# CHAPTER 2
# ENGINE TEST FACILITIES

## Introduction

1. The purpose of an engine test facility is to ground run, test and prove aero engines before they are installed into an aircraft. For many years very few, if any, aircraft units were provided with an engine ground test facility; they were considered unnecessary since it was the practice at that time for the propulsion technicians to ground run and test engines whilst fitted into the aircraft. One of the reasons for this was the fitting and removing of engines into and from the airframes, was often a time consuming and involved task. A new or reconditioned engine when fitted usually remained installed in the aircraft until it was time expired, or required a major repair, at which time it was removed and returned to the manufacturer. Almost all engine maintenance was performed 'on wing' (engine installed), engines were seldom removed from the aircraft for rectification. This procedure has disadvantages, particularly when an engine requires complicated or prolonged rectification, or is unserviceable awaiting spares. During this period, although the rest of the aircraft may be serviceable, it is not available for flying because the installed engine is in an unserviceable condition. Today's modern aircraft however, must be utilized to a far greater extent than those in the past, because their high cost reflects in the number of aircraft available. Another drawback to installed engine testing is that the ground test schedule is constrained by the limitations of the cockpit instruments and equipment.

2. When modular engines were introduced into the RAF, and it was decided that engine maintenance was to be carried out to a far greater depth at unit level, the units concerned were equipped with an engine ground run and test facility. The RAF have used engine test facilities on some maintenance units since the earliest days. However the first gas turbine engine test stand introduced into the Service was located at RAF St Athan, and was used to test such early gas turbine engines as the Rolls Royce Derwent and the De Havilland Goblin. Since then, as gas turbine engines have increased in both complexity and thrust, engine test facilities have progressed with them. Present facilities used to ground run and test most fully modular engines are of the cantilever or overhead design, from which the engine is suspended during the test run. These feature such improvements as a coupling system that automatically couples the engine connections to the test stand, and an advanced thrust measuring system.

## Types of Engine Test Facilities

### General

3. There are many types of engine ground run and test facilities now used throughout the Service, ranging from fully computerized test facilities capable of complete engine ground testing, to the basic engine test stand used for only the simplest of engine ground runs. The selection of a test facility for a particular unit, will depend upon a number of factors, which include;

- Role of the aircraft concerned.
- Number and type of engines in the aircraft fleet.
- Depth of maintenance carried out on the unit.

For example, it would be pointless having an elaborate test facility on a unit where very little maintenance work is carried out, and engines are returned to the manufacturer for overhaul and repair. Conversely, units maintaining modular engines WILL require an efficient test facility, for it follows that one of the advantages of modular maintenance, namely the speed of engine rectification or module replacement, would be jeopardized if time is lost in transportation to, and waiting for, an engine to be tested at a shared run-up facility at another unit. Therefore units involved in modular engine maintenance have one of the following types of facility:

- Engine test facility.
- Engine run-up facility.

NOTE. Although the names of the facilities are similar, care must be taken to avoid confusing one with the other, for there are major basic differences between them as will be shown later in the chapter.

**The Engine Test Facility**

4. The engine test facility (ETF) is a purpose built, semi-permanent structure, and is usually designed and constructed to test and prove a particular type and mark of engine (Figs 7.2.1 and 7.2.2). However, with modifications, it is capable of testing other marks of engine within certain broad parameters. All units involved in the maintenance of fully modular engines have an engine test facility, and although they all differ in certain respects, the majority consist of the following basic features:

- Control cabin and ancillary rooms.
- Fuel Storage tank.
- Acoustic enclosure.
- Exhaust attenuator.
- Overhead propulsion unit and test stand.

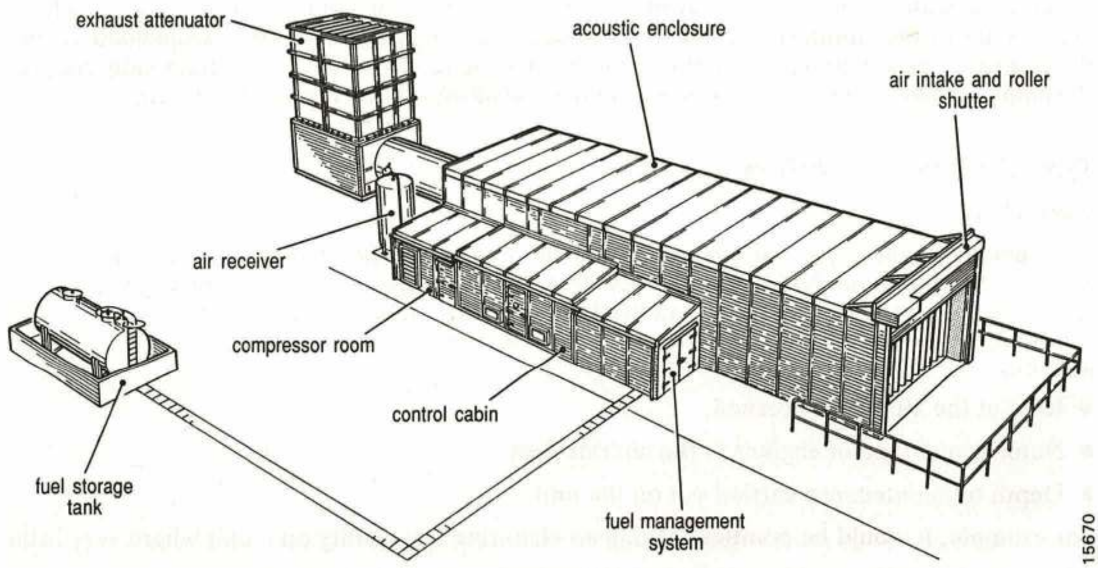


**Fig 7.2.1 General Layout of Engine Test Facility**

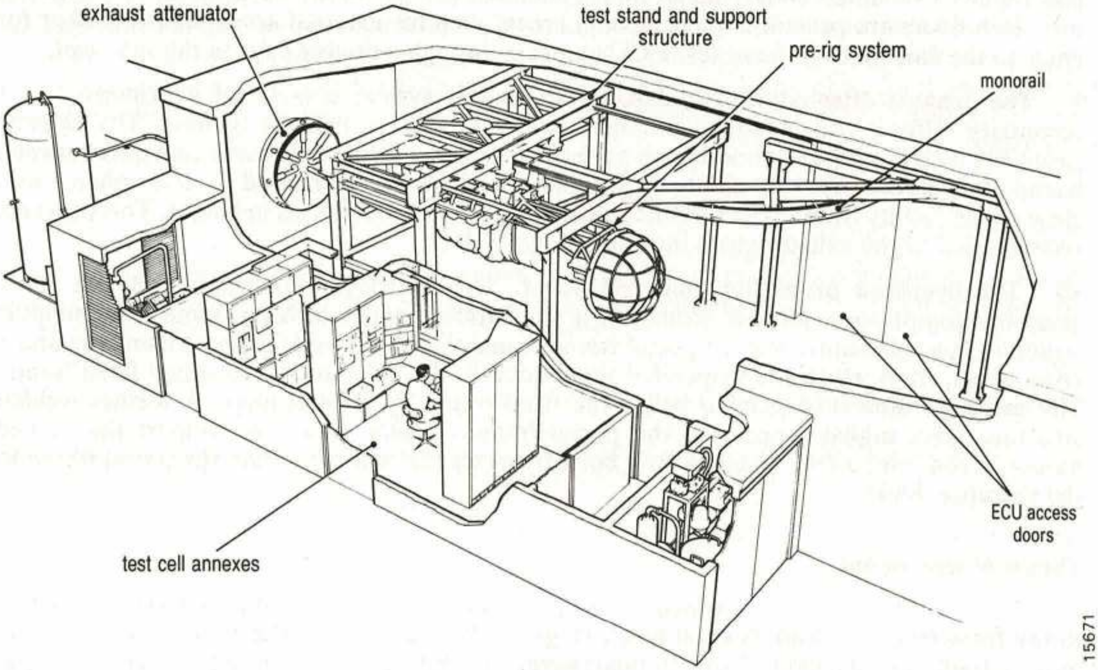


**Fig 7.2.2 Engine Test Facility**

5. **Control cabin and ancillary rooms.** The control cabin and ancillary rooms are located along the side wall of the acoustic chamber, and are constructed of modular acoustic panels. The control cabin (or control room) houses the operators responsible for running the engine. It has acoustic doors, and a window that enables the operators to observe the engine under test. The control cabin is fitted with a control console, which includes the instrument gauges, the engine control box, and the necessary levers to operate the propulsion unit. It contains a computer, which has an engine monitoring system, and audio and visual alarm systems. The control cabin also houses the electrical supply and distribution system cabinets, containing the equipment to produce the required voltages and frequencies for use by the facility. Power is supplied from the mains electrical supply. Some ETFs have a fully computerized propulsion unit test system (ref para 45) that would be housed in the control cabin.

6. The ancillary rooms form an annex and include a compressor room, that accommodates a compressor with an automatic starting and control system. The compressor supplies air to a large capacity receiver situated outside the annex. High pressure air is required for engine starting and other control services. There is also a fuel room, housing the fuel metering and filtration equipment, which receives its supply from a fuel storage tank, through underground pipelines.

7. **Fuel storage tank.** The fuel tank is sited away from the facility, and supplies fuel to the propulsion unit via the fuel filtration and metering units in the fuel room.

