# ORPHEUS MARK 803

## LIGHTWEIGHT TURBOJET ENGINE

BRISTOL SIDDELEY

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## LIGHTWEIGHT TURBOJET ENGINE

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BRISTOL SIDDELEY ENGINES LIMITED P O BOX 3 FILTON BRISTOL

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# BRISTOL SIDDELEY ORPHEUS MARK 803

## LIGHTWEIGHT TURBOJET ENGINE

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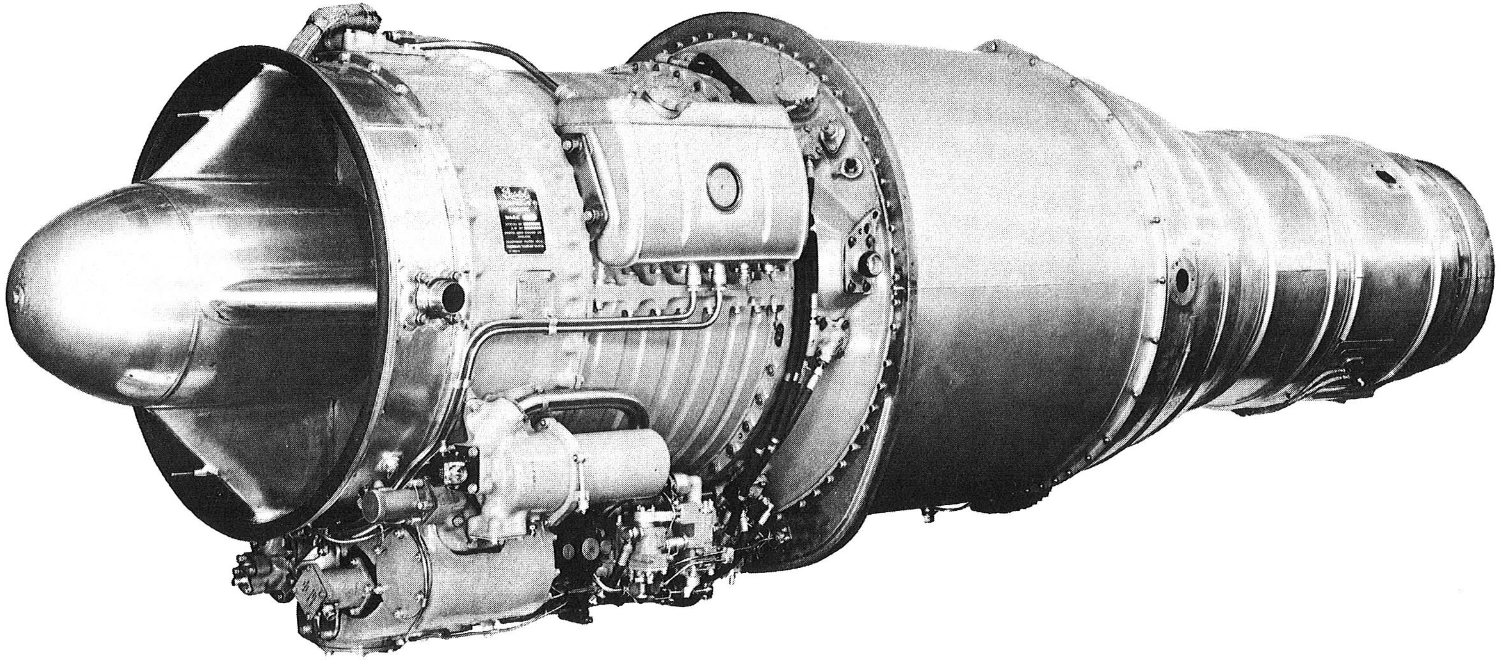
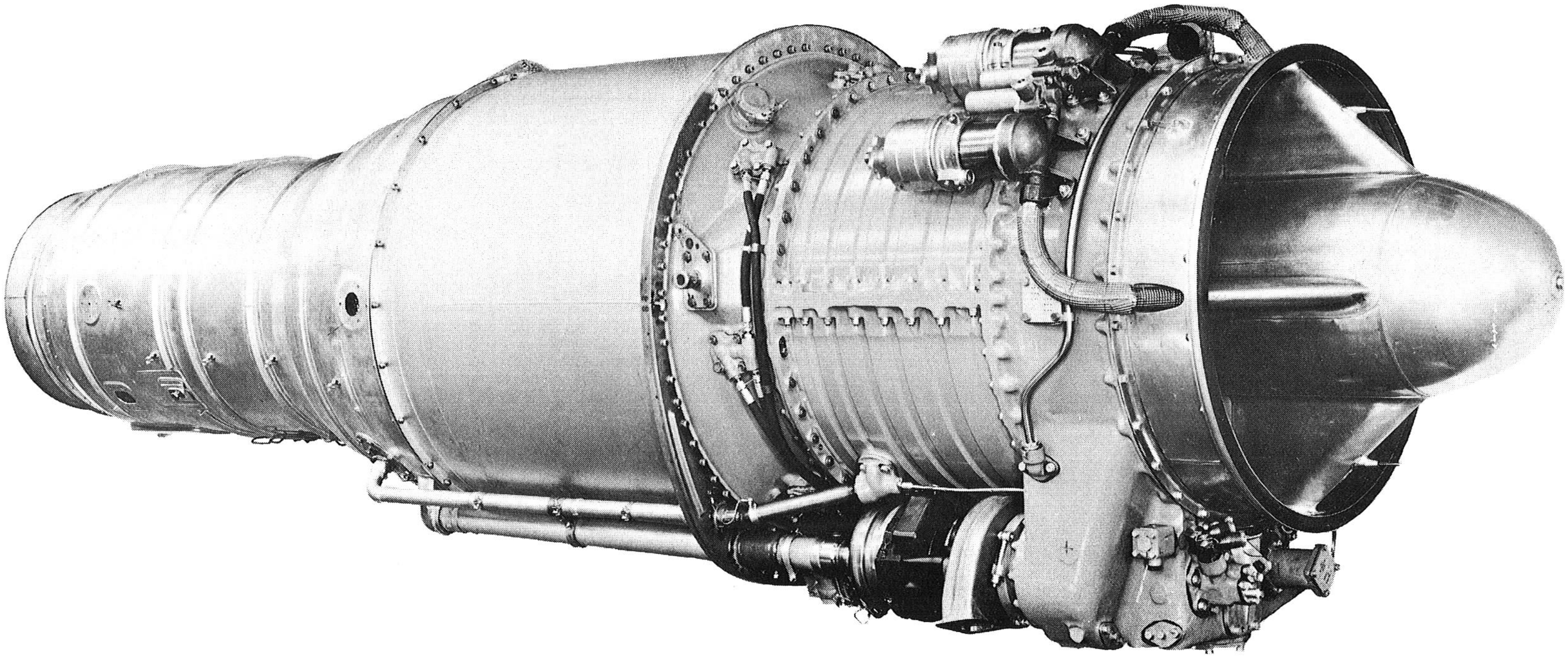


The Orpheus Mark 803 Engine

EPD 20



The Orpheus Mark 803 Engine

## INTRODUCTION

The Orpheus was designed as a turbojet engine in the medium thrust range for applications where low weight, simplicity and ease of maintenance are of prime importance. The purpose of this publication is to present the characteristics and development history of the Orpheus Mark 803 which powers the Fiat G.91, first generation N.A.T.O. lightweight fighter, together with some information about the 'after-sales' services available.

