values should be recorded. To obtain reliable results, two or three separate runs should be made and on each occasion the mean of three readings taken in stabilised conditions at 1 minute intervals should be taken as the observed rpm. The mean of the observed rpm readings should then be corrected to standard temperature conditions by means of the appropriate chart and the corrected value should be plotted on the full throttle curve for the calibrated engine. In the example shown in Figure 4, the rpm are higher than the value aimed at but are within the tolerance.

6.1.7 A cube law curve should now be drawn to pass through the point plotted by the method given in paragraph 6.1.6 for the corrected value of rpm. This curve should be extended as necessary to intersect the full throttle curve for the type engine and the point of intersection will give the acceptance rpm of the fan. This value should be recorded together with details of the direction and speed of the wind at the time of calibration. A report on the calibration, including details of the environment in which the fan was tested and the acceptance rpm established for it, should then be submitted to the CAA for approval.

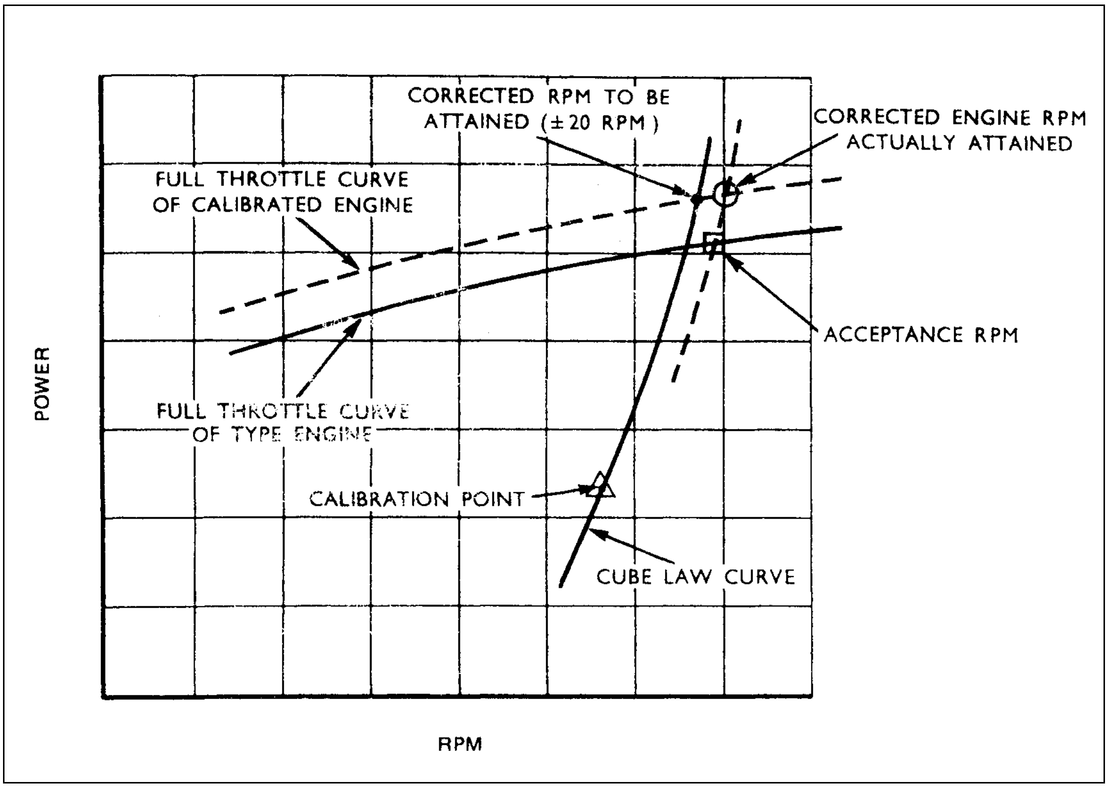


Figure 4 Calibration of Fixed-pitch Fan Fitted to Unsupercharged Engine

6.2 **Supercharged Engines**

Engines with single-speed superchargers are tested either with fixed- pitch fans or with variable-pitch fans, the type of fan required being determined by the method given in paragraph 4.4. Typical calibration procedure is as follows:

6.2.1 Draw the power/rpm curves for constant manifold pressure at Maximum Take-off, Maximum Continuous Power and, if applicable, Maximum Weak Mixture Power for both the calibrated engine and the type engine, as shown in Figure 5.

6.2.2 For a fixed-pitch fan, plot on the graph the test fan calibration point (normally the point of Maximum Continuous power and rpm) and through it draw a cube law curve representing the power absorption characteristics of the fan. For a variable-pitch fan with governor control, plot the 97% rpm point of the type engine, as determined by paragraph 4.4.3 and draw the cube law curve through it. Extend the cube law curve as necessary to intersect the Maximum Take-off, Maximum Continuous Power and Maximum Weak Mixture constant manifold pressure curves for the calibrated engine. The point of intersection with the Maximum Take-off constant manifold pressure curve gives the corrected rpm to be attained, subject to a tolerance of ±20 rpm, when the test fan has been adjusted and the calibrated engine is running at the Maximum Take-off manifold pressure on a standard day.

6.2.3 The appropriate correction chart (Leaflet 7-5) should now be used to find the corresponding values of rpm to be obtained in the actual conditions of fan air temperature and atmospheric pressure prevailing at the site.

6.2.4 With the calibrated engine installed on the test bench and fitted with the test fan in the cell for which the calibration is required, the engine should be run until normal running conditions have stabilised. It should then be opened up to Take-off manifold pressure and careful note taken of the rpm obtained. A cross-check should be made by means of the 'Hasler' indicator.

6.2.5 To obtain the value of rpm determined by the method given in paragraph 6.2.3 (within ±20 rpm), the fan should be cropped or the pitch adjusted as necessary. The fan should then be remounted on the engine and the engine should be run at Take-off, Maximum Continuous and Maximum Weak Mixture manifold pressures in turn. Where applicable, the sequence of events for cropping the fan and then running the engine fitted with the calibrated fan, should be the same as in paragraphs 6.1.5 and 6.1.6.

6.2.6 The rpm observed when the engine is running with the fan finally adjusted should be corrected to conditions at sea-level on a standard day. The corrected rpm at Take-off manifold pressure should be plotted on the Take-off Power curve for the calibrated engine and the corrected rpm for Maximum Continuous and Maximum Weak Mixture on the appropriate power curves. These points should be linked by a test fan power absorption curve of approximately cube law form drawn through them.