8. **The acoustic enclosure.** The acoustic enclosure is constructed of noise absorbing weather proof panels. It makes provision for the exhaust attenuator, and houses the test stand and its supporting structure. Air intake silencers at the front end of the enclosure admits cooling air, and ensure an even laminar air flow is supplied to the test stand during testing. An external

roller shutter mounted above the air intake silencers can be closed when the facility is not in use. Two doors are provided for personnel access, one for external access and the other for entry to the control cabin annexes. ECU access is through a double door in the side wall.

9. **The exhaust attenuator.** The exhaust attenuator system consists of a primary and a secondary diffuser connected by an augmentor tube, and an exhaust silencer. The exhaust gases mix with the transient cooling air as they expand through the diffusers, and pass between sound absorbtive splitter elements of the silencer. They are discharged to atmosphere, well clear of the facility through an exhaust stack approximately 10 metres in height. This prevents recirculation of the exhaust gases into the air intake flow.

10. **The overhead propulsion unit test stand.** The overhead propulsion unit test stand assembly comprises a support structure, a fixed frame, and a moving frame. The support structure is a substantial welded portal frame, consisting of two side support members and a cross beam, from which are suspended the monorail, the hoist and the test bed fixed frame. The moving frame is suspended below the fixed frame by flexural links. A further welded structure gives added support to the portal frame. Gantry structures support the curved monorail run, and a two speed electric hoist traverses the monorail from the portal frame to the entrance doors.

**Thrust Measurement**

11. The moving frame (from which the propulsion unit is suspended during test), is attached to the fixed frame by four flexural links, (Figs 7.2.3a and 7.2.3b). The four links permit the moving frame to have limited longitudinal movement. When the power unit on test is running, the thrust developed will impel the moving frame forward. The movement is measured by the thrust measuring system that is mounted on the fixed frame, and is connected to both analogue and digital indicators on the console in the control cabin.

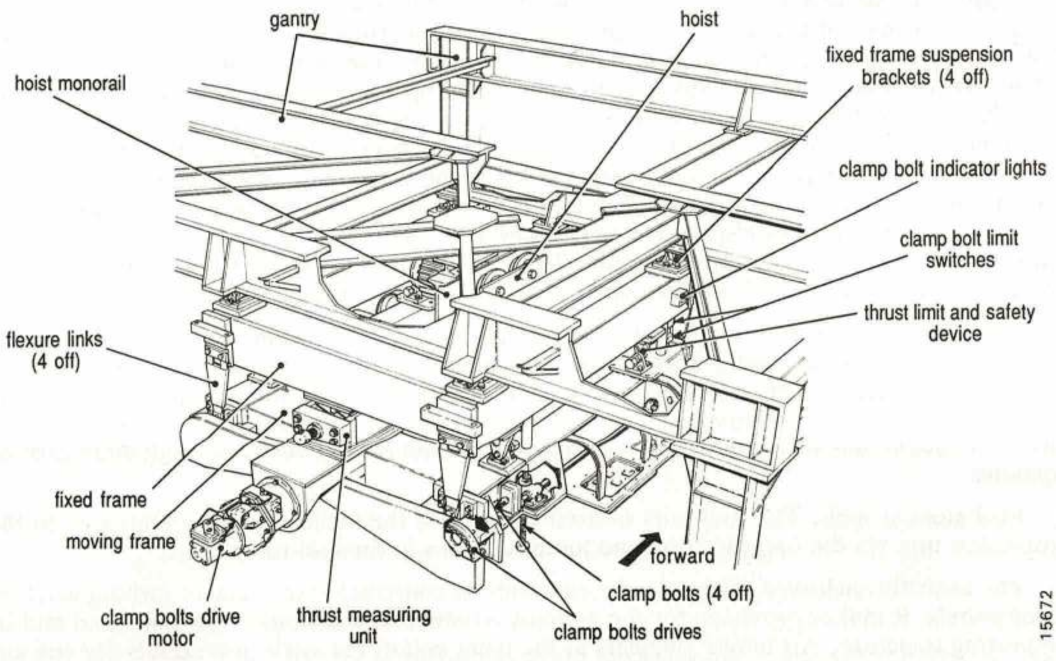


**Fig 7.2.3a Propulsion Unit Test Stand**

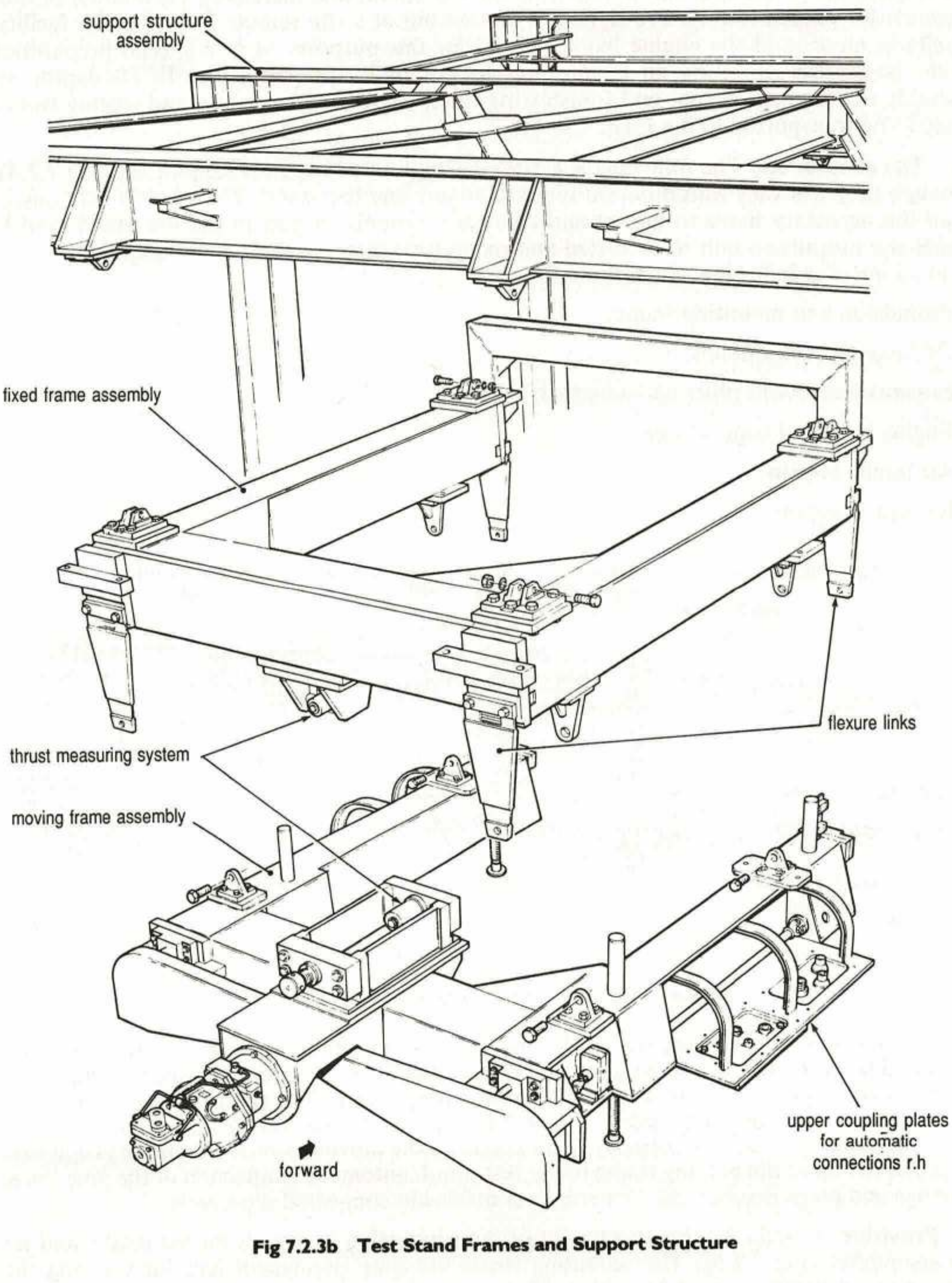


**Fig 7.2.3b Test Stand Frames and Support Structure**

## Engine Pre-rigging

12. Engine pre-rigging is the servicing proceduure that is carried out on the ECU before it goes to the ETF for the test run. Its purpose is to reduce to a minimum the time taken to fit

and remove the propulsion unit to and from the test stand, thus increasing the amount of time available for engine testing. Pre-rigging is carried out at a site remote from the test facility, usually in an area of the engine bay allocated for this purpose, or in a special preparation room. It consists of fitting an adaptor set to the ECU, preparing the ECU/adaptor set assembly for the engine run, and transferring them into a transportation and rigging trolley ready to be transported to the ETF.

13. **The adaptor set.** The following is a brief description of a typical adaptor set (Fig 7.2.4), although they will vary with different types of engine and test stand. The adaptor set consists of all the necessary items to mount and connect a propulsion unit to the test stand, and to enable the propulsion unit to be tested and its performance assessed. The equipment can be grouped into the following assemblies.

- Propulsion unit mounting frame.
- Off-take pipe assemblies.
- Engine connections pipes and adaptors.
- Engine electrical connections.
- Air intake system.
- Jet pipe assembly.