The first mark of Orpheus - the B.Or.1 - had its initial run on December 19th 1954 and its success was such that within six months it had completed an official Type Test at a thrust of 3285 lb. Two months later the engine made its maiden flight in the Folland Gnat aircraft which had been designed around the Orpheus engine. Throughout the time since its first run, the Orpheus has been undergoing a process of intensive development not only to ensure the mechanical reliability of the engine but also to seek improvements in performance. Even at the first established rating of 3285 lb the engine had a thrust/weight ratio superior to any other fully Type Tested engine in the world and later Orpheus engines have completed official Type Tests at 4050 lb, 4230 lb, 4520 lb, 4850 lb, 5000 lb, and 6810 lb, thrust. The speed with which the development programme has been performed is clearly illustrated below:-

| | |
|---|---|
| First manufacturing instruction issued | January 1954 |
| All detail drawings cleared | June 1954 |
| First run of engine | 17th December 1954 |
| First flight | July 1955 |
| Official Type Test at 3285 lb thrust (B.Or.1) | May 1955 |
| Official Type Test at 4050 lb thrust (B.Or.1) | January 1956 |
| Official Type Test at 4520 lb thrust (B.Or.2) | October 1956 |
| Official Type Test at 4850 lb thrust (B.Or.3) | May 1957 |
| Official Type Test at 5000 lb thrust (Mark 803) | February 1959 |
| *Official Type Test at 6810 lb thrust (B.Or.12) | October 1959 |
| *Official Type Test at 5000 lb thrust (Mark 803) | December 1959 |
| *Official Type Test at 4230 lb thrust (Mark 100) | January 1960 |

*These tests were to the new Fighter Schedule (D.E.R.D.2100 Issue 4 Schedule B) which necessitates operating the engine for 30 hours at take-off power.

Orpheus engines of all types have now accumulated almost 18,500 hours running on the test bed and 18,000 engine hours in flight in eight different types of aircraft.

The success of the Orpheus quickly attracted the interest of European aircraft manufacturers and the N.A.T.O. military authorities, so that when the requirements for a tactical lightweight fighter emerged, the Orpheus became the natural choice of power unit and the development of the engine received support from the Mutual Weapons Development Programme. Three fighters were ordered for N.A.T.O. evaluation - the Fiat G.91, the Breguet Taon and the Dassault Etendard VI - all fitted with Orpheus Mark 801 engines. As these three aircraft all have larger electric and hydraulic power requirements than the Folland Gnat which is powered by an Orpheus Mark 701 engine, a new gear casing with drive faces to accommodate the larger accessories and a Lucas 'D' size fuel pump is fitted to the Mark 800 series engines.

The first run of the Orpheus B.Or.3 (development nomenclature of the Mark 801) took place in December 1956, and deliveries for prototype aircraft began in January 1957. The development of the engine was extremely rapid and the official Type Test at 4850 lb thrust was successfully completed in May 1957.

The Orpheus Mark 803 engine described in this brochure is an improved version of the Mark 801 and has been introduced to allow the functions of the N.A.T.O. lightweight fighters to be extended to include operation at high altitude in addition to the ground attack role for which they were originally designed.

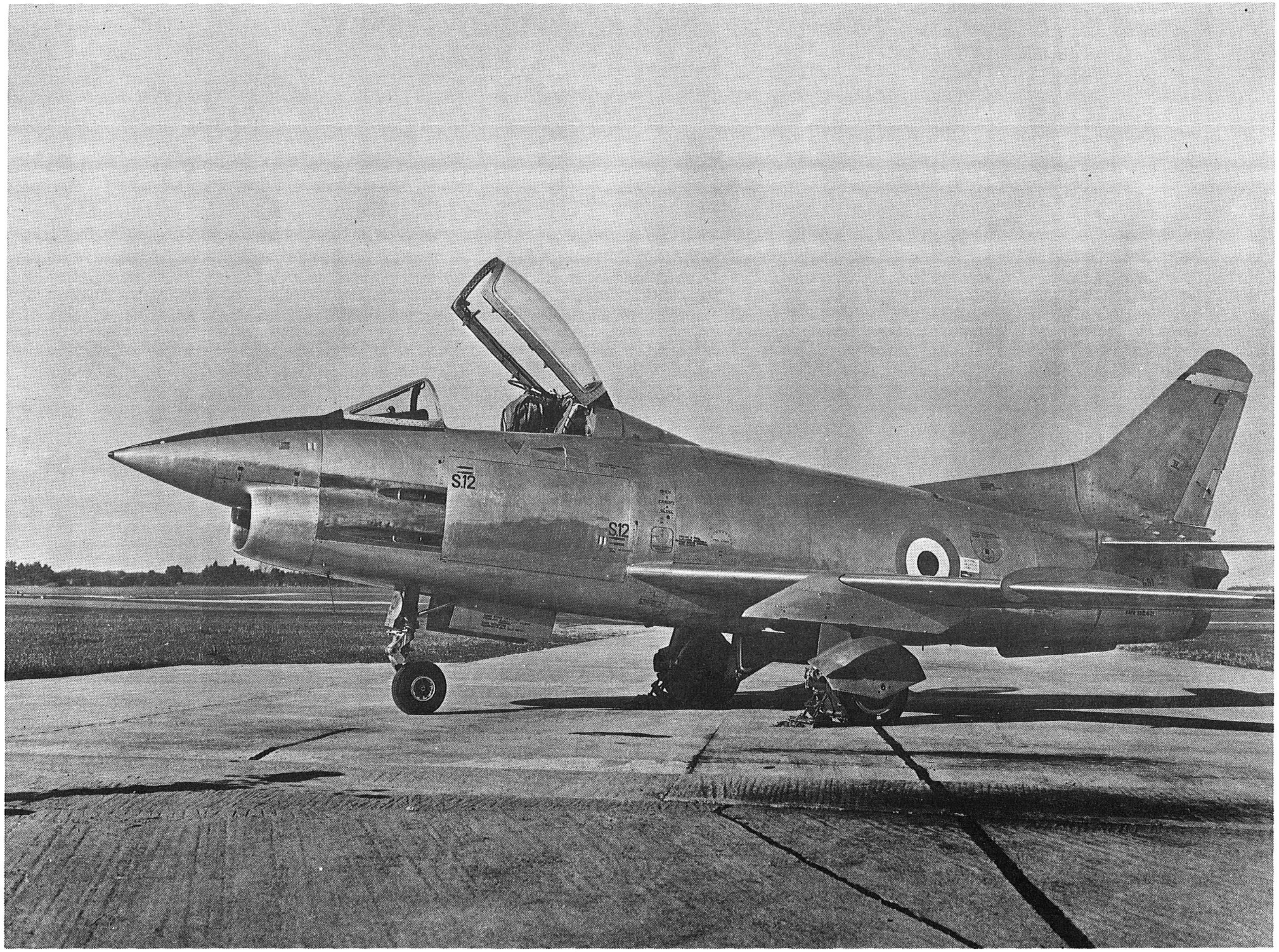
In order to achieve this the Mark 803 engine incorporates a modified compressor similar to that used by the Mark 701 engines in the Gnat, which, in conjunction with refinements to the control system, ensures surge-free operation at high altitude.