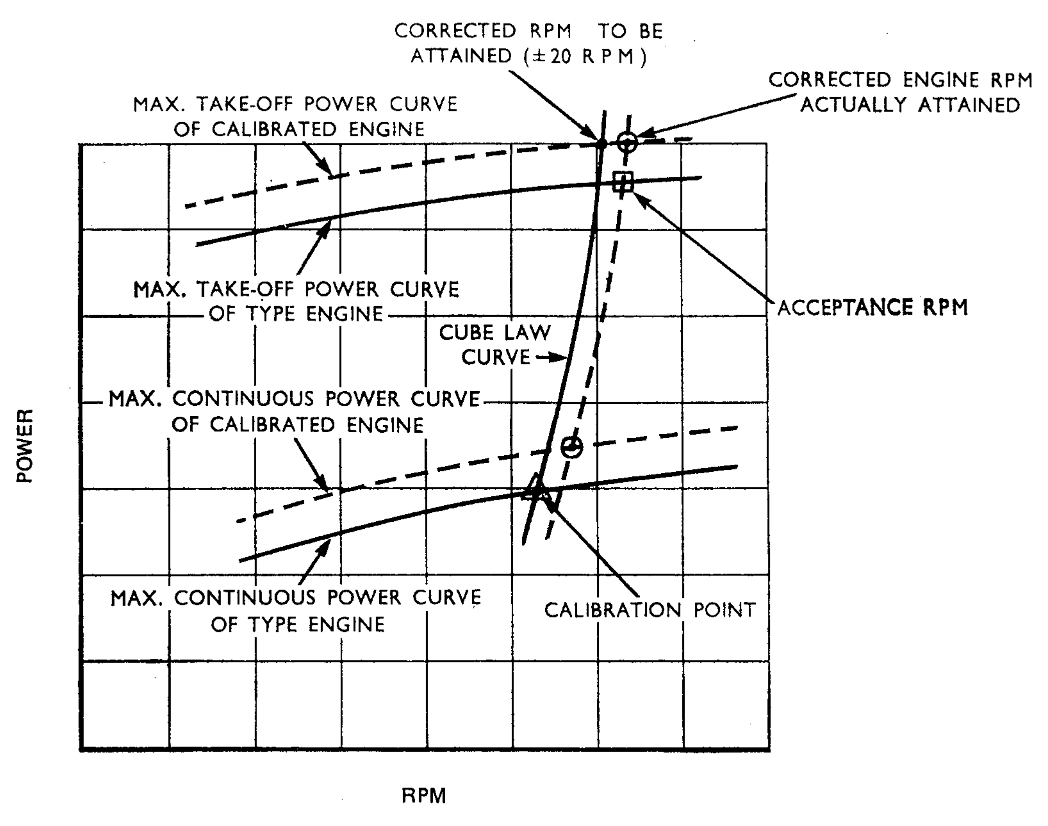


Figure 5 Calibration of Fixed-pitch Fan Fitted to Supercharged Engine

6.2.7 The fan power absorption curve should be extended as necessary to cut the Maximum Take-off Power curve for the type engine. The point of intersection gives the acceptance rpm of the fan. The points where the fan power absorption curve cuts the Maximum Continuous and Maximum Weak Mixture curves give rpm datum points which may be used, as recommended by the engine manufacturer, for engine tuning. These values should be recorded, together with details of the direction and speed of the wind at the time of the calibration. A report on the calibration, including details of the environment in which the fan was tested and the acceptance rpm established for it, should then be submitted to the CAA for approval.

7 Using the Calibrated Fan

After calibration, a test fan should only be used to test engines of the type for which it has been calibrated and in the particular cell in which the calibration has been made. If the environmental conditions of the test cell are changed, the fan must be recalibrated. The overhauled engine to be tested should be mounted on the test bench within the cell and the calibrated fan should be assembled to it: the engine should then be run according to the approved Test Schedule appropriate to the type of engine (see Leaflet 7–1).

7.1 Before starting the engine, its lubrication system should be primed with warm engine oil. The oil should be fed in under pressure whilst the engine is turned over by hand, care being taken to ensure that the oil is completely distributed through the bearings, gears and accessories drives. Should the engine not be run within three hours of priming it should be reprimed.

7.2 The engine should be correctly adjusted before the commencement of the test and a check should be made that the test plant controls have been correctly assembled. In the case of supercharged engines, the regulating valve of the depression box on the air intake should be fully open; in the case of normally-aspirated engines no depression box should be fitted.

7.3 After starting, the engine should be run-in according to the instructions in the Test Schedule approved for the engine type. Running-in is Stage 1 of the Endurance Test and the other stages should then follow in the sequence prescribed. During the test a suitable position for the thermometer which records the temperature of the air passing through the fan should be determined; a position between 2·5 to 4 metres (8 to 12 feet) forward of the engine and outside the arc of the fan usually proves satisfactory.

8 Acceptance Conditions

The acceptance conditions for overhauled engines when tested with a fan and the performance corrections to be made are prescribed in JAR–E 1030 of British Civil Airworthiness Requirements and repeated in the following paragraphs. Apart from the general running standard of each engine and its ability to satisfactorily complete the prescribed tests, the specific standards of performance of 8.1 or 8.2, as appropriate, must be obtained to the satisfaction of the CAA.

8.1 Engines Rated in accordance with the Requirements in force on and after 18th November, 1946 (ICAO Ratings)

8.1.1 The rpm obtained during the power check tests of the Final Test (Stage 10; and Stage 7 in respect of any other supercharger gears), when corrected to standard atmospheric conditions at sea- level, in accordance with paragraph 9, shall not be less than 98% of the acceptance rpm of the fan. Also in the case of a supercharged engine, the corrected supercharger compression ratio (at 15°C) obtained during Stages 8 and 9 of the Final Test and the corrected rpm obtained during the corresponding power check tests of the Final Test shall satisfy the following expression:

$$\frac{r_2}{r_1} + \left(\frac{N_2}{N_1}\right) \text{ shall be not less than } 1{\cdot}96$$

where r_2 = supercharger compression ratio of the engine being tested at the observed rpm of the test.

r_1 = supercharger compression ratio of the standard engine at the observed rpm of the test as derived from the Engine Technical Certificate.

N_2 = corrected rpm obtained from the power check tests for engine being tested

N_1 = acceptance rpm of the fan.

8.1.2 Fuel Consumption

In the case of overhauled engines tested with a fan, the fuel consumption shall be within the limits approved by the CAA.

8.1.3 Oil Consumption

The mean oil consumption obtained from the tests of Stages 3 and 4 of the Endurance Tests and Stage 4 of the Final Test, shall be within the declared limits. In the event of the engine not being able to comply with this requirement during the tests of Stages 3 and 4 of the Endurance Test, it shall be rejected for rectification and re-submission to the Endurance Test. Alternatively, subject to the agreement of the CAA, the endurance running of Stages 3 and 4 of the Endurance Test may be extended up to a maximum of an additional 2 hours, until the consumption falls within the required limits over a period of at least 30 minutes' duration. The consumption shall be checked in each supercharger gear. As a further alternative, where the applicant is of the opinion that the oil consumption can be improved by adjustment during strip examination, the endurance portion of the Final Test may, at the discretion of the CAA, be extended by the addition of a run limited to a minimum of 1 hour at the declared Maximum Continuous Power conditions. The running shall be equally divided between the supercharger gears. During the period of oil consumption measurement, ignition checks, or operation of any accessory or any other tests or adjustment which may affect consumption, shall be avoided. The oil consumption in each supercharger gear shall be reasonably consistent.

8.1.4 Accelerations

Accelerations shall be smooth and free from hesitation or other signs of fuel-metering trouble.

8.1.5 Single Ignition Check

The power drop when running with single ignition shall not exceed the declared maximum.

8.1.6 Cleanliness

The engine shall be free from leaks at all joints and connections, etc.