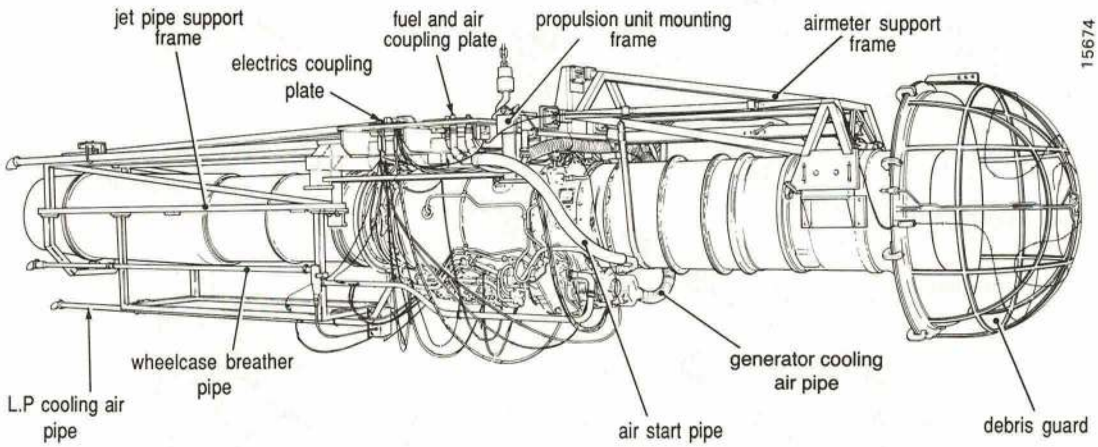


**Fig 7.2.4 Propulsion Unit pre-rigged with Adaptor Set**

14. **Propulsion unit mounting frame.** The propulsion unit mounting frame carries the ECU suspended from the engines three main mountings. The ECU pipe-lines, couplings and plugs, mate with corresponding connections on the mounting frame. The services conveyed by the pipe-lines, couplings and plugs are then routed to horizontal plates on the side of the mounting frame, that align with complementary connections on the moving frame. When the propulsion unit is offered up to the moving frame of the test stand, automatic connection of the pipe lines, couplings and plugs is achieved. The engine controls are connected separately.

15. Provision is made for the attachment of the supporting frames of the air intake and jet pipe assemblies (Fig 7.2.5). The mounting frame has four attachment feet for securing the frame to the transportation and rigging trolley.

16. When the ECU is fully dressed with the adaptor set, DC generator, air starter motor, and slave exhaust collector and exhaust frame, it is termed a 'Propulsion Unit'.

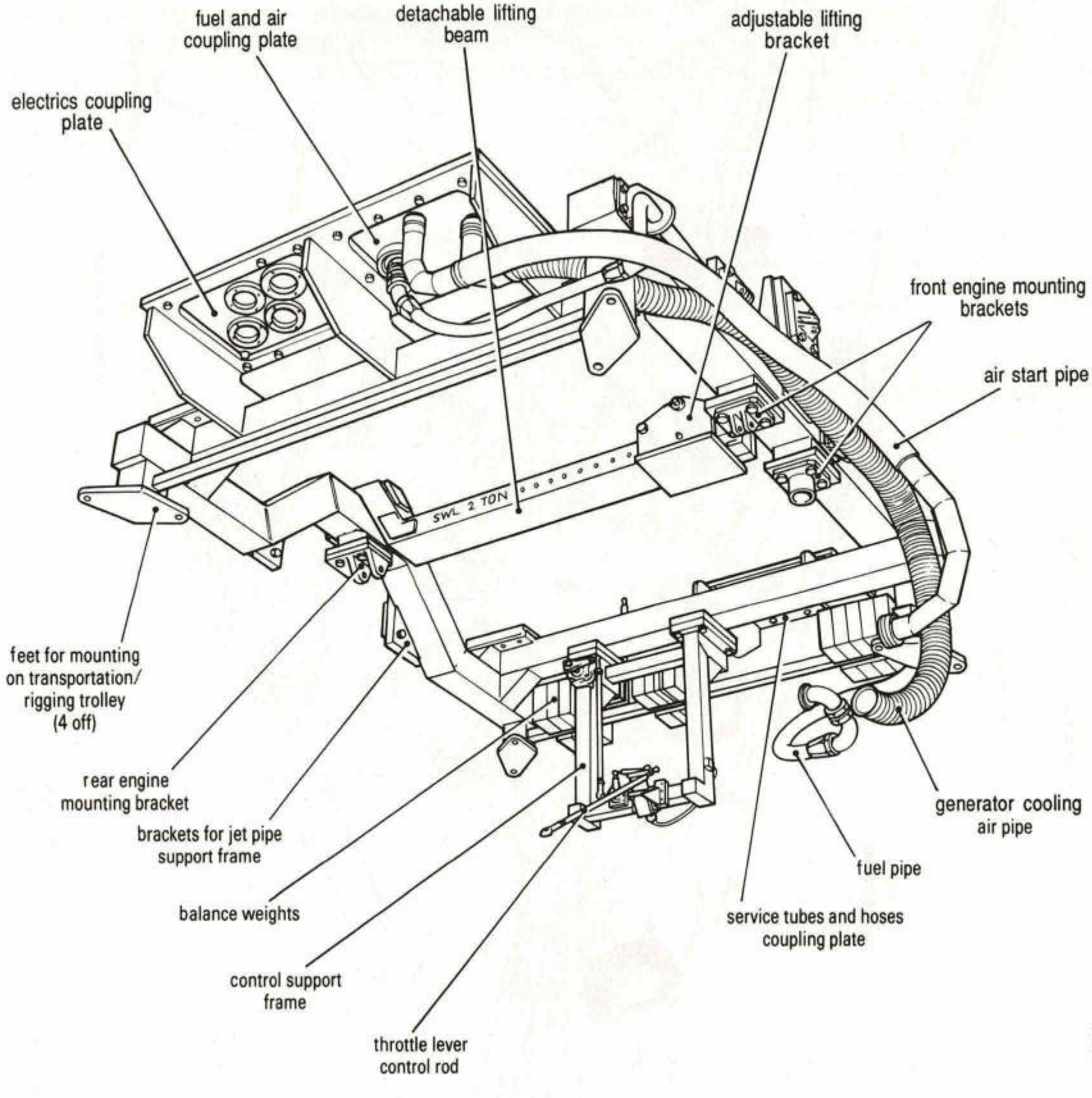


**Fig 7.2.5 Propulsion Unit Mounting Frame**

## Engine Run-up Facility

17. The engine run-up facility (Fig 7.2.6) was originally called the 'Mobile engine run-up facility', and was designed for quick defect checking of gas turbine engines. However, since its introduction, its role has broadened, and its use is no longer confined solely to fault diagnosis, but to full engine testing of certain semi-modular engines. The term 'mobile' has now been dropped from the name, hence the facility is simply called the 'Engine run-up facility' (ERUF). It is a transportable unit, but is normally located on a permanent site. The facility is designed to test specified ECUs, with thrust ratings of up to 135 KN (30 000 lbf).

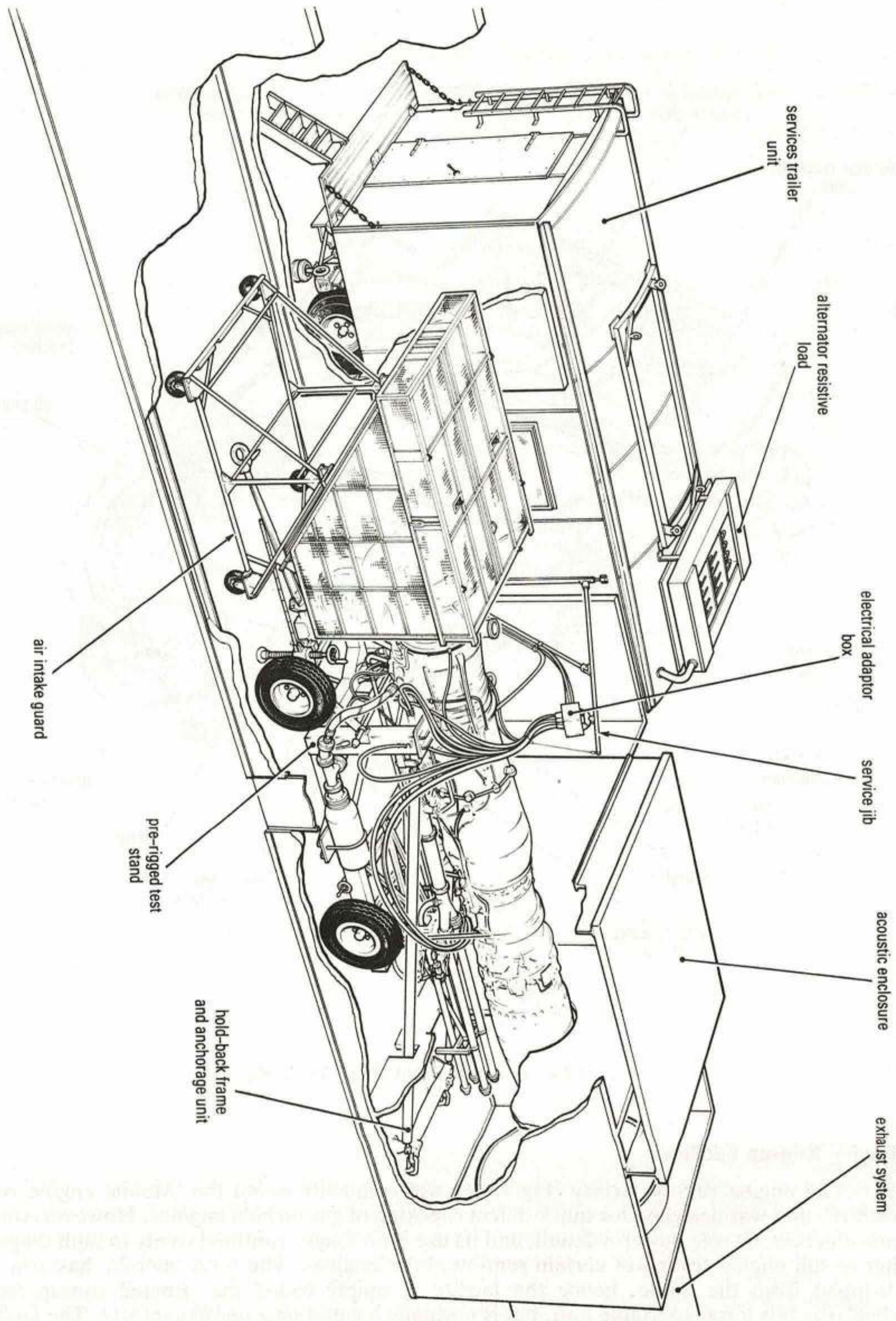


Fig 7.2.6 Engine Run-up Facility

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18. The ERUF consists of the following main units:

- Services trailer unit.
- The test stand.
- Acoustic enclosure.
- Exhaust attenuator.
- Fuel storage tank (sited away from the facility).