An identical version of the Mark 803 engine is to be produced under licence in Germany for the Fiat G.91, but since there are some changes to the installational features the engine change unit will be designated the Mark 803D - 11. The changes consist of the addition of a Graviner Firewire fire detection system and the fitting of a 6 kW electrical generator in place of the 4 kW generator normally fitted to the Mark 803.

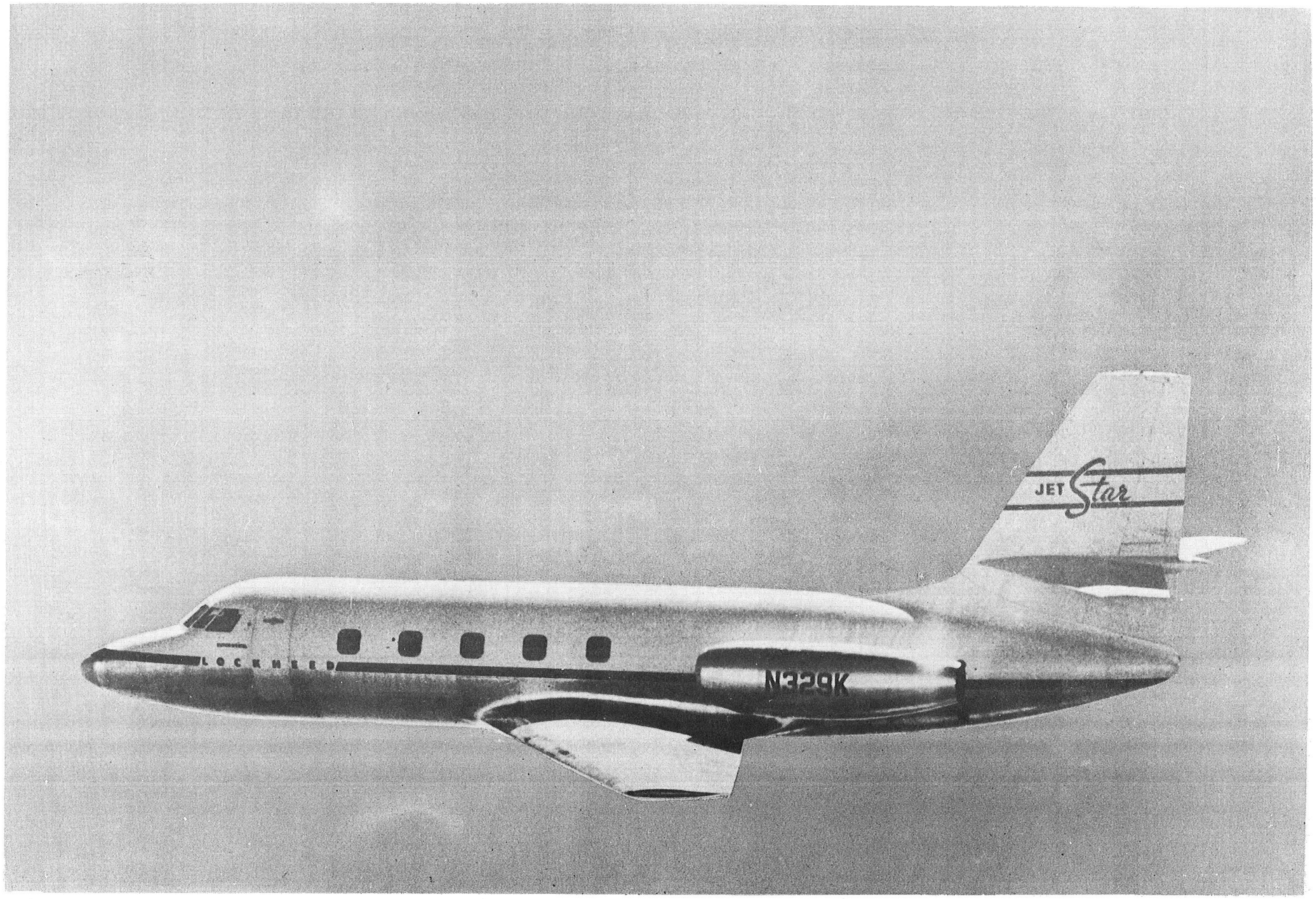
Compared with the Mark 801, the Mark 803 also provides increased performance. The take-off thrust at sea level static conditions is increased from 4850 lb to 5000 lb, and at 40,000 ft. there will be a 9% increase in thrust and a 5% reduction in specific fuel consumption.

In addition to the Gnat, Gnat Trainer and The N.A.T.O. aircraft the Orpheus is flying in the Lockheed JetStar and the Fuji T1F-2.

Other aircraft which specify the Orpheus engine are the Folland Gnat Mk.2, the Fiat G.91 Trainer, the Short SB-5 and Hunting H.126 research aircraft, the Hispano H.A.300 and the Hindustan H.F.24.