8.2 Engines Rated in accordance with the Requirements in force before 18th November, 1946 (pre- ICAO Ratings)

The acceptance conditions for engines with pre-ICAO ratings are identical to those in paragraph 8.1, except that Maximum Cruising Power conditions should be substituted for Maximum Continuous Power conditions wherever these conditions are specified.

9 Performance Corrections

9.1 The corrections used in order to convert the observed engine rpm to standard atmospheric conditions at sea-level and to assess the performance of the supercharger where applicable, shall be approved by the CAA for each type of engine. These corrections shall be prepared in the form of charts (see Leaflet 7–5).

9.2 For the rpm correction the variation of power with rpm at Maximum Take-off manifold pressure (and at Maximum Climbing or Maximum Continuous manifold pressure in any other supercharger gears) shall be established and a chart giving the correction factor for a suitable range of atmospheric conditions shall be prepared. If variations in wind speed and direction can appreciably affect the power absorption characteristics of a fan in a particular test cell, suitable corrections may be established, but before being used they shall be approved by the CAA.

Leaflet 7-4 Storage Procedures

1 Introduction

Under normal operating conditions the interior parts of an engine are protected against corrosion by the continuous application of lubricating oil and operating temperatures are sufficient to dispel any moisture which may tend to form; after shutdown the residual film of oil gives protection for a short period. When not in regular service, however, parts which have been exposed to the products of combustion and internal parts in contact with acidic oil, are prone to corrosion. If engines are expected to be out of use for an extended period they should be ground run periodically or some form of anti- corrosive treatment applied internally and externally to prevent deterioration.

1.1 The type of protection applied to an engine depends on how long it is expected to be out of service, if it is installed in an aircraft and if it can be turned.

1.2 This Leaflet gives guidance on the procedures which are generally adopted to prevent corrosion in engines but, if different procedures are specified in the approved Maintenance Manual for the particular engine, the manufacturer's recommendations should be followed.

1.3 The maximum storage times quoted in the Leaflet are generally applicable to storage under cover in temperate climates and vary considerably for different storage conditions. Times may also vary between different engines and reference must be made to the appropriate Maintenance Manual for details.

2 Installed Piston Engines

If it is possible to run a piston engine which is installed in an aircraft and expected to be out of service for a period of up to one month, sufficient protection will be provided by running the engine every seven days, but if the period of inactivity is subsequently extended, continued periodic ground running would result in excessive wear and the engine should be placed in long term storage. The run should be carried out at low engine speed (1000 to 1200 rev/min), exercising the engine and propeller controls as necessary to ensure complete circulation of oil, until normal working temperatures are obtained. If the engine cannot be run for any reason, the manufacturer may recommend that it should be turned by hand or motored by means of an external power supply, but generally it will be necessary to inhibit the engine as described below.

2.1 Long Term Storage

When a piston engine is likely to be out of service for a period in excess of one month it must be treated internally and externally with a corrosion inhibitor. The treatments described below are normally considered satisfactory for six months but this may be extended to twelve months in ideal storage conditions. At the end of this period the engine should be prepared for service, given a thorough ground run and re-protected or, alternatively, removed from the aircraft and stored as described in paragraph 4.

2.1.1 Internal Protection

a) **American Method**

   i) Drain the oil sump and tank and refill with storage oil as prescribed by the manufacturer.

   ii) Run the engine at low speed (1000 to 1200 rev/min) until normal operating temperatures are obtained.

   iii) Spray cylinder protective into the induction system until white smoke issues from the exhaust, then switch off the engine but continue spraying until rotation has ceased.

   iv) Drain the oil sump and remove the filters.

   v) Remove the sparking plugs and spray a fixed quantity of cylinder protective into each cylinder while the engine is turned by hand. A further quantity should then be sprayed into the cylinders with the engine stationary.

   vi) Fit dehydrator plugs in each cylinder and replace oil filters.

   vii) Place a quantity of desiccant in the intake and exhaust and blank off all openings.

b) **British Method**

   i) Drain the oil sump and tank and refill with the storage oil recommended by the manufacturer.

   ii) Run the engine at low speed (1000 to 1200 rev/min) until normal operating temperatures are obtained.

   iii) Drain all oil from the system and remove filters.

   iv) Remove sparking plugs and spray the specified quantity of cylinder protective into each cylinder while the piston is at the bottom of its stroke, at the same time spraying the valve springs and stems with the valves closed and the valve heads and ports with the valves open. Also spray the valve rocker gear.

   v) Turn the engine at least six revolutions by hand, then spray half the previously used quantity of cylinder protective into each cylinder with the engine stationary.

   vi) Replace oil filters and fit dehydrator plugs.

   vii) Blank off all openings into the engine (intake, exhaust, breathers, etc.).

   viii) Replenish oil tank to normal level with storage oil as specified.

c) **Special Requirements**

   i) Coolant systems should be drained and thoroughly flushed unless an inhibited coolant is used.

   ii) Fuel system components such as fuel pumps, injectors, carburettors or boost control units also require inhibiting. This is done by draining all fuel and oil as appropriate and refilling with storage or mineral oil as recommended by the manufacturer. Blanking caps and plugs should then be fitted to retain the oil.

   iii) Auxiliary gearboxes should also be inhibited. The normal lubricating oil should be drained and the gearbox refilled with storage oil.

   iv) If the propeller is removed the propeller shaft should be sprayed internally and externally with cylinder protective and correct blanks fitted.

2.1.2 External Protection

Exterior surfaces of the engine should be thoroughly cleaned with an approved solvent such as white spirit, by brushing or spraying and dried with compressed air. Any corrosion should be removed, the area re-treated in accordance with the manufacturer's instructions and chipped or damaged paintwork renewed. The following actions should then be taken:

a) All control rods should be liberally coated with a general purpose grease.

b) Magneto vents should be covered.

c) Sparking plug lead ends should be fitted with approved transport blanks, exposed electrical connections masked and rubber components covered with waxed paper or mouldable wrap.

d) Spray holes in fire extinguisher pipes should, if possible, be blanked off, using polythene sleeving or waxed paper suitably secured.

e) An approved preservative (normally lanolin or external air drying varnish) should be sprayed over the whole engine, in a thin even film.

2.2 General Precautions

It is most important that an installed stored engine should not be turned, since this would lead to removal of cylinder protective from the cylinder walls and possibly result in the formation of corrosion at those positions. Physical restraint is seldom practicable, particularly when a propeller is fitted, but warning notices should be fixed on the propeller and in the cockpit to prevent inadvertent rotation of the engine.

3 Installed Turbine Engines

Installed turbine engines which are to be out of use for a period of up to seven days require no protection apart from fitting covers or blanks to the intake, exhaust and any other apertures, to prevent the ingress of dust, rain, snow, etc. A turbine engine should not normally be ground run solely for the purpose of preservation, since the number of temperature cycles to which it is subjected is a factor in limiting its life. For storage periods in excess of seven days additional precautions may be necessary to prevent corrosion.

3.1 Short-term Storage

The following procedure will normally be satisfactory for a storage period of up to one month.

3.1.1 Fuel System

The fuel lines and components mounted on the engine must be protected from the corrosion which may result from water held in suspension in the fuel. The methods used to inhibit the fuel system depend on the condition of the engine and whether it is installed in an aircraft or not and are fully described in the appropriate Maintenance Manual. On completion of inhibiting, the fuel cocks must be turned off.