19. **The services trailer unit.** The services trailer unit is a mobile control cabin which houses the operators, the engine operating controls and engine instrumentation. It manages the fuel metering equipment, electrical and compressed air services. It is also equipped with a desk top computer, which assists the operators to run, control and monitor the performance of the engine on test.

20. **The test stand.** The test stand (7.2.7) is a mobile engine stand upon which the ECU is mounted during test. It is fitted with special equipment to run a particular type and mark of engine. The special equipment includes engine air starter pipes, cooling and breather pipes, high energy ignition boxes and adaptors. Attachment lugs are welded to the stands two main upright supports to enable the stand to be tethered in the acoustic enclosure during test. The stand is also used to transport the engine to and from the test site.

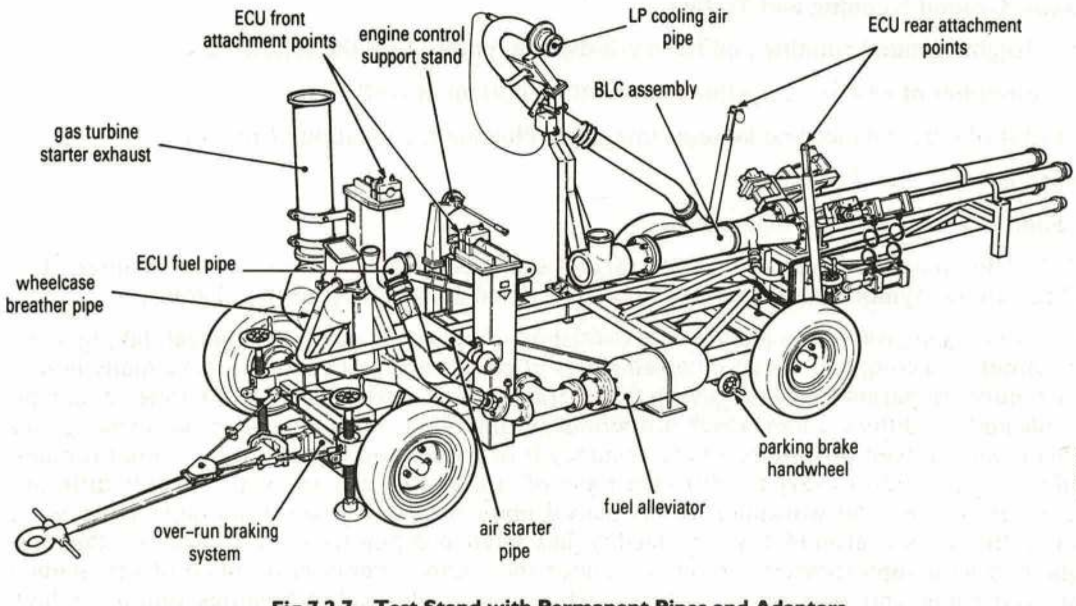



**Fig 7.2.7 Test Stand with Permanent Pipes and Adaptors**

21. **The acoustic enclosure.** The acoustic enclosure houses the rigged test stand, and air intake guard, and hold back and anchor unit. The air intakes guard is placed in front of the ECU during test to prevent foreign object damage occurring whilst the engine is on test. The hold back and anchor unit is a permanent fixture, which has two restraining arms that attach to lugs welded to the two main uprights on the pre-rigged test stand.

22. **The exhaust attenuator.** The exhaust attenuator is built into the end of the acoustic chamber to receive the jet efflux from the ECU, and to reduce the noise produced by the engine.

23. **Pre-rigging.** Mounting of the ECU into a test stand, making the interface connections between the test stand equipment and the engine, and the fitting of various additional items of equipment essential for the test run, is known as pre-rigging. These procedures are usually carried out in the pre-rig area of the engine bay.

## International Standard Atmosphere

24. The performance of an engine can be dramatically effected by differences in air intake pressure, temperature and density. If, on any day at a given time, the air pressure, temperature and density were to be recorded at all of the run up facilities throughout the Service, it is quite possible that no two locations would give the same results. Furthermore, if they were re-recorded four hours later, all of the resulting readings would probably be totally different from the first recordings. Therefore, to establish a basic common standard to which comparisons of engine performance can be made, the results of all engine proving checks are corrected to the International Standard Atmosphere at sea level, which is:

| | |
|---|---|
| Temperature | + 15°C |
| Pressure | 1013.25 millibars |
| Density | 1.225 $kg/m^3$ |

ISA is defined by the International Civil Aviation Organisation (ICAO).

## Engine Ground Running and Testing

25. Engine ground running and testing is usually required for the following:

- Calibration of new ECUs prior to installation into an aircraft.
- Proof of performance and systems integrity following rectification or repair.
- Major component changes.
- Fault investigation and diagnosis.

NOTE. In some instances abbreviations and symbols have been used in the chapter. The abbreviations, symbols and their definitions are listed at annex 'A' to this chapter.

26. An engine ground run and test can consist of a brief mechanical proving test, taking just a few minutes to complete, to an involved series of checks and tests that may take many hours. The number of parameters that govern the operation of an aero engine and the range of engine speeds and conditions under which it operates during flight, make engine ground testing and proving an involved procedure where accuracy is of paramount importance. Ground running and testing procedures vary for different types of engine, and can also vary between different marks of engine. The workload that is placed upon the facility operators depends to what extent the engine ground running facility has been computerized, test facilities that are equipped with sophisticated computers relieve the engine operators of much of the manual data recording and proving procedures, whilst less sophisticated facilities require a high operator input during the test.

27. **Fitting the propulsion unit to the test stand.** When a propulsion unit arrives at an 'Engine test facility' on a transportation and rigging trolley, it has been fully rigged complete with intake air meter, debris guard, and exhaust collector, and is ready to be fitted to the test stand. It is positioned under the hoist in the acoustic chamber (or test cell), where a hoist lifts it clear of the transportation and lifting trolley. To keep the propulsion unit balanced laterally during the necessary lifting operations, weights are either added to or removed from the propulsion unit.

The weights are part of the test stand accessories. The hoist and propulsion unit traverses the monorail to the test stand, where four slots (open at one end) on the mounting frame engage with four mounting bolts on the test stand moving frame. The weight of the propulsion unit is transferred from the hoist to the four mounting bolts and the hoist is disconnected and removed.

28. **Securing the propulsion unit.** The propulsion unit is secured to the moving frame of the test stand by selecting a lever on the test stand to the locked position. Movement of the lever operates the Clamp Bolt Drive Motor, which actuates the movement of the four mounting bolts. All four bolts rotate upwards together, raising the propulsion unit, until it is firmly clamped to the moving frame. During the upward movement, all the ECU pipe connections, couplings and plugs automatically engage with corresponding connections on the test stand. When the propulsion unit is locked and secured to the moving frame, indicator lights illuminate on the console in the control cabin, and also on the test stand panel. The engine control rods, and the vibration transducer cables are all that remain to be connected.

29. **Engine static checks.** The purpose of engine static checks are to test the functions of the engine control amplifier which includes the gas turbine temperature, the engine speed and pulse probes, and tachometers, and their associated gauges on the control cabin console. The tests save time and effort, and reduce engine running time when faults and unserviceable equipment are detected before the engine is started. Static checks are carried out using a number of test sets.

30. **Final preparations for test.** The following are the final operations that are performed before the engine test run:

- Bleed the engine fuel system (if it has been inhibited).
- Fill or top up the oil tank as required.
- Dry crank the engine.
- Wet crank the engine.
- Check oil filters and magnetic plugs.

Dry cranking of the engine is carried out to circulate the engine oil throughout the lubrication system after filling of the oil tank, and also to check the rotating assemblies of the engine for serviceability and run down time. The dry crank consists of carrying out all of the run up pre-start checks (ref para 34), and then switching the start isolator switch to the ON position. The engine starter cranks or motors the engine over, but the fuel is not switched on. If the dry crank is satisfactory, it is followed by a wet crank. A wet crank is required before the first real start, or if any part of the fuel system has been disturbed. It is similar to a dry crank except that the fuel switch is switched to ON and the throttle is opened to the Idle position. However, ignition does not occur when the engine is turned over on the start isolator switch. Finally the engine oil filters and magnetic plugs are removed, inspected, and then refitted, before the engine oil tank is topped up.

31. **Pre-start precautions.** The following checks are always carried out prior to starting an engine in an engine test facility. The checks may be supplemented by local procedures. The precautions are:

- Engine blanks. Remove engine intake and exhaust blanks, and ensure that the intake and exhaust ducts are free from loose articles.
- Controls. Ensure that all rigging pins have been removed from the engine controls; manually operate the controls and check them for freedom and full range of movement.
- Tools. Remove all loose tools and check test cell tool kit shadow board.