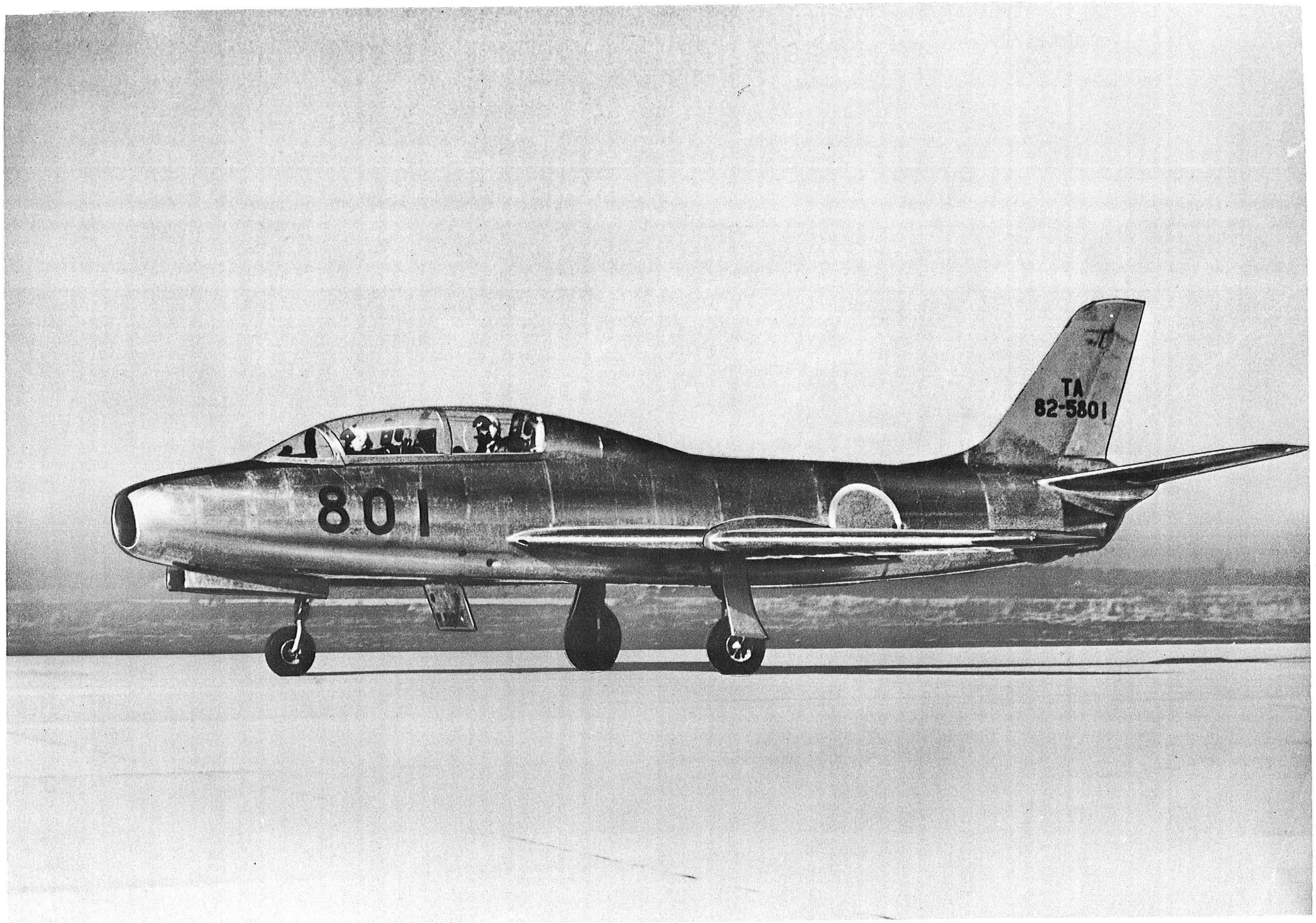



The Fiat G 91




The Lockheed Jetstar

EPD 23




The Fuji T1F-2


Folland Gnat

Folland Gnat Trainer

## SECTION 1

## ENGINE DESCRIPTION AND PERFORMANCE

The Orpheus is a single-spool turbojet engine having a seven-stage axial compressor and a single-stage turbine. It is designed to meet the requirement for an engine in the medium thrust range for applications where low weight, ease of maintenance and simplicity are of prime importance.

### Air Intake Duct

This is a fabricated component made from aluminium alloy sheet. It consists of an outer drum, four hollow vanes and a hollow centre body. The forward end of the outer drum carries a channel section in which there is a synthetic rubber sealing ring. This ring can accommodate the expansion of the engine and ensures an air-tight joint with the aircraft's air intake duct. The rearward end of the outer drum carried a machined flange which bolts onto the engine air intake casing.

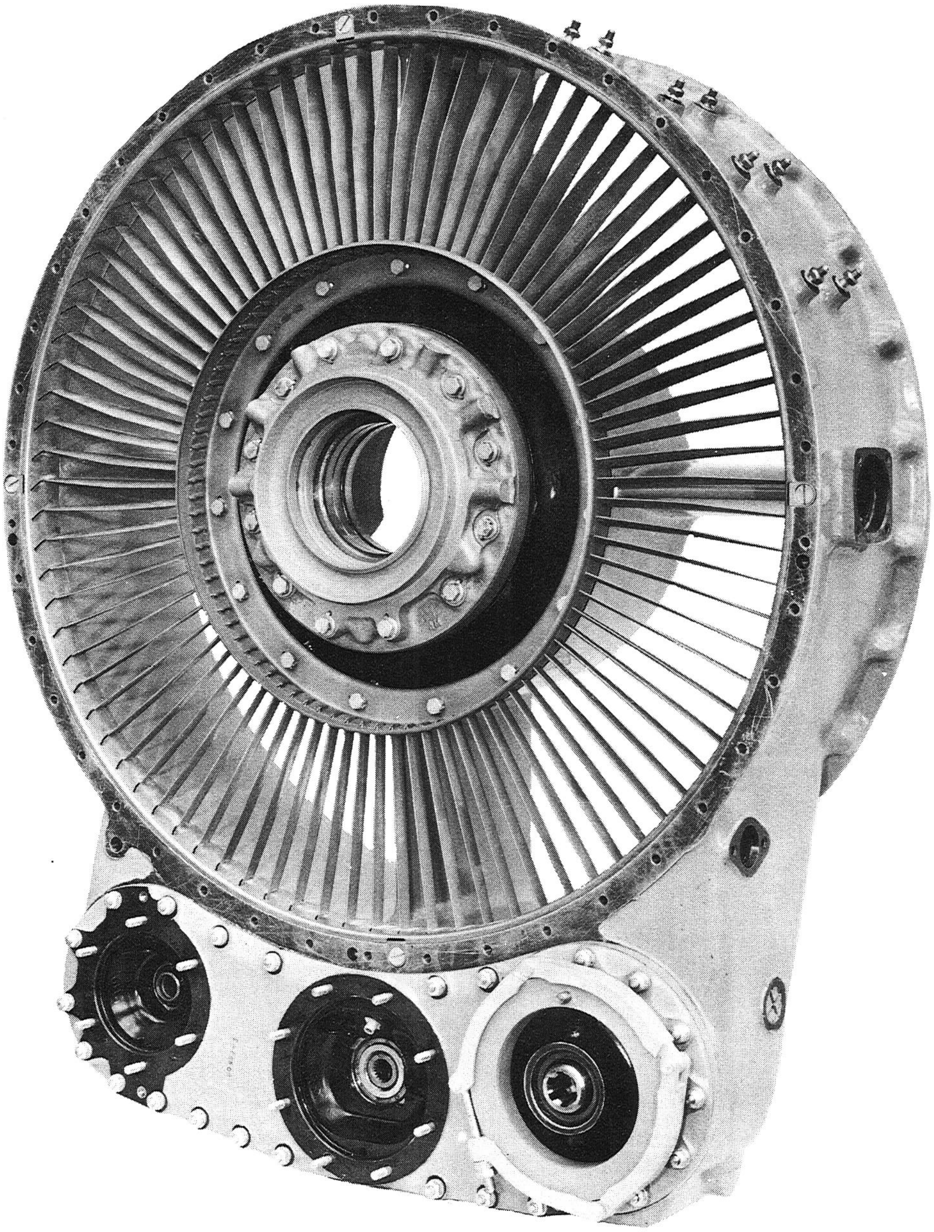
The centre body acts as a fairing for the engine starter which is normally of the cartridge type. Two pipes carrying the gas to the starter pass through the starboard and upper vertical hollow vanes. The exhaust gas from the starter is piped to atmosphere through the port vane.