3.1.2 Lubrication Systems

Some manufacturers recommend that all lubrication systems (engine oil, gearbox oil, starter oil, etc.) of an installed engine should be drained and any filters removed and cleaned, while others recommend that the systems should be filled to the normal level with clean system oil or storage oil. The method recommended for a particular engine should be ascertained from the appropriate Maintenance Manual.

3.1.3 External Treatment

Exterior surfaces should be cleaned as necessary to detect corrosion, then dried with compressed air. Any corrosion should be removed, affected areas re-treated and any damaged paintwork made good in accordance with the manufacturer's instructions. Desiccant or vapour phase inhibitor should be inserted in the intake and exhaust and all apertures should be fitted with approved covers or blanks.

3.2 Long-term Storage

For the protection of turbine engines which may be in storage for up to six months, the short-term preservation should be applied and, in addition, the following actions taken:

a) Grease all control rods and fittings.

b) Blank-off all vents and apertures on the engine, wrap greaseproof paper round all rubber parts which may be affected by the preservative and spray a thin coat of external protective over the whole engine forward of the exhaust unit.

3.2.1 At the end of each successive six months storage period an installed engine should be re- preserved for a further period of storage. Alternatively, the engine may be removed from the aircraft and preserved in a moisture vapour proof envelope.

4 Uninstalled Engines (Piston and Turbine)

Engines which have been removed from aircraft for storage, or uninstalled engines which are being returned for repair or overhaul, should be protected internally and sealed in moisture vapour proof (MVP) envelopes. This is the most satisfactory method of preventing corrosion and is essential when engines are to be transported overseas.

4.1 A piston engine should be drained of all oil, the cylinders inhibited as described in paragraphs 2.1.1 b), iv) to viii), drives and inside of crankcase sprayed with cylinder protective and all openings sealed.

4.2 A turbine engine should be drained of all oil, fuel system inhibited, oil system treated as recommended by the manufacturer and blanks fitted to all openings.

4.3 Particular care should be taken to ensure that no fluids are leaking from the engine and that all sharp projections, such as locking wire ends, are suitably padded to prevent damage to the envelope.

4.4 The MVP envelope should be inspected to ensure that it is undamaged and placed in position in the engine stand or around the engine, as appropriate. The engine should then be placed in the stand, care being taken not to damage the envelope at the points where the material is trapped between the engine attachment points and the stand bearers.

4.5 Vapour phase inhibitor or desiccant should be installed in the quantities and at the positions specified in the relevant Maintenance Manual and a humidity indicator should be located in an easily visible position in the envelope. The envelope should then be sealed (usually by adhesive) as soon as possible after exposure of the desiccant or vapour phase inhibitor.

4.6 The humidity indicator should be inspected after 24 hours to ensure that the humidity is within limits (i.e. the indicator has not turned pink). An unsafe reading would necessitate replacement of the desiccant and an examination of the MVP envelope for damage or deterioration.

4.7 After a period of three years storage in an envelope the engine should be inspected for corrosion and re-preserved.

5 Inspection

Engines in storage should be inspected periodically to ensure that no deterioration has taken place.

5.1 Engines which are not preserved in a sealed envelope should be inspected at approximately two-weekly intervals. Any corrosion patches should be removed and the protective treatment re-applied, but if external corrosion is extensive a thorough inspection may be necessary.

5.2 Envelopes on sealed engines should be inspected at approximately monthly intervals to ensure that humidity within the envelope is satisfactory. If the indicator has turned pink the envelope should be unsealed, the desiccant renewed and the envelope resealed.

6 Equipment and Materials

6.1 Equipment

The spraying equipment should be of a type approved by the engine manufacturer and should be operated in accordance with the instructions issued by the manufacturer of the equipment. For inhibiting cylinders a special nozzle is required and this should be checked immediately before use to ensure that the spray holes are unblocked. Correct operation of the spray gun may be checked by spraying a dummy cylinder and inspecting the resultant distribution of fluid.

6.2 Materials

Only the types of storage and inhibiting oil recommended by the manufacturer should be used for preserving an engine. American manufacturers generally recommend oils and compounds to American specifications and British manufacturers generally recommend storage oil to DEF 2181, wax-thickened cylinder protective to DTD 791, turbine fuel system inhibiting oil to D. Eng. R.D. 2490 and external air drying varnish approved under a DTD 900 specification. Only approved alternatives should be used and any instructions supplied by the manufacturer in respect of thinning or mixing of oils should be carefully followed.

6.3 Blanks

Approved blanks or seals should be used whenever possible. These are normally supplied with a new or reconditioned engine and should be retained for future use. Pipe connections are usually sealed by means of a screw-type plug or cap such as AGS 3802 to 3807 and plain holes are sealed with plugs such as AGS 2108; these items are usually coloured for visual identification. Large openings such as air intakes are usually fitted with a specially designed blanking plate secured by the normal attachment nuts and the contact areas should be smeared with grease before fitting, to prevent the entry of moisture. Adhesive tape may be used to secure waxed paper where no other protection is provided, but should never be used as a means of blanking off by itself, since it may promote corrosion and clog small holes or threads.

7 Removal from Storage

For an engine which was not installed in an aircraft during storage the installation procedure described in the appropriate Maintenance Manual should be carried out, followed by a thorough ground run and check of associated systems. For an engine which was installed in an aircraft during storage the following actions should be taken:

a) Remove all masking, blanks and desiccant.

b) Clean the engine as necessary, e.g. remove excess external protective and surplus grease from controls.

c) Ensure fire extinguisher spray pipe holes are clear.

d) Replace any components which were removed for individual storage, de-inhibiting as necessary.

e) Drain out all storage oil, clean oil filters and refill with normal operating oil.

f) Piston engines; remove sparking plug blanks and turn engine slowly to drain excess oil from the cylinders, then fit plugs and connect leads. Turbine engines; prime the fuel system in accordance with the manufacturer's requirements.

g) Prime the engine lubricating oil system.

h) Start the engine and carry out a check of the engine and associated systems.

8 Records

Appropriate entries must be made in the engine log book giving particulars of inhibiting procedures or periodic ground running. Such entries must be signed and dated by an appropriately licensed engineer or Approved Inspector.

Leaflet 7-5 Piston Engine Overhaul – Correcting Engine Test Results

1 Introduction

1.1 JAR–E of British Civil Airworthiness Requirements prescribes that all performance results obtained during the bench testing of aero-engines must be corrected to the conditions of temperature and pressure in the standard atmosphere. Correction formulæ from the Requirements which are applicable to the testing of low-power, air-cooled engines are repeated in this Leaflet; other parts of the Requirements relevant to testing piston engines after overhaul are repeated in CAAIP Leaflets 7–1, 7–2 and 7–3.

1.2 This Leaflet also explains how to make corrections for the effects of prevailing atmospheric conditions during the calibration of test fans, and includes charts which may be used to make such corrections.