- Equipment. Remove all equipment not required for the engine run.
- Fire fighting equipment. Ensure that the fire fighting equipment is serviceable and readily available for use.

32. **Test crew.** The engine test crew usually consists of three personnel, two of whom must be qualified engine operators, and must include a SNCO who is the test facility supervisor. The supervisor is responsible for analysing the data accumulated during the engine test run, and assessing whether or not the engine meets the 'Acceptance Standards' (this is known as 'Passing off' the engine). The supervisor is also responsible for carrying out the propulsion unit pre-start checks.

## Engine Ground Test

33. **Requirements and tests.** The specific requirements, procedures and acceptance standards for engine ground running and testing of new propulsion units, or those that have been repaired, is to be found in the relevant engine Air Publication. However, the following operations are a brief and general example of a ground test run on a typical fully modular, low by-pass engine, after rectification tasks have been carried out. The test run includes:

- Pre-start checks.
- Starting the propulsion unit.
- Preliminary run test.
- Reduced performance curve test.
- Acceleration and deceleration test.
- Shutting down propulsion unit.
- Pass off before removal test.

34. **Pre-start check.** Pre-start checks are a series of checks that must be satisfactorily completed before an engine is turned over or started. Basically, they consist of ensuring that the propulsion unit and test facility are prepared and in a safe condition for the propulsion unit to be started, and that the control console and instrumentation are ready and functioning.

35. **Starting the propulsion unit.** The test run must be carried out with two qualified operators in the control cabin at all times whilst the engine is running.

- If a klaxon or other audible warning is provided it should be sounded, alerting personnel in the vicinity of the facility that an engine is about to be run.
- Press the starter button until the LP compressor shaft rotation light illuminates.
- When the HP compressor shaft rotation speed reaches 15 per cent, open the throttle lever to the Idle position. Check that the starter cuts out, and the LP rotation light is extinguished.

NOTE. The turbine gas temperature must be closely monitored to ensure that it does not exceed the engine temperature limitations. If it seems likely to do so as the engine speed accelerates from zero to the Idle speed, the throttle lever must be retarded to the OFF position and the propulsion unit shut down.

When the propulsion unit has stabilized at Idle speed, records the following:

- Time taken to:
  - Engine light-up.

■ Idle speed.

■ Starter cut out.

• Maximum turbine gas temperature.

Ensuring the following:

• That the oil pressure and fuel pressure warning lights go out.

• That the propulsion unit is run at Idle speed for at least three minutes.

36. **Preliminary run test.** A preliminary run test is carried out on all propulsion units after starting the engine, the content of the test varies for different types of engine. However, before proceeding with the run check for fuel, oil and air leaks after the propulsion unit has been started, any leaks that are found must be rectified before continuing with the preliminary run. If a bleed valve is fitted to the engine, its operation must be checked during the preliminary run. If the valve is operating correctly, it will be open during the engine starting cycle and will close with increasing engine speed. When the valve closes, it will remain in the closed position during all engine performance checks, and until the engine is finally shut down.

NOTE. For example, on some engines the bleed valve should close after initial starting at 61 per cent $N_H$, and will remain closed until the throttle is retarded for engine shut down, when it will open again at 45 per cent $N_H$. The operation of the bleed valve (to the closed position) is usually indicated by a small increase in $N_H$ and a decrease in TGT. This is because the bleed valve air no longer goes to by-pass, but passes through the HP compressor. Another indication of bleed valve malfunction is excessively low rev/min at Idle setting, indicating that the valve is open. The bleed valve will require adjustment if it is not within the limits quoted in the engine Air Publication.

37. **Reduced performance curve test.** As its name suggests, the reduced performance curve test is to establish if the engine's power output and performance meets the required acceptance standards (ref para 47). The curve is plotted on a special graph, using the results from three thrust settings (Fig 7.2.10). Normally three thrust settings are adequate to prove the engine's serviceability state. However, should there be any doubt about the results of the curve of the graph, a 'Full performance curve test' must be carried out, which tests the engine at seven or eight different thrust settings. The graph curve is then plotted by using the increased number of test results. The reduced performance curve test is a mandatory requirement following a module change, but may also be carried out after engine rectification has been completed, or for fault diagnosis. A typical test procedure is as follows.

• Gradually move the throttle lever to each of the following thrust levels, and allow the power unit to stabilize for three minutes at each thrust level:

  • 16.8kN (3 800 lbf).
  • 20.0kN (4 500 lbf).
  • 26.5kN (5 960 lbf).

  Record all instrument values at each thrust level plus:

  • Check bleed valve operation.
  • Check that drain valves close with increasing speed.
  • Carry out tangential and radial vibration checks.

On completion of the test, return throttle lever to Idle setting.

38. **Acceleration and deceleration test.** The purpose of this test is to establish the time taken

for the engine to respond to rapid movement of the throttle lever between given throttle settings, and to ensure that the engine remains stall and surge free during quick acceleration and deceleration. Engine reaction to rapid throttle lever movement is governed by the 'Acceleration Control Unit' (ACU) in the engine fuel system. If the fuel system, and the ACU in particular, are operating within their design parameters, the rapid accelerations should be smooth, surge free and accomplished within a given time. Typically an engine should accelerate from Idle setting to maximum thrust in less than eight seconds, and from 70 per cent $N_H$ to max thrust in less than five seconds. All throttle lever movements must be made in less than one second when performing acceleration (slam) tests. A typical acceleration and deceleration test will include the following:

- Ensure bleed valve is closed.
- Gradually move the throttle lever to achieve 70 per cent $N_H$ and stabilize the engine speed for three minutes.
- Slam throttle lever to maximum thrust and allow the propulsion unit to stabilize at maximum thrust for one minute. Record the time taken for the engine to reach maximum thrust from 70 per cent $N_H$.
- Slam the throttle lever to 70 per cent $N_H$, record the time taken for the propulsion unit to reduce from maximum thrust to 70 per cent $N_H$.
- Gradually retard throttle lever to the Idle position, and allow propulsion unit to stabilize for three minutes.
- Slam the throttle lever to maximum thrust and allow the propulsion unit to stabilize for one minute. Record the time taken for the propulsion unit to establish maximum thrust from the Idle setting.
- Slam the throttle lever to Idle, and record the time taken for the propulsion unit to return to Idle setting.
- Run the propulsion unit at Idle for at least a further 30 seconds.

NOTE. If the engine commences to stall, the throttle lever must be retarded immediately and the engine shut down. Stall indications are a rapid rise in TGT, and a stagnation of $N_H$. Record the maximum TGT and $N_H$ if the propulsion unit is shut down because of stall conditions.

39. **Shutting down the propulsion unit. (Normal shut-down).**
Following completion of the tests, the engine must be shut down as follows:

- Move throttle lever to the Idle position, allow to stabilize for 30 seconds, and then move the lever quickly to shut off position.
- Record the HP compressor and LP compressor run down times.
- Ensure all switches and selectors are off, and all systems made safe.
- Record the following data:
  - Maximum vibration.
  - Engine oil level.
  - Engine oil temperature.

40. **Pass-off test.** Before removing the propulsion unit from the test stand.

- Remove, inspect and refit:
  - Oil pressure filters.

- Return oil strainers.
- Magnetic chip detectors.

- Restore the oil level, note the consumption of the oil during the test run.
- Crank the propulsion unit to circulate the oil through the systems.
- Start the propulsion unit. Open the throttle lever to 85 per cent $N_H$, check for fuel, gas and oil leaks.
- Return the throttle to the Idle position for 30 seconds.
- Shut-down the propulsion unit.

NOTE. Control setting check. A check of all control settings is carried out to ensure that they are within limits, and that all male control rods are in safety.