The upper and lower vertical vanes each carry one prong of a two-prong pitot tube in order to supply the indication of air intake total pressure to the engine fuel control system.

### Air Intake Casing

This is a magnesium-zirconium casting located between the air intake duct and the forward end of the compressor casing. It carries all the engine accessories and accessory drives, the compressor thrust bearing, the engine starter and the compressor entry guide blades.

The starter is attached to the front of the casing and its drive is transmitted direct to the centre of the compressor rotor via two quill shafts which are in line and meet in an internally splined shaft which carries a bevel gear externally. This bevel gear meshes with another on a vertical shaft which carries the main drive down to a housing in the lower part of the air intake casing. This housing, which is integral with the casing, carries all the engine accessories.



Air Intake Casing

EPD 27

The entry guide blades are fabricated from stainless steel strip and are held between inner and outer carrier rings of the same material. The blades are welded to the carrier rings on the inner and outer ends and the whole assembly is mounted on the air intake casing by means of a flange on the inner carrier ring.

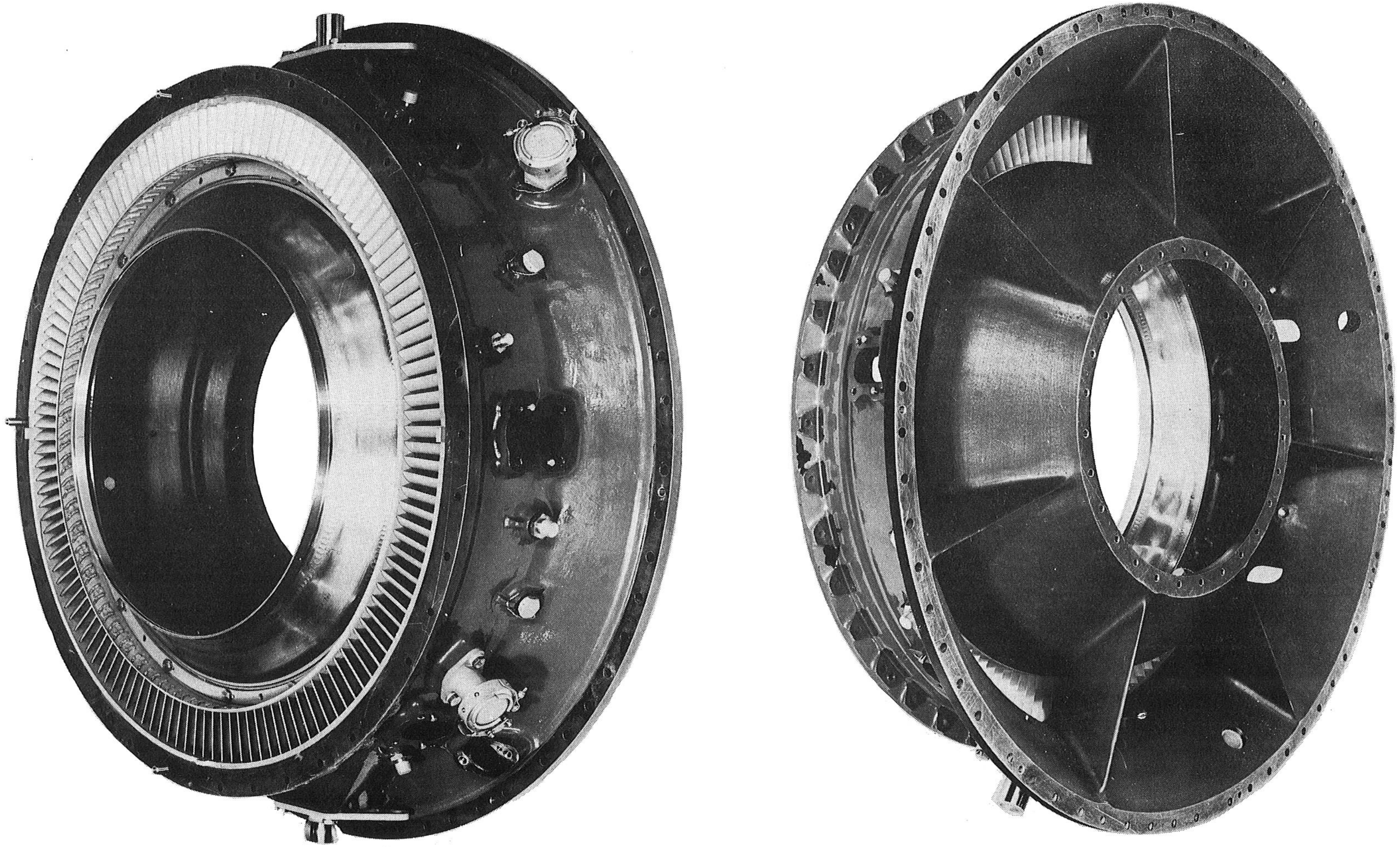
The upper surface of the air intake casing carries the engine breather pipe which will normally pass to atmosphere through a flush outlet in the engine cowling.

## Compressor Casing

This is a parallel drum cast in two halves from magnesium-zirconium alloy. The two halves are held together by bolts passing through flanges on the horizontal centre line. The casing contains six rows of stator blades which are located in circumferential grooves of dovetail section. All the blades are precision forged, the first two rows being in aluminium alloy and the last four in heat resisting steel. The blades are held in place by spring clips. An air bleed is taken from the 5th stage to provide cooling air via an external pipe to the turbine bearing and the rear face of the turbine disc.

## Compressor Rotor

The rotor consists of seven stages each being supported on a separate disc. The discs are forgings and increase in diameter progressively towards the high pressure end. The first two stages are parallel to about 0.4 of their radius where they are held together by ten bolts spaced around the abutment flanges. From these flanges outwards the discs are dished so that they diverge and at their extremities a spacer ring between them forms a smooth contour with the blade root platforms. The next three stages consist of parallel discs which are bolted together and to the second stage at about 0.7 of their radius. The remaining two stages are held by the same bolts as the three previous stages but are dished and diverge from the abutment flanges outwards. The torque is transmitted throughout by means of dowels located in the abutment flanges of adjacent discs so that the attachment bolts only carry tensile loads. Between the second and third discs there is an extra conical member which provides additional rigidity to the rotor as a whole. The spacer rings, also forgings, are located between adjacent discs by spigots and pegs.