1.3 This Leaflet should be read in conjunction with CAAIP Leaflets 7–1, 7–2 and 7–3.

2 General

Varying atmospheric conditions affect engine performance by an appreciable amount and corrections must therefore be made for deviations of atmospheric pressure and temperature from standard at the time of test. Humidity changes, whilst not generally as significant as pressure or temperature changes, also have an influence on the results and therefore a method of correcting for humidity is given in paragraph 3.3. If this method is not used, an alternative method approved by the CAA must be used. If the engine power is affected by deviation of cylinder temperature from the values prescribed in the test schedules, appropriate corrections may also be made, but the corrections must be approved by the CAA before use in the calculations.

3 Engines Tested with a Dynamometer

When an engine is tested on a dynamometer test bench, the brake power is obtained from the products of the net weight lifted by the dynamometer and the rotational speed of the dynamometer rotor, divided by the dynamometer constant (Leaflet 7–2). This gives the observed brake power for the engine (power) and represents the particular power output of the engine under the conditions of air intake temperature, atmospheric pressure, engine manifold pressure and exhaust back pressure at the time of test. To ensure that the power of an engine is within the acceptance limits for the engine type, these results must be corrected to conditions which are standardised for all tested engines, namely to the sea-level conditions of pressure and temperature in the standard atmosphere. These are 101.325 kN/m^2 (29.92 inHg) and 15°C respectively.

3.1 Power Correction Formulæ

The corrected brake power, P (BHP), of normally aspirated engines and supercharged engines in which there is no provision for inter-cooling, after-cooling or heating the charge before it enters the cylinders, is given by the formulæ:

SI Units

$$P_c = P_o \frac{(400 + t_o)\left(M_c - \frac{P_c}{R}\right)}{(400 + t_c)\left(M_o - \frac{P_o}{R}\right)}$$

Non-SI Units

$$BHP_c = BHP_o \frac{(400 + t_o)\left(M_c - \frac{P_c}{R}\right)}{(400 + t_c)\left(M_o - \frac{P_o}{R}\right)}$$

where P(BHP) = brake power, kW (horsepower)

t = air intake temperature, °C

M = manifold pressure, kN/m^2 (inHg)

p = exhaust back pressure, kN/m^2 (inHg) = atmospheric pressure + any increase in pressure due to the test plant exhaust system. (In the examples given p is assumed to be equal to atmospheric pressure)

R = engine compression ratio

Friction Power (Pf or FHP) is given by the formulæ:

SI Units

$P_f = 27 \times 10^{-16} \times N^2 \times d^2 \times l^2 \times n$

Non-SI Units

$FHP = 15 \times 10^{-10} \times N^2 \times d^2 \times l^2 \times n$

where N = crankshaft rotational speed, rpm

d = cylinder bore, mm (in)

l = length of stroke, mm (in)

n = number of cylinders

Suffix 'o' denotes an observed condition, corrected for instrument error only.

Suffix 'c' denotes the condition in the required (sea-level atmospheric) atmosphere.

NOTES:

1) Standard sea-level atmospheric pressure = 1·01325 x N/m^2 = 1013·2 mbar = 29·92 inHg = 760 mmHg = 14·7 lbf/in^2.

2) 1 kN/m^2 = 1 kPa = 10 mbar.

3) 1 lbf/in^2 = 6.895 kN/m^2.

4) 1 inHg = 3.386 kN/m^2.

3.1.1 Unsupercharged Engines

For an unsupercharged engine running at constant rpm at full throttle, the manifold pressure is normally assumed to be atmospheric, which means that to correct the observed power to sea-level conditions the formulæ can be written as follows:

SI Units

$$P_c = P_o \frac{(400 + t_o)\left(101.325 - \frac{101.325}{R}\right)}{(400 + t_c)\left(P_o - \frac{P_o}{R}\right)}$$

Non-SI Units

$$BHP_c = BHP_o \frac{(400 + t_o)\left(29.92 - \frac{29.92}{R}\right)}{(400 + t_c)\left(P_o - \frac{P_o}{R}\right)}$$

EXAMPLE: If the full-throttle brake power of a particular engine (compression ratio 5.25:1) is observed to be 196 kW on a day when the air temperature is 17°C and barometric pressure is 1000 mbar (100 kN/m^2), then corrected to standard sea-level conditions the brake power would be:

$$P_c = 196 \frac{(400 + 17)\left(101.325 - \frac{101.325}{R}\right)}{(400 + 15)\left(100 - \frac{100}{R}\right)}$$

= 196 x 1.005 x 1.013

= **199.54 kW**

NOTE: Assuming the declared Maximum Take-off Power of the engine is 196 to 204 kW at sea-level, the result satisfies the acceptance conditions of BCAR.

3.1.2 Supercharged Engines

During the Endurance and Final Tests of a supercharged engine, the power output and the supercharger compression ratio are measured, the former with an unrestricted air intake and the latter with a restricted intake obtained by using a depression box fitted to the intake.

a) **Power.** When correcting the power observed during a test run with unrestricted air intake to standard sea-level conditions at the same manifold pressure, the correction formula can be written:

SI Units

$${}_c = P_o \frac{(400 + t_o)\left(M_c - \frac{101.325}{R}\right)}{(400 + 15)\left(M_o - \frac{P_o}{R}\right)}$$

Non-SI Units

$$BHP_c = BHP_o \frac{(400 + t_o)\left(M_c - \frac{29.92}{R}\right)}{(400 + 15)\left(M_o - \frac{P_o}{R}\right)}$$

EXAMPLE: If the brake power of a particular engine, having a compression ratio of 6.5:1 and running at a manifold pressure of 41·3 inHg (140 kN/m^2) is observed to be 348.5 kW on a day when the air intake temperature is 20°C and the barometric pressure is 1010 mbar (101 kN/m^2), the corrected brake power will be:

$$P_c = 348.5 \frac{(400 + 20)\left(140 - \frac{101.325}{6.5}\right)}{(400 + 15)\left(140 - \frac{101}{6.5}\right)}$$

= 348.5 x 1.012 x 0.999

= **352.329 k W**

b) **Supercharger Compression Ratio.** The variation of supercharger compression ratio with variation of air temperature at constant air intake pressure is given by:

$r_c = r_o (1 + k (t_o - t_c))$ when correcting to a lower air temperature

and $r_c = \frac{r_o}{1 + k(t_c - t_o)}$ when correcting to a higher air temperature

In the above formulæ the additional notation is used:

r = supercharger compression ratio

k = supercharger temperature constant for particular engine.

The supercharger compression ratio is determined during Stages 8 and 9 of each test by running the engine with the air intake restricted such that the throttle is fully open at Maximum Continuous (or Maximum Climbing) Power and at Take-off Power conditions respectively. With the throttle lever set to obtain the appropriate manifold pressure, the regulating valve on the intake depression box should be closed progressively until the boost control has fully opened the throttle. The corresponding air intake pressure should be found (see paragraph 4.3.1), and should then be corrected to sea-level temperature conditions in the standard atmosphere by means of the appropriate formula.