**Removal of Propulsion Unit from Test Stand**

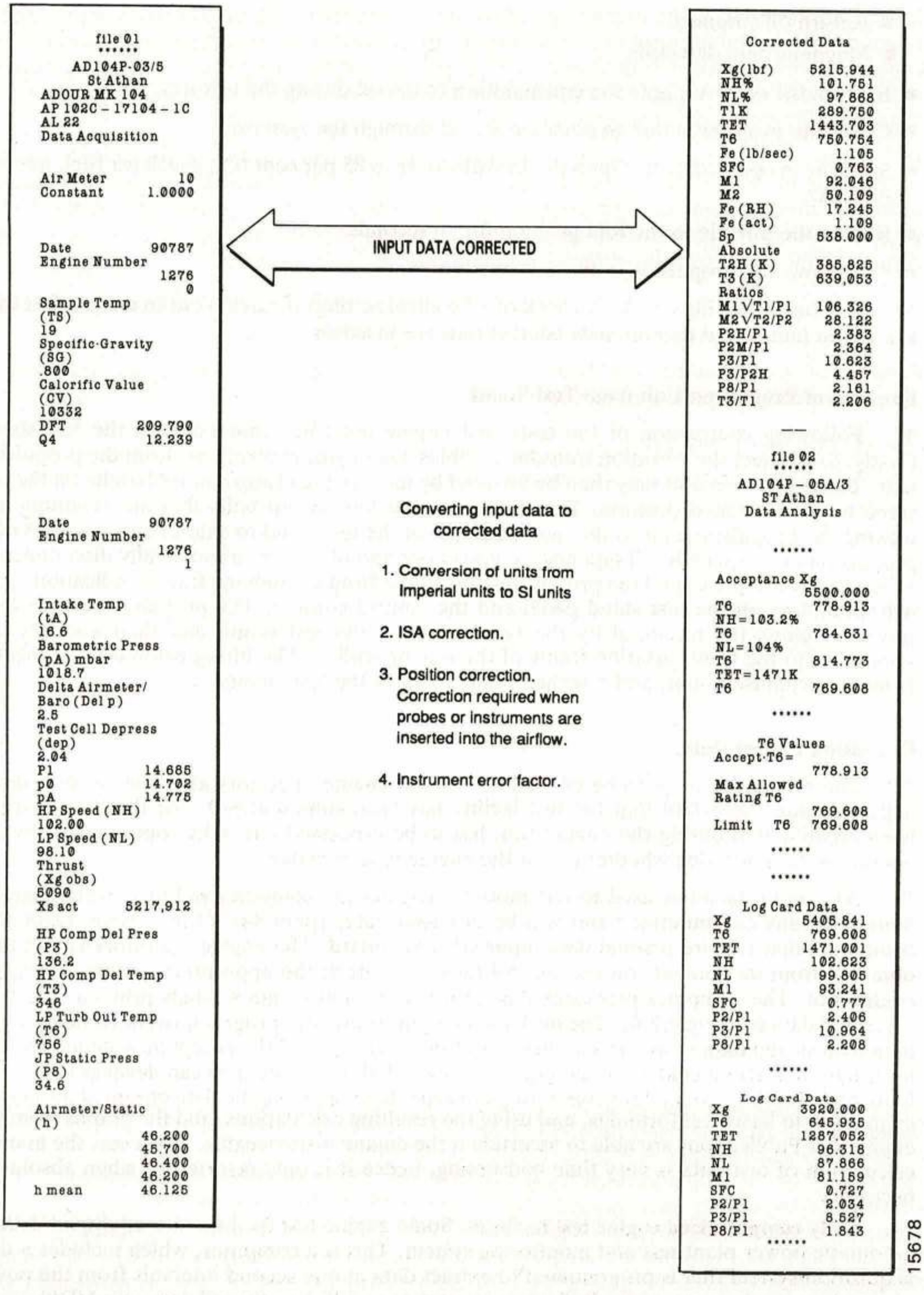
41. Following completion of the tests, the engine must be removed from the test stand. Firstly, disconnect the vibration transducer cables and engine control rods from the propulsion unit. The propulsion unit may then be lowered by moving the clamp control handle on the test stand to the unlocked position. This will cause the four clamp bolts that are retaining and locking the propulsion unit to the moving frame of the test stand to extend and lower. As the propulsion unit descends, all pipelines, connections and plugs are automatically disconnected. When this is complete, and the propulsion unit is free from the moving frame, indication lights will illuminate on the test stand panel and the control console. The propulsion unit is then traversed along the monorail by the hoist, clear of the test stand, and then lowered and secured onto the transportation frame of the rigging trolley. The lifting beam is disconnected from the propulsion unit, and it is then ready to leave the test facility.

**Processing Engine Data**

42. The remaining work to be carried out by the engine operators after engine shut-down depends upon the extent that the test facility has been computerized. For the data that has been accumulated during the engine run, has to be processed either by computer, or by the operators, to determine whether or not the engine is serviceable.

43. All run-up facilities used to test modular engines are computerized to varying degrees. Some are fully computerized and will be discussed later (para 44). Others have 'Desk top' computers that require manual data input via a keyboard. The engine operators key in data obtained from instruments on the control cabin console at the appropriate points during the engine run. The computer processes this information, and within seconds prints a tape with corrected data (see Fig 7.2.8). The desk top computers are also programmed to compare input data with stored data to assess whether or not the engine meets the acceptance standards, this information is also included on the tape. However desk top computers can develop faults. If a fault does develop, all qualified operators are capable of applying the data obtained during the engine run to basic test formulas, and using the resulting calculations, and the graphs from the engine Air Publications are able to ascertain if the engine is serviceable. However, the manual calculation of test data is very time consuming, hence it is only resorted to when absolutely necessary.

44. **Fully computerized engine test facilities.** Some engine test facilities are equipped with an automatic power plant test and monitoring system. This is a computer, which includes a data acquisition system that is programmed to extract data at one second intervals from the power plant whilst it is being test run. It displays input data and ISA corrected data on a VDU screen

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Date 90787
Engine Number
1276
1

Intake Temp
(tA)
16.6
Barometric Press
(pA) mbar
1018.7
Delta Airmeter/
Baro (Del p)
2.5
Test Cell Depress
(dep)
2.04
P1 14.685
p0 14.702
pA 14.775
HP Speed (NH)
102.00
LP Speed (NL)
98.10
Thrust
(Xg obs)
5090
Xs act 5217,912

HP Comp Del Pres
(P3)
136.2
HP Comp Del Temp
(T3)
346
LP Turb Out Temp
(T6)
756
JP Static Press
(P8)
34.6

Airmeter/Static
(h)
46.200
45.700
46.400
46.200
h mean 46.125

Corrected Data

Xg(lbf) 5215.944
NH% 101.751
NL% 97.868
T1K 289.750
TET 1443.703
T6 750.754
Fe (lb/sec) 1.105
SFC 0.763
M1 92.046
M2 50.109
Fe (RH) 17.245
Fe (act) 1.109
Sp 538.000
Absolute
T2H (K) 385,825
T3 (K) 639,053
Ratios
M1√T1/P1 106.326
M2√T2/P2 28.122
P2H/P1 2.383
P2M/P1 2.364
P3/P1 10.623
P3/P2H 4.457
P8/P1 2.161
T3/T1 2.206

—

file 02
******
AD104P – 05A/3
ST Athan
Data Analysis

******

Acceptance Xg
5500.000
T6 778.913
NH = 103.2%
T6 784.631
NL = 104%
T6 814.773
TET = 1471K
T6 769.608

******

T6 Values
Accept·T6 =
778.913
Max Allowed
Rating T6
769.608
Limit T6 769.608

******

******

Log Card Data
Xg 5405.841
T6 769.608
TET 1471.001
NH 102.623
NL 99.805
M1 93.241
SFC 0.777
P2/P1 2.406
P3/P1 10.964
P8/P1 2.208

******

Log Card Data
Xg 3920.000
T6 645.935
TET 1287.052
NH 96.318
NL 87.866
M1 81.159
SFC 0.727
P2/P1 2.034
P3/P1 8.527
P8/P1 1.843
******

**Fig 7.2.8 Extract from Computer Print-out of Engine Ground Run**

for the information of the engine operators. There are three coloured VDU screens, and a visual display keyboard assembly. The system also passes 10 frames of data per second to the computer for comparison with stored ECU operating and limiting parameters, and is capable of assessing all aspects of ECU performance, to determine if the power plant is acceptable, or if it is to be rejected.

45. Prior to the engine start the operator keys into the computer the nature of the rectification or the repair. If, for example, a module has been changed, the operator's input states the module number. The computer then prints a series of instructions on the VDU screen, leading the operator through the entire test run. It prints fresh instructions as they are required, and also warns the operator if limitations are being exceeded.

46. The computer has the capacity to carry out the following test procedures:

- The complete calibration of new ECUs prior to installation in an aircraft.
- Proof of performance and system integrity after rectification or repair, component replacement and reconditioning which includes:
  - Measurement of thrust and mass air flow.
  - Measurement and analysis of vibration levels.
  - Measurement of fuel flow rates.
  - Check for correct ECU functioning, speed, temperature and acceleration.

**Test Stand Pass-off Acceptance Standards**

47. **Acceptance standards.** The engine performance acceptance standards are contained in a separate chapter in the engine Air Publication. All results of the engine test run are read against the acceptance standards, and a direct comparison made between the temperatures, pressures, speeds and other criteria of the acceptance standards, and the resulting figures from the engine run. Every conceivable aspect that will affect the engine operation, performance and safety is accounted for, and the results of the engine run must meet all of these requirements before being accepted as serviceable. It is in this chapter of the Air Publication that the engine charts and graphs are to be found.

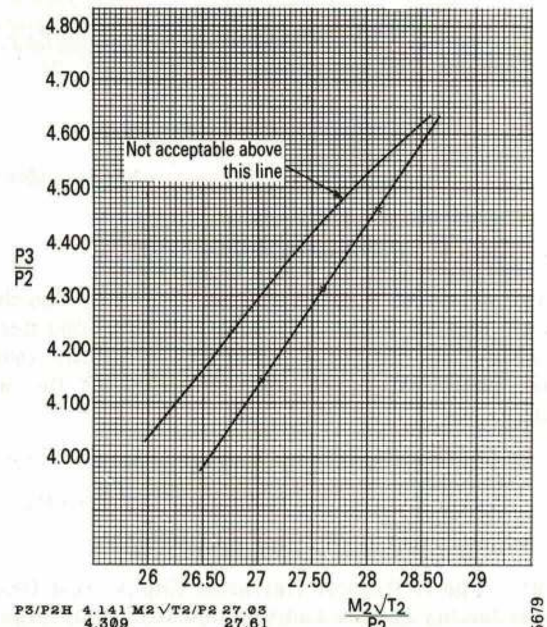


**Fig 7.2.9 HP Compressor Working Line Limit – Reduced Performance Curve Test**

48. **Engine proving graphs.** The use of graphs to assess the serviceability of an engine after a test has been carried out is necessary in test facilities that do not have computers, or at computerized facilities where the computer is unserviceable. Two examples of the graphs used are shown by Figs 7.2.9 and 7.2.10. When a computer is not available, the test facility operators manually convert the raw data recorded from the instruments during the engine run, to corrected data that can be substituted into formulae and applied to the graphs. The graphs illustrated have

been plotted from corrected figures that have been obtained from the computer print out tapes of an engine test run. The ultimate results on the graphs would be the same, whether arrived at by computer or by manual calculations.