Delivery casing

The rotor blades are all precision forgings and are held in fir-tree slots broached in the disc rims. The axial location of all stages except the first and seventh is assured by the abutment of the spacer rings, whilst the first and seventh stages are provided with tongues on their roots which abut on the disc rims.

The bolts which hold the first two stages and the stiffening cone also hold a forged centre piece which locates on the inner races of the rotor thrust bearings. A stacked pair of ball bearings with split inner races support and carry the rotor end thrust, their outer races being held in a housing in the air intake casing. A system of labyrinth seals prevents the passage of oil from the intake casing and thrust bearing to the compressor.

Three radial tubes at 120$^{\circ}$ spacing between the fourth and fifth stage rotor discs transmit air under pressure to a central tube in the axis of the rotor. This tube is sealed at the downstream end so that the air passes to the forward end where it serves to pressurize the labyrinth seals around the rotor thrust bearings.

The compressor rotor is bolted to the turbine drive shaft by the principal long bolts running from stage 2 to stage 7, and an air seal outside the joint meters compressor delivery air to the turbine disc for cooling purposes.

## Delivery Casing

This component is an aluminium alloy casting which is located between the delivery end of the compressor casing and the combustion chamber. The casing consists of two diverging walls separated by seven vanes. Air flows from the compressor into the divergent annulus via guide vanes of aerofoil section which are fabricated from aluminium alloy and held between inner and outer rings.

On the outside of the delivery casing are the two main mounting trunnions. On the port side of the engine the trunnion is of sperical form to provide lateral location for the engine. On the starboard side a cylindrical trunnion is provided and the aircraft mounting block must be arranged to accommodate the whole of the lateral expansion of the engine. Seven equi-spaced ports in the outer drum of the delivery casing are flanged to take the fuel burners. These are held on faired struts which project into the delivery

Combined flame tube and turbine stator blades casing annulus. The burners themselves are at the end of cylindrical stems which point axially downstream into the flame tubes.

Three bleed ports are provided in the delivery casing. Two of these provide bleed air for cabin pressurization and such services as windscreen anti-icing and pressure suits, whilst the third, which is smaller, is for fuel tank pressurization.

Combustion Chamber

This is of the cannular type with individual flame tubes in an annular chamber. The outer skin of the chamber is a welded drum of heat resisting steel with machined flanges at each end. It is supported at the forward end on the delivery casing whilst at the downstream end it supports the turbine exhaust duct.

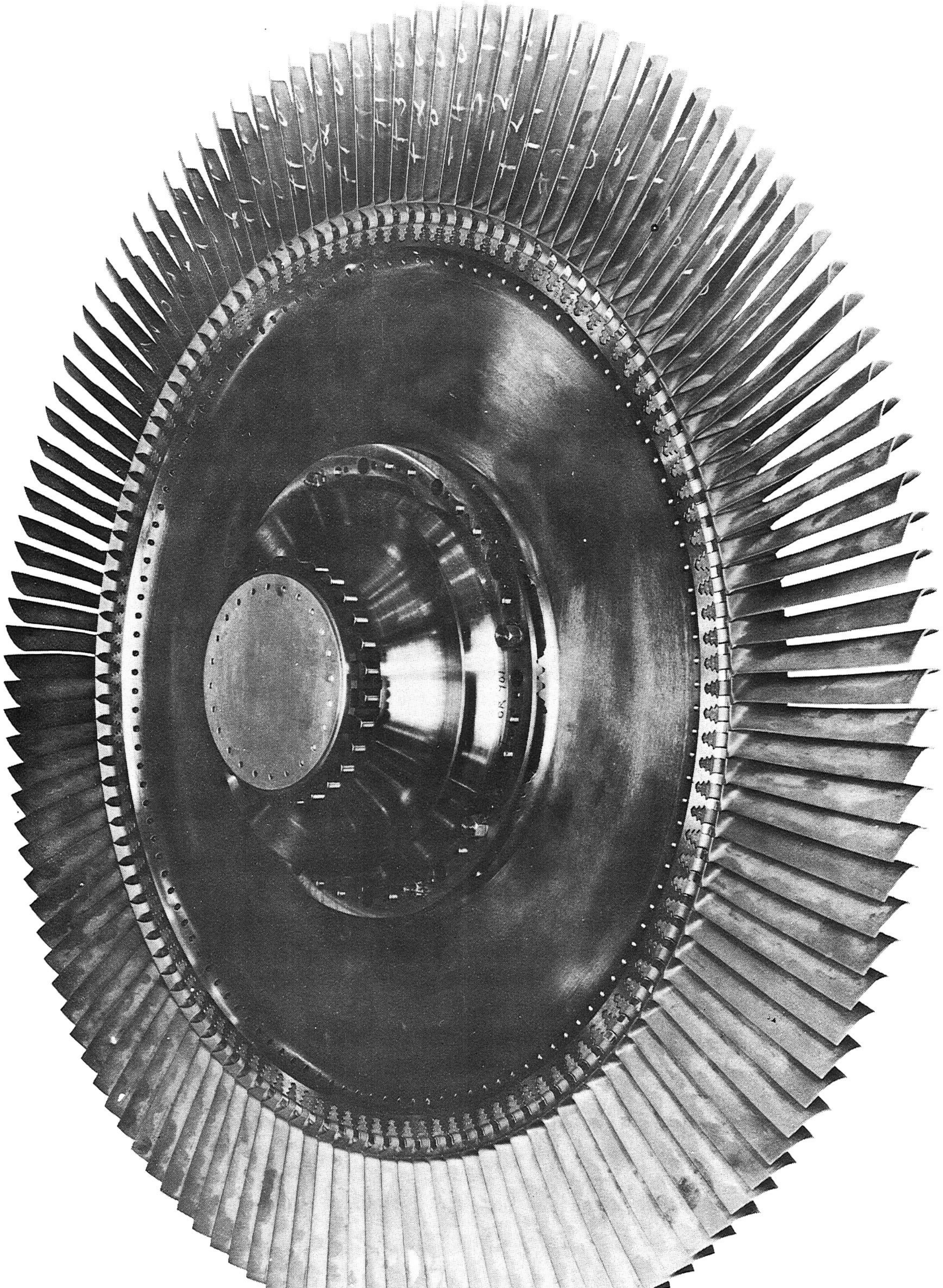
The inner skin, which is of fabricated sheet steel construction, provides a tunnel through the turbine drive shaft passes. The inner skin is only supported at its upstream end where it is bolted to the inner drum of the delivery casing. At the downstream end it is free to expand axially and a piston ring type seal on its periphery seals on the inner circumference of the turbine stator segments, thus preventing leakage of combustion chamber secondary air.