EXAMPLE: If when testing the above engine the observed manifold pressure at Maximum Continuous Power conditions is 140 kN/m^2) and the observed air intake pressure is 101 kN/m^2, the compression ratio will be:

$$r_o = \frac{M_o}{P_o} = \frac{140}{101} = 1{\cdot}386$$

Assuming the value of 'k' for this engine is 0·001 under test conditions where the intake temperature is 20°C, the supercharger compression ratio corrected to the sea-level temperature of a standard day will be:

$r_c = 1.386\ [1 + 0{\cdot}001\ (20 - 15)] = 1.386 \times 1.005 = \mathbf{1.392}$

NOTE: Since the sum of the ratios of the corrected sea-level power and the corrected supercharger compression ratio to the values established in the Engine Technical Certificate is greater than 1·96, the results satisfy the acceptance conditions prescribed in BCAR.

i.e. $\frac{352.329}{351} + \frac{1.392}{1.4} = 1.004 + 0.994 = \mathbf{1{\cdot}998}$

3.2 Power at Altitude

3.2.1 When drawn on a relative density basis the variation of power with altitude at constant crankshaft rotational speed and manifold pressure may be given by a straight line between the power at sea-level and the power at the full throttle height.

3.2.2 The variation of power with height at constant crankshaft rotational speed and full throttle, when drawn on a relative density basis, may be a curve at high powers but at low powers this curve may be extended as a straight line to the negative friction horsepower at zero density.

3.3 Humidity Corrections

In order to determine power ratings in dry air, or conversely to determine the power output in given conditions of atmospheric humidity, the following corrections should be used unless more accurate data are available:

SI Units

$$P_c = \frac{P_o + P_f}{1 - xh} - P_f$$

Non-SI Units

$$BHP_c = \frac{BHP_o + FHP}{1 - xh} - FHP$$

where x is a factor depending on mixture strength

and h is the humidity, i.e. $\frac{\text{water vapour strength}}{\text{barometric pressure}}$

NOTE: Since the effect of free water on power output is within ±1% over the range of water/air ratios normally encountered in operation, and the amount of free water is exceedingly difficult to measure, no corrections for free water need be made.

3.3.1 For constant fuel flow, the effect of humidity on air/fuel ratio is given by:

$$Z_c = \frac{Z_o}{1 - h}$$

where Z = air/fuel ratio.

3.3.2 Table 1 gives values of x over a range of air/fuel ratios corrected to dry air conditions for aircooled engines with fuel-metering systems which compensate for manifold pressure and charge temperature.

Table 1

Air/fuel ratio	9	10	11	12	13	14	15	16
Values of x	2·15	1·80	1·54	1·32	1·18	1·07	1·02	1·00

3.3.3 The following is the temperature correction which should be used in the case of air-cooled engines when the above-mentioned corrections for humidity are utilised:

SI Units

$$P_c = \frac{P_o + P_f}{1 + C(t_c - t_o)} - P_f$$

Non-SI Units

$$BHP_c = \frac{BHP_o + FHP}{1 + C\,(t_c - t_o)} - FHP$$

where C is a constant determined for the appropriate dry air mixture strength.

3.3.4 Table 2 gives values for C over a range of air/fuel ratios corrected to dry air conditions.

Table 2

Air/fuel ratio	9	10	11	12	13	14	15	16
Values of C	·00167	·00181	·00195	·00207	·00216	·00224	·00226	·00228

The value of C applicable to take-off conditions when water-methanol injection is used is 0·0022.

4 Test Fan Calibration Corrections

During the calibration of engine test fans (Leaflet 7–3), the rpm obtained will be influenced by the conditions of atmospheric temperature and pressure prevailing at the site. Thus cold conditions have two contradictory effects; the engine power tends to increase because of the increased charge density but an increase in rpm is opposed by the increased power absorbed by the fan as a result of the denser air. The net result is that the observed rpm will be lower than under standard sea-level conditions. Corrections of observed rpm to conditions in the standard atmosphere should be made by means of suitable charts; charts suitable for particular engines are normally included by the manufacturer in the approved Test Schedule for the engine concerned. However, two charts, one for normally-aspirated engines and one for supercharged engines, each of which is suitable for a wide range of engines when testing at altitudes between sea-level and 1000 feet, are included in this Leaflet and the following paragraphs explain their use.

NOTE: If engines are to be tested in cells at altitudes above 1000 feet, specially prepared charts should be requested from the engine manufacturer.

4.1 Unsupercharged Engines

4.1.1 When testing unsupercharged engines at full throttle it can be assumed that barometric changes affecting the engine power, and therefore tending to increase or decrease the engine rpm, are counterbalanced by the variation in fan loading. It is therefore necessary to correct for air temperature only and this can be done with the aid of the chart in Figure 1.