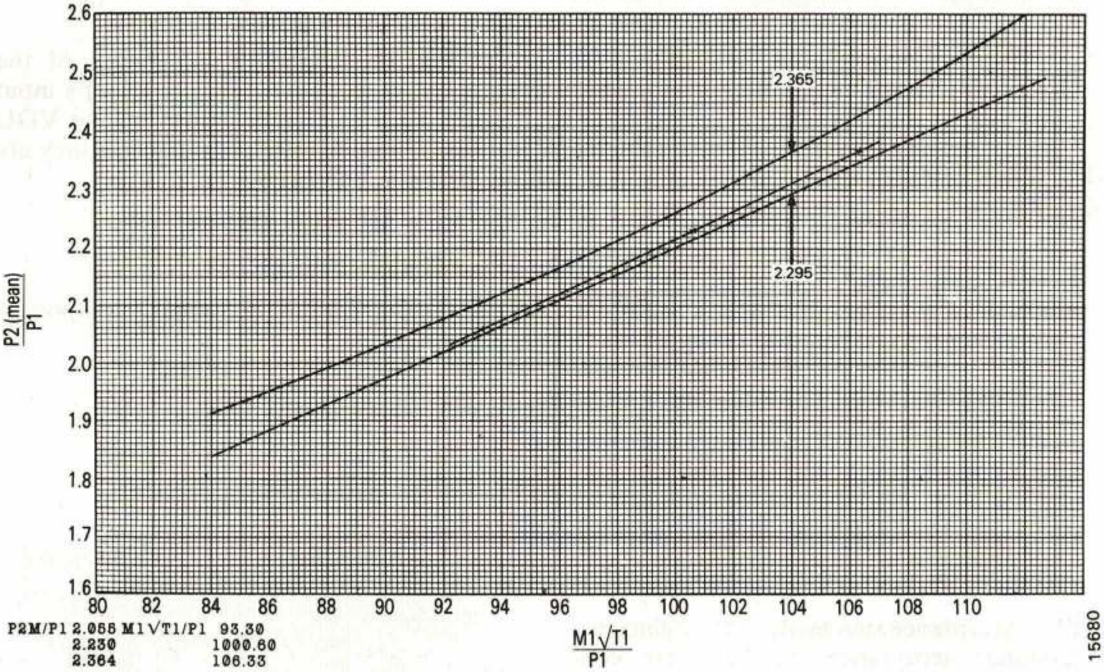


**Fig 7.2.10 LP Compressor Working Line Limit – Reduced Performance Curve Test**

**Further Engine Test Facilities**

49. The test facilities discussed so far in this chapter have been purpose built, and used to run and test modular and semi-modular engines. There are a number of other types used throughout the Service, ranging from those using large test beds with dual dynamometers, to the basic test stands, that are used for the simplest of engine runs. The following briefly describes three of those currently in use.

(1) The Helicopter Universal Engine Test House.

(2) The un-installed engine Test Facility.

(3) The Engine Run Test Stand.

50. **The Helicopter Universal Engine Test House (HUETH).** The HUETH is a purpose built test facility for the running and testing of large helicopter engines. The facility has a test cell that houses a large engine test bed, at the front end of which are mounted two dynamometers in tandem and connected by a carden shaft. The HUETH is a versatile facility, capable of testing engines whose designs differ considerably. Engines that transmit the drive to the aircraft gear boxes through the front of the engine, are mounted on the test bed with the air intakes facing the dynamometers, and connected to them by an adaptor shaft (Fig 7.2.11). Conversely those engines that are designed to drive the aircraft gear boxes from a free turbine through the rear of the engine, are mounted on the test bed with the exhaust facing the dynamometers, and connected to them by a torque tube and flywheel assembly (Fig 7.2.12).

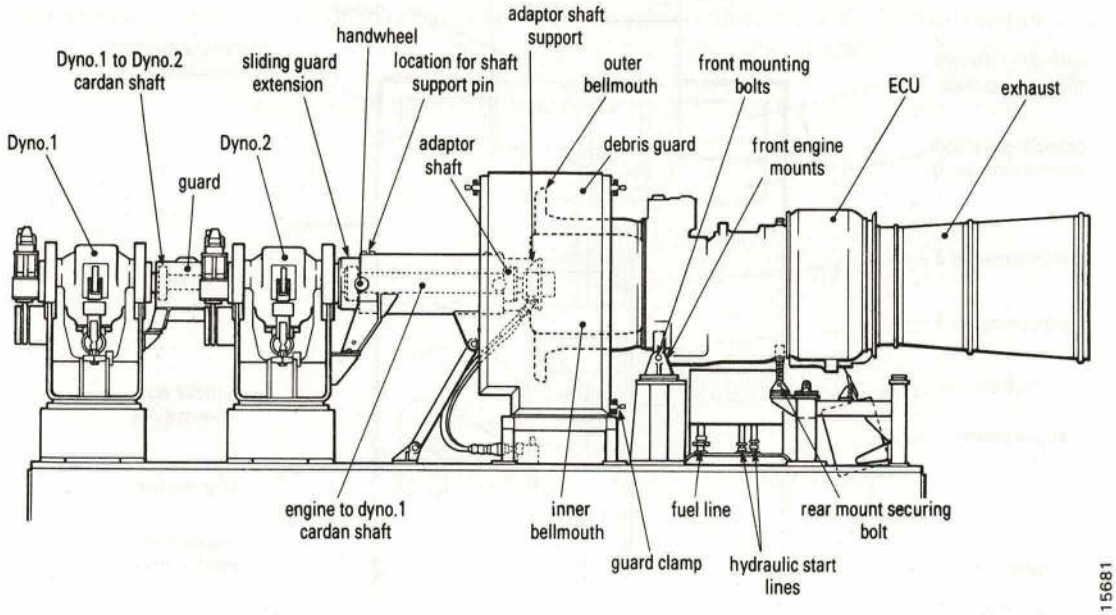


**Fig 7.2.11 Test Position of Engine with Front Drive**

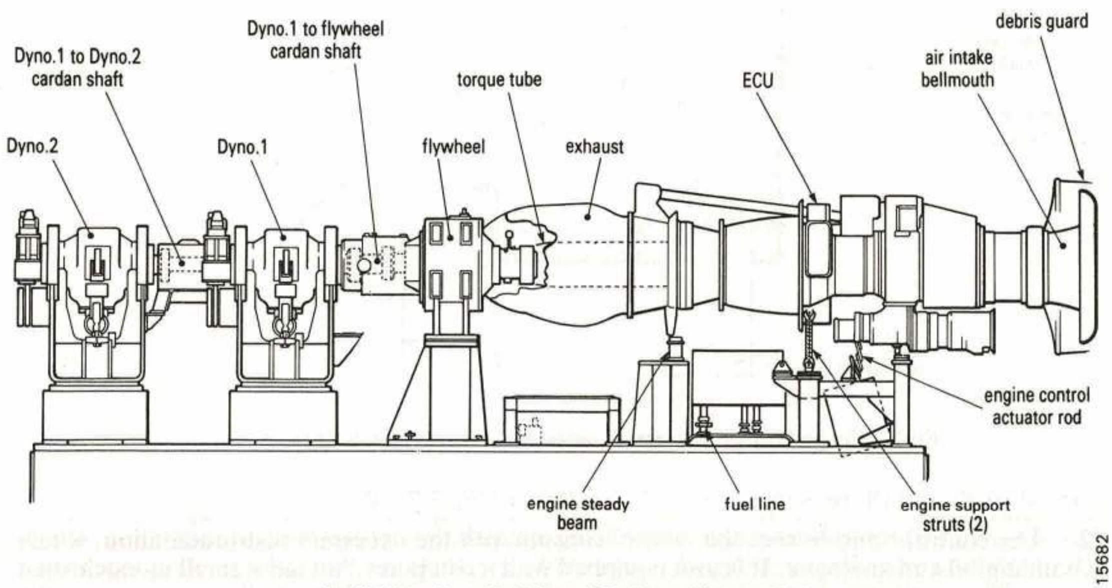


**Fig 7.2.12 Test Position of Engine with Rear Drive**

51. There are air inlets at both ends of the test cell, to admit airflow for engine testing. One inlet only will be open during the engine run, depending upon which way the engine is mounted. There are also two separate exhaust systems, (one for each type of engine) which are conveniently located to duct exhaust gases from the cell. Both of the systems culminate in