Flame Tubes

These are seven in number and are fabricated from Nimonic 75 sheet. They are cylindrical for the greater part of their length with a conical upstream section and a progressive development to a 1/7th segment of an annulus at the downstream end where the turbine stators are welded into position.

The flame tubes have a nose support and swirler at their upstream ends. These components are precision castings and the cylindrical stem of the burner passes through their centres. A spherical bearing in the nose support permits the flame tube to slide on the stem to allow thermal expansion.

The welded turbine stators are integral with the flame tubes and are of hollow sheet metal construction with machined inner and outer segments also welded into place. Adjacent tubes are bolted together at their outer segments, so that the segments abut against each other to form a continuous annulus. The outer segments, so bolted, abut on the turbine shroud support



Turbine rotor

EPD 30

ring to provide axial location, whilst dogs in the segments provide circumferential location. Cooling air passes radially inwards through the stators and exhausts into the turbine through holes drilled in the inner segment flange.

Interconnectors between adjacent flame tubes permit the transmission of combustion from one tube to another. For engine starting, and relighting in flight, two high energy igniter plugs are provided on opposite sides of the engine.

## Turbine

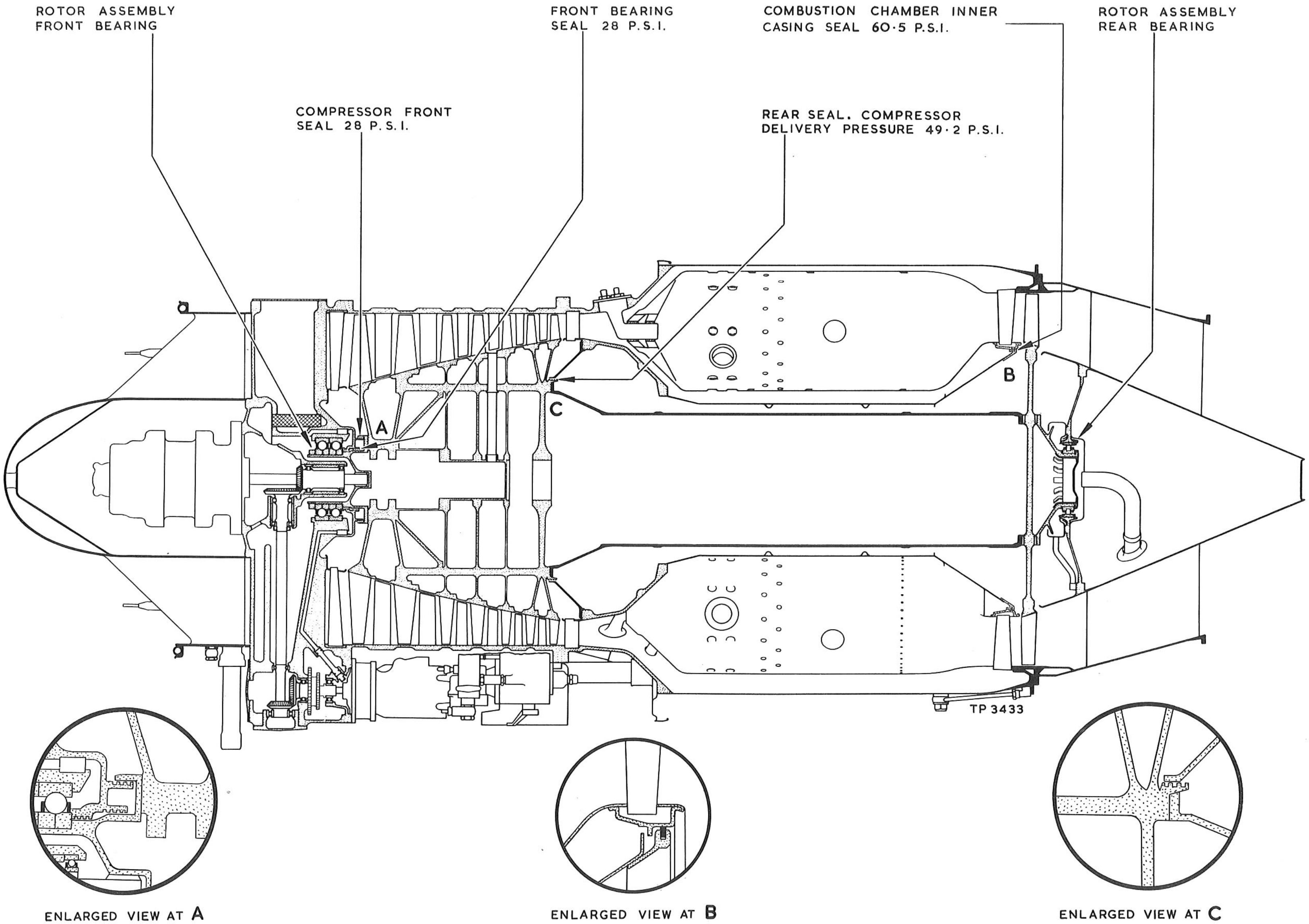
The single-stage turbine wheel is forged from heat resisting steel and is connected by Hirth couplings to the turbine drive shaft on its front face and via a conical component on its rear face to the engine rear bearing.

The turbine blades which are not shrouded are held in fir-tree slots broached in the rim of the disc and locked axially by means of hollow pins which pass from the inside of the rim on the rear face, radially through the rim and into the blade root. The pins are sheared to remove the blades and new pins are fitted on re-building. The blade platforms are remote from the rim of the disc to provide a measure of protection against thermal shock in the rim.

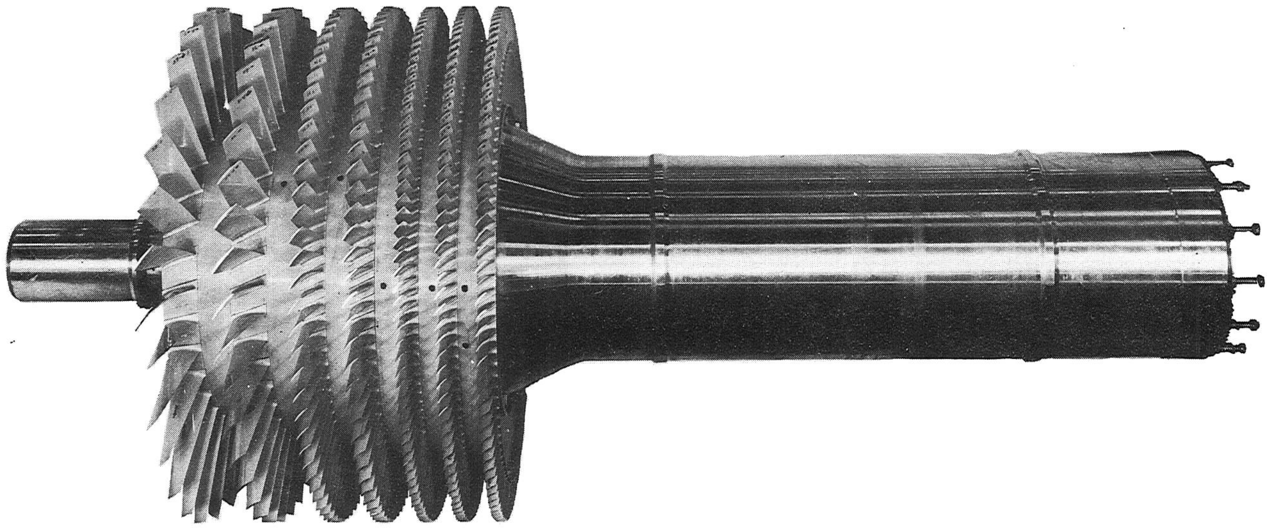
The turbine is shrouded by a split ring of heat resisting steel which is closed by a lap joint and held in a shroud support flange. The support flange is in two pieces, one being integral with the turbine exhaust duct and the other being bolted to the exhaust duct flange so that it is held between this flange and the combustion chamber outer skin flange. This half of the shroud support flange also acts as an abutment for the outer segments of the turbine stators.

## Exhaust Duct

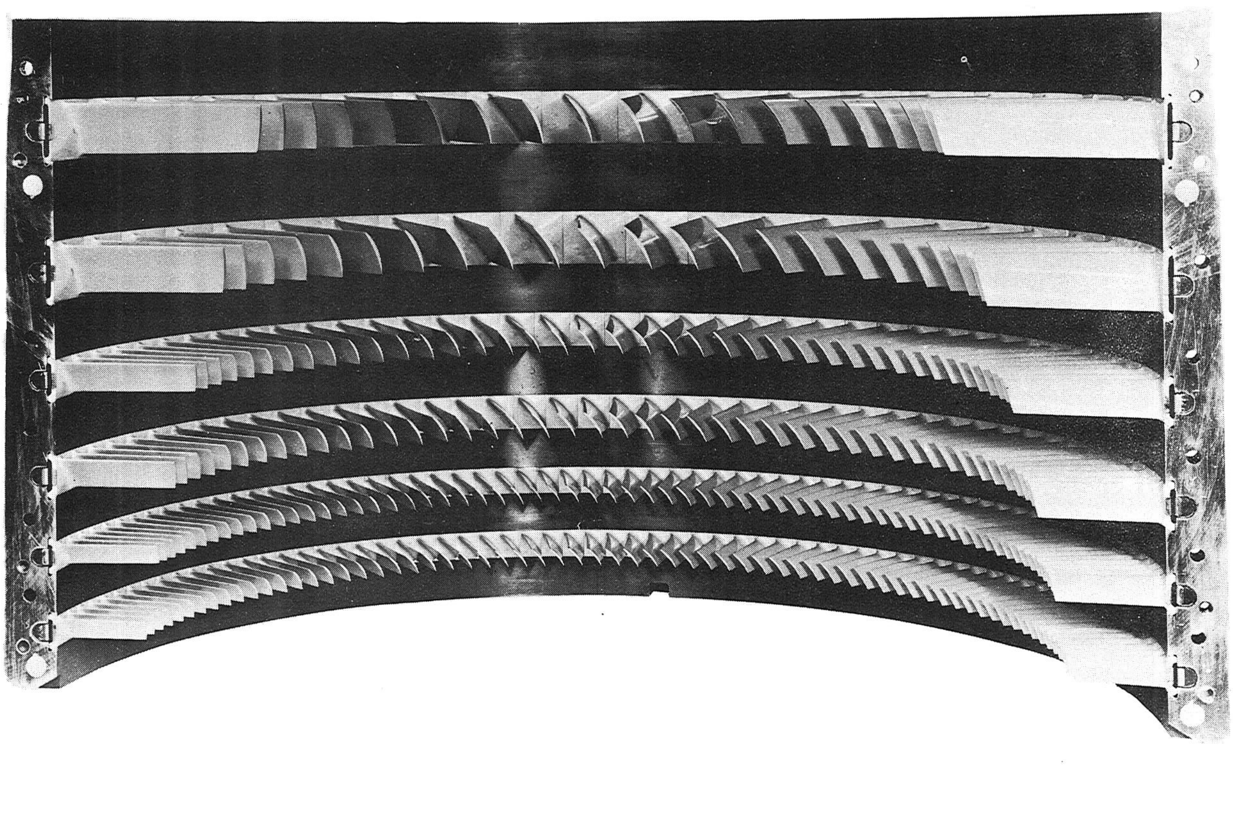
This is a fabricated component consisting of a central exhaust cone connected by eight radial cambered vanes to an outer wall. Attached to the exhaust cone is a forged diaphragm which supports the outer race of the engine rear bearing. One of the eight vanes is thicker than the rest as it accommodates the air and oil pipes which cool and lubricate the rear bearing. The rear bearing oil is not scavenged but drains into the exhaust duct whence it is dispersed with the exhaust gases.




Engine bearings and air seals



Compressor rotor



Compressor casing

# ORPHEUS MARK 803 ENGINE

## LEADING PARTICULARS

| | |
|---|---|
| TYPE | Jet propulsion engine employing an axial compressor driven by a turbine in conjunction with a cannular type of combustion chamber having separate flame tubes. |
| LENGTH | 75.47 ins. (191,7 cm) Intake face to exhaust flange. |
| | 96.1 in. (244 cm) Tip of nose fairing to end of exhaust cone. |
| DIAMETER | 32.4 in. (82,3 cm) Diameter of combustion casing flange. |
| FUEL SPECIFICATION | D.Eng.R.D.2482 (AVTUR) Specific gravity 0.80 |
| | D.Eng.R.D.2486 (AVTAG) Specific gravity 0.77 |
| OIL SPECIFICATION | D.Eng.R.D.2487 (Synthetic) |
| OIL CONSUMPTION | 2 pints/hour maximum |
| WEIGHT (bare and dry) | 850 lb (385 kg) |
| CENTRE OF GRAVITY | 1.3 in. (3,3 cm) aft of trunnion centre-line |
| GYROSCOPIC COUPLE Due to rotating assembly at maximum r.p.m. and assuming a rate of precession of 1 rad./sec. | 2900 lb ft. (40.100) kg cm) |
| ADDITIONAL WEIGHT FOR:- | |
| Typical oil tank and fittings | 10 lb (4,54 kg) |
| Typical bulkhead | 5 lb (2,27 kg) |
| Typical fuel filter | 12 lb (5,44 kg) |
| Cartridge starter and 2 shot breech | 64 lb (29 kg) |

| | | | |
|---|---|---|---|
| Miscellaneous E.C.U. items | 6 lb | (2,72 kg) | |
| Jet pipe and