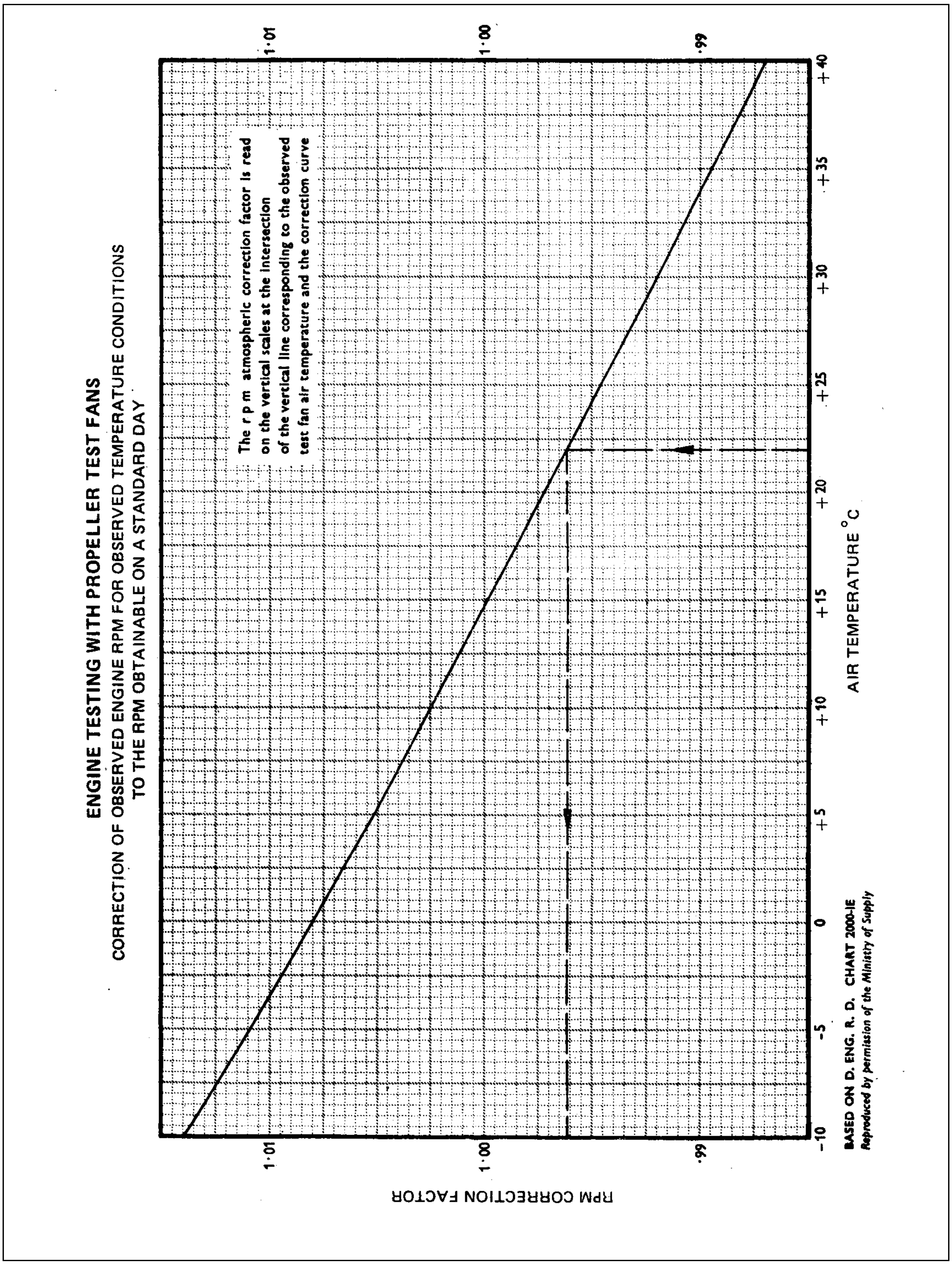


Figure 1

4.1.2 To use the chart, a vertical line should be projected from the observed air temperature point on the horizontal scale to the correction curve, and from the point of intersection a horizontal line should be projected to cut the vertical scale. This gives the rpm correction factor by which the observed rpm should be multiplied.

EXAMPLE: If the observed air temperature is +22°C, the rpm correction factor is 0·9962. If the observed rpm is 2650, the corrected rpm = 2650 x 0·9962 = 2640.

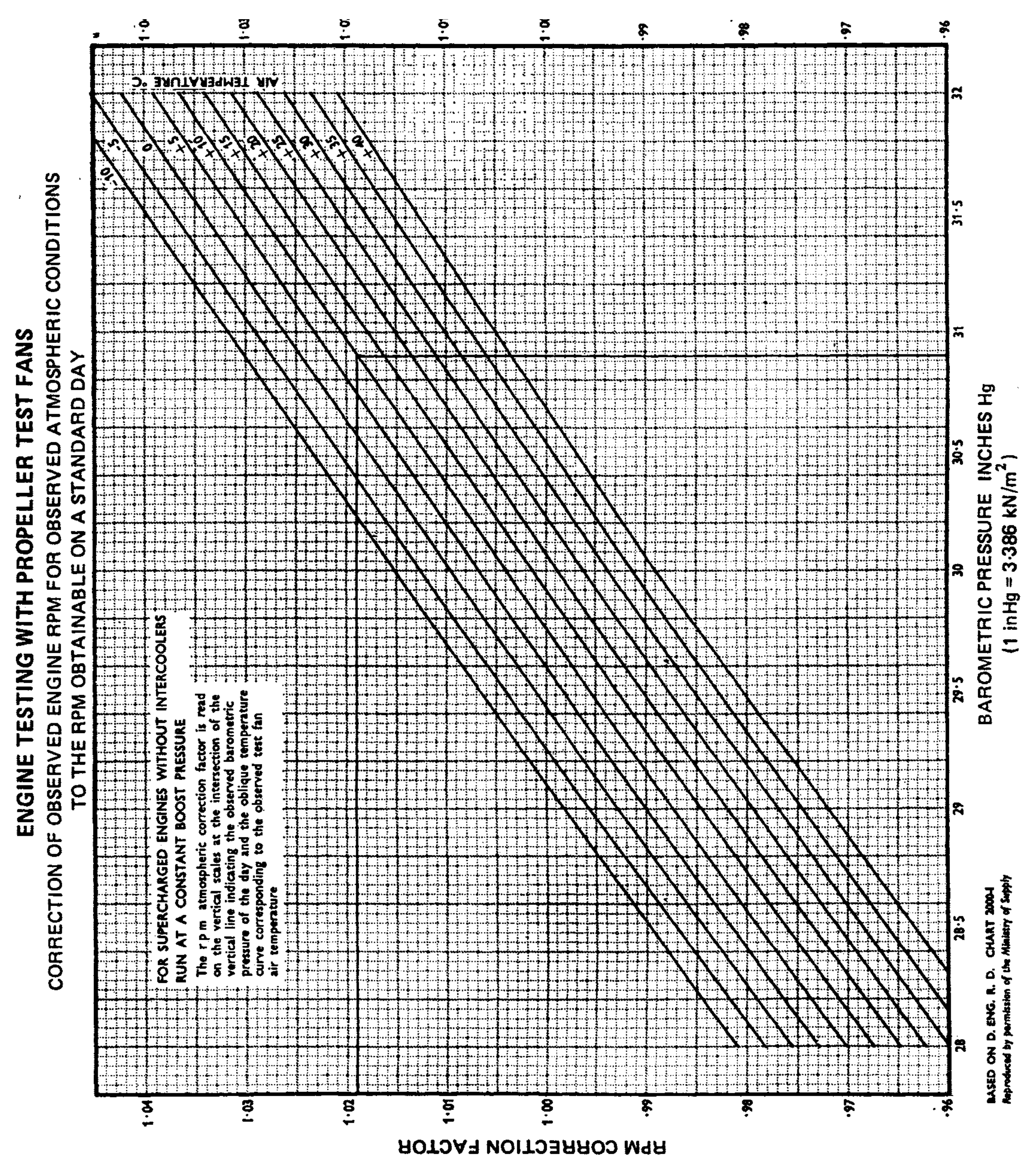
4.2 Supercharged Engines

4.2.1 When checking the performance of a supercharged engine with a test fan, the engine is run at the required manifold pressure and the effects of barometric changes on engine adjustment are corrected by throttle adjustment. However, the fan loading will vary with the air density and corrections must therefore be made for barometric pressure as well as for air temperature. The fan air temperature, as recorded by the thermometer in the test cell, is assumed to be the same as the air intake temperature. The chart shown in Figure 2 can be used for correcting the rpm of a wide range of air-cooled supercharged engines.

4.2.2 The method of using the chart is to select the point corresponding to the observed barometric pressure on the barometric pressure scale and project a vertical line from this point until it intersects the curve corresponding to the observed air temperature. A horizontal projection from the point of intersection will give the rpm correction factor by which the observed rpm should be multiplied.

EXAMPLE: Referring to Figure 2, if the observed barometric pressure is 104.6 kN/m^2 (30·9 inHg) and the observed air temperature is +10°C, the rpm correction factor is 1·019. If the observed rpm is 2640, the corrected rpm = 2640 x 1·019 = 2690.

4.2.3 It sometimes happens that altitude-rated engines reach full throttle before the required manifold pressure can be obtained: either a low full throttle altitude rating, low atmospheric pressure or poor engine performance may be the cause. If, for any reason, a supercharged engine is run at full throttle during the power check (without, of course, exceeding the required manifold pressure), it should be corrected as though it were a normally-aspirated engine by the method given in paragraph 4.1.