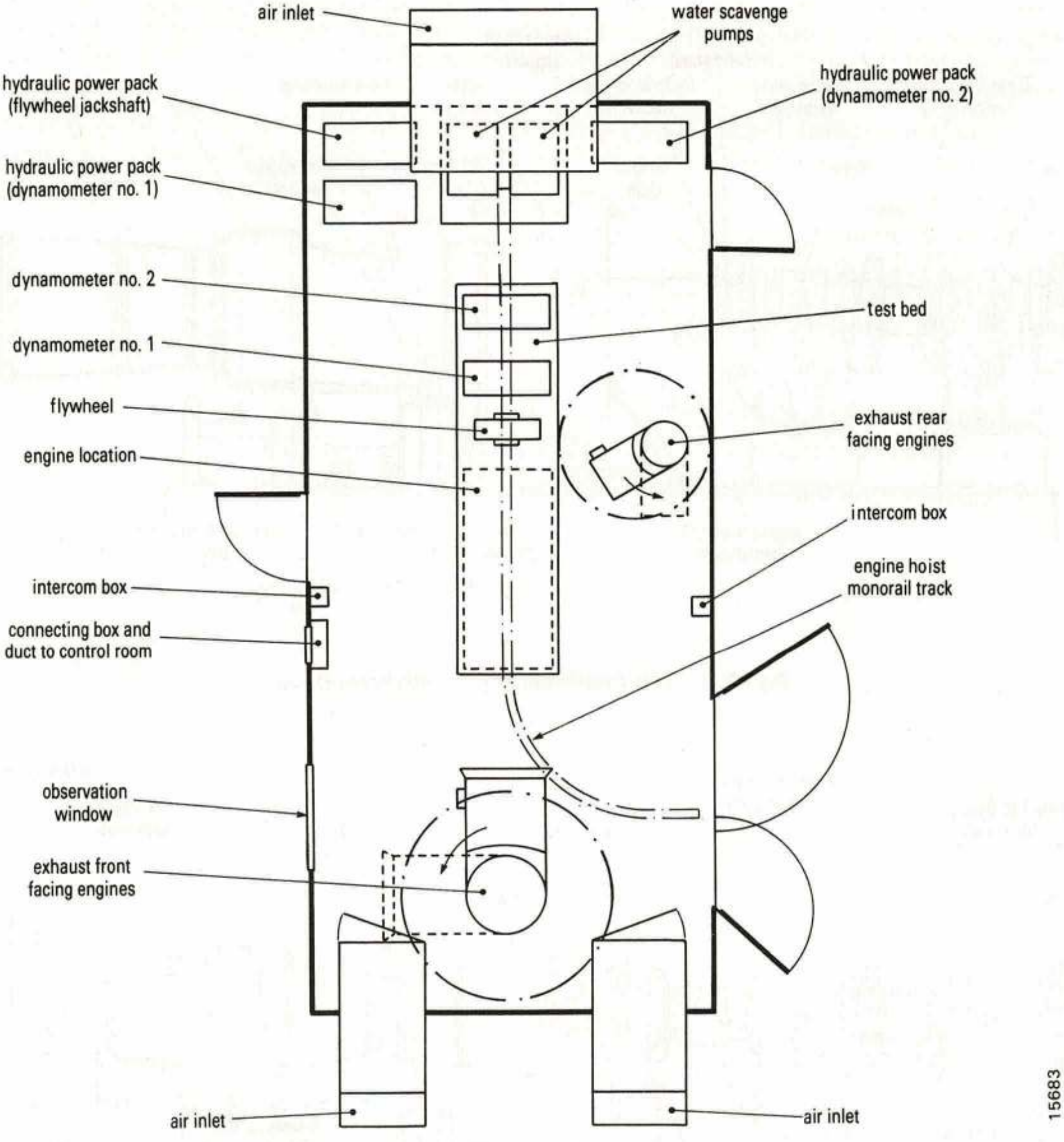


**Fig 7.2.13 Helicopter Universal Engine Test House General Layout**

vertical stacks, which pass through the test cell roof (Fig 7.2.13).

52. The control room houses the control console with the necessary instrumentation, which is both digital and analogue. It is also equipped with a computer that has a small monochrome screen. The computer is programmed to lead the operators through the engine run, the relevant details of the test required being keyed in by the operators prior to the engine start (ref para 46). The sequence of instructions required to run the engine appear on the screen. The computer also has the capacity to assess engine performance from information keyed in by the operator during the engine run, and this operates in the same manner as that discussed earlier in the chapter (ref para 43).

NOTE. The dynamometers are the hydraulic type using water as the braking medium. The engines derive their driving torque from a free turbine, and are rated in shaft horse power. Any residual thrust at the exhaust nozzle is discounted in the power rating readout on the control room console gauges.

53. **The Un-installed Engine Test Facility (UETF).** The UETF (Fig 7.2.14) is a mobile self-contained facility which is designed to test helicopter engines (Rolls Royce Gnome). It comprises a welded rectangular main base frame upon which are mounted:

- A control cabin.
- An engine mounting frame.
- Fuel tank and system.
- Engine inhibiting tank and system.
- Electrical and indicating system.
- Fire extinguisher stowage.

The facility is mounted on a mobile base or chassis.

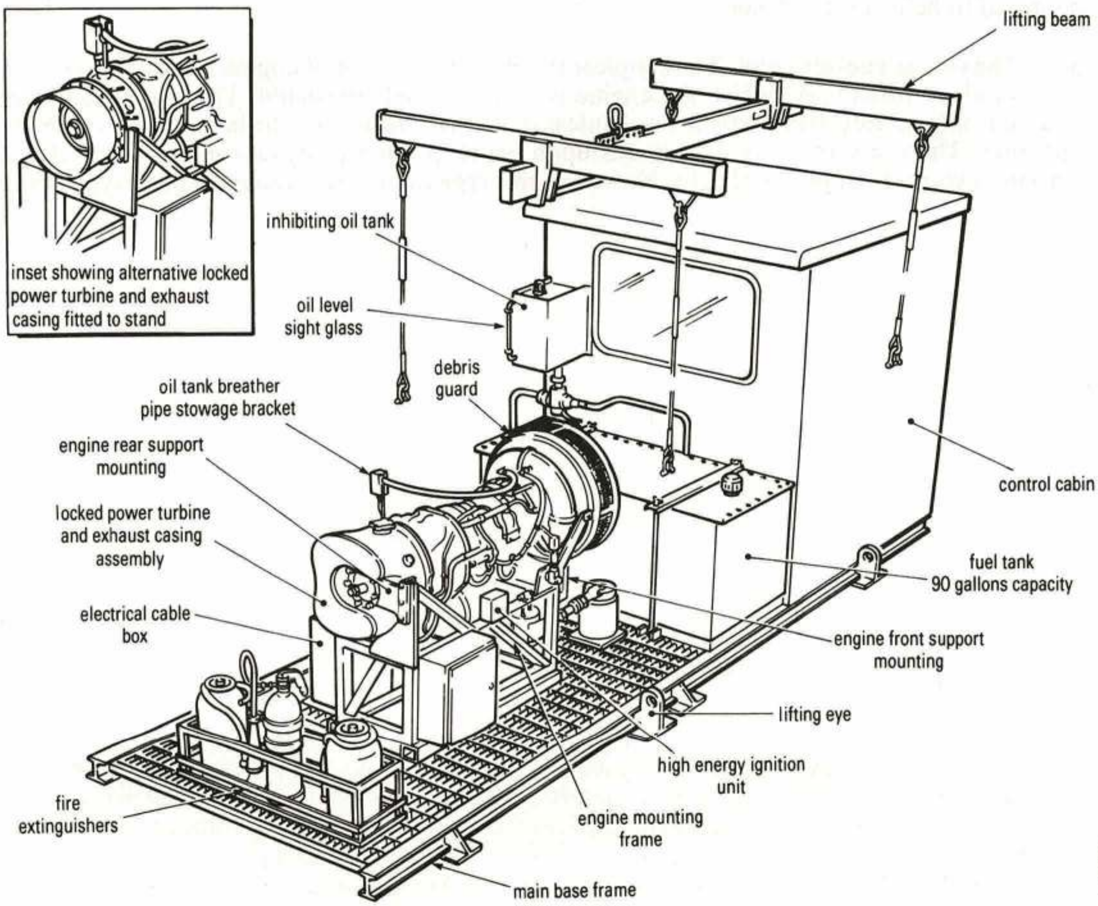


**Fig 7.2.14 Uninstalled Engine Test Facility (Rolls Royce Gnome Engines)**

**Engine Preparation and Ground Test**

54. The engine to be tested is installed into the engine mounting frame, connected, and prepared for run up whilst the UETF is in the hangar. When it is ready to be tested, the facility is towed to the appointed run up site. The only ground run tests beyond the scope of the facility are engine power tests. (For ground running purposes a special exhaust casing is installed to lock the power turbine). However, engine performance is monitored by using graphs plotted with results from corrected engine temperature and rev/min readings.

55. A further check for engine efficiency is the Stall Margin Test. The test requires the engine speed to be increased from Idling to a speed above which the inlet guide vanes (IGVs) become fully open. They are then locked into the fully open position by operating a valve, which is part of the ground test equipment. The engine speed is then slowly reduced until the engine stalls, immediately that this occurs the engine is shut down. The difference between the engine speed at which the IGVs would normally start to close, and the speed at the point of stall, is called the stall margin. The initial stall margin figures are established by the manufacturers, and the resulting figures from the test run are compared with them. As the engine efficiency decreases with wear and blade erosion, the speed at which the engine stall increases, and the stall margin decreases. It should be noted that stall margin checks are confined to helicopter engines.

56. **The engine run-up stand.** The simplest example of this type of engine test facility consists of a stand or frame upon which the engine is mounted and connected. The engine is started and run only to idle RPM, for a mechanical and leak check prior to being installed in the airframe. There are other run-up stands upon which complete engine runs are carried out, with the exception of power checks. However, this type of facility is the most basic type that is used.

## Glossary of Abbreviations and Symbols

| Abbreviation | Definition |
|---|---|
| ECU | Engine change unit. |
| LP | Low pressure. |
| HP | High Pressure. |
| ISA | International standard atmosphere. |
| Revs/min | Revolutions per minute. |
| TGT | Turbine gas temperature. |

| Symbols | Definition |
|---|---|
| $N_L$ | LP compressor shaft speed. |
| $N_H$ | HP compressor shaft speed. |

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GROSVENOR HOUSE
34