ENGINE TESTING WITH PROPELLER TEST FANS

CORRECTION OF OBSERVED ENGINE RPM FOR OBSERVED ATMOSPHERIC CONDITIONS TO THE RPM OBTAINABLE ON A STANDARD DAY

FOR SUPERCHARGED ENGINES WITHOUT INTERCOOLERS RUN AT A CONSTANT BOOST PRESSURE

The r p m atmospheric correction factor is read on the vertical scales at the intersection of the vertical line indicating the observed barometric pressure of the day and the oblique temperature curve corresponding to the observed test fan air temperature

BASED ON D. ENG. R. D. CHART 2000-I
Reproduced by permission of the Ministry of Supply

Figure 2

4.3 **Supercharger Performance Corrections.**

The requirements for testing piston engines after overhaul (Leaflet 7–1) prescribe that a supercharger compression ratio check shall be made whilst the engine is run at Maximum Continuous Power (or Maximum Climbing Power for Schedule II engines) and Maximum Take-off Power conditions with reduced air intake pressure. The supercharger performance is checked by running the engine at full throttle at the required rpm and manifold pressure with a restricted air intake and observing the absolute air intake pressure under these conditions. Since the absolute air intake pressure is inversely proportional to the compression ratio, any difference in the ratio from standard will be shown by changes in the intake pressure. The compression ratio of a supercharger varies with the air intake temperature and with the tip speed of the impeller.

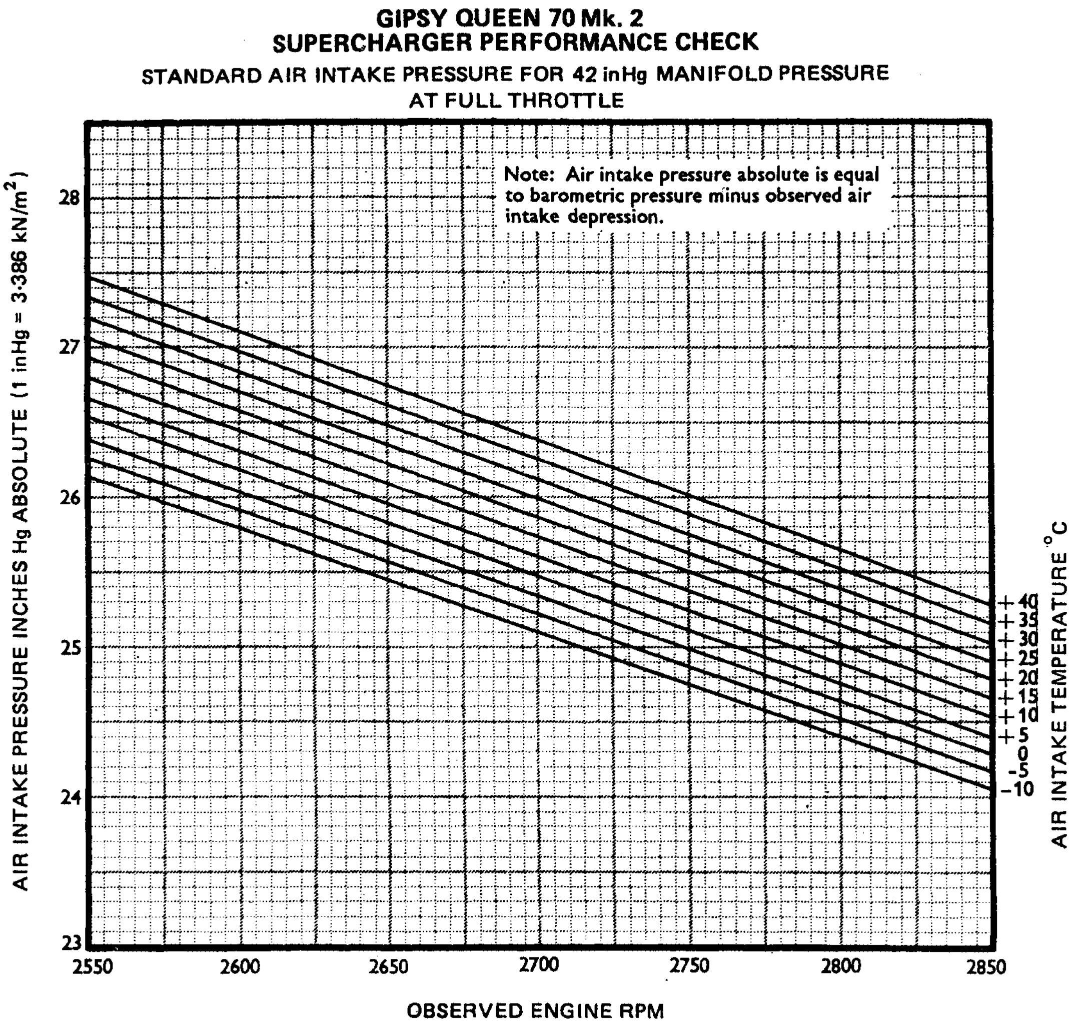


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Figure 3

4.3.1 For each particular supercharged engine, it is usual for the engine manufacturer to prepare a supercharger performance correction chart based on the performance of the type-tested engine and to include this chart in the approved Test Schedule for the engine type. From the chart the absolute air intake pressure which should be obtained at the observed rpm and observed intake temperature can be determined. The performance of the supercharger can then be assessed by comparing this pressure with the absolute pressure actually observed in the intake of the engine under test. The observed air intake pressure is taken as the difference between the barometric pressure in the test cell and the pressure indicated on a depression gauge fitted to the depression box.

4.3.2 A specimen supercharger performance correction chart is shown in Figure 3; the chart illustrated is for the Gipsy Queen 70 Mk. 2 engine. To find the required absolute air intake pressure, the observed rpm should be read off on the horizontal scale and a vertical line should be projected from it to intersect the curve appropriate to the observed air intake temperature. A horizontal line projected from the point of intersection will give the absolute air intake pressure in inches of mercury.

4.3.3 If the observed absolute air intake pressure is greater than the figure obtained from the chart, the supercharger performance is below the performance of the supercharger of the standard engine as derived from the Engine Technical Certificate. The acceptance conditions for the performance of overhauled engines when tested with a fan (Leaflet 7–3) state that the corrected supercharger compression ratio (at 15°C) obtained during Stages 8 and 9 of the Final Test and the corrected rpm obtained during the corresponding power check tests shall satisfy the following expression:

$\frac{r_2}{r_1} + \left(\frac{N_2}{N_1}\right)^2$ shall not be less than 1·96

where r_1 = supercharger compression ratio of the standard engine at the observed rpm of the test as derived from the Engine Technical Certificate.

r_2 = supercharger compression ratio of the engine being tested, at the observed rpm of the test.

N_1 = acceptance rpm of the fan.

N_2 = corrected rpm obtained from the power check tests for engine being tested.

EXAMPLE: A Gipsy Queen 70 Mk. 2 engine is run at a manifold pressure of 42 inHg and at 2700 rpm with an air intake temperature of +5°C. If the barometer reading is 30 inHg and the depression gauge reading is 5 inHg, the observed air intake pressure is 25 inHg. Reading from the chart in Figure 3, the intersection of the vertical line corresponding to 2700 rpm and the curve for +5°C intake temperature gives an absolute intake pressure of 25·5 inHg.

Where $r_1 = \frac{42}{25.5} = 1.647$

$r_2 = \frac{42}{25} = 1.68$

$N_1 = 2700$

and assuming $N_2 = 2680$

$$\frac{1.68}{1.647} + \left(\frac{2680}{2700}\right)^2 = 1.02 + 0.985 = \underline{2.005}$$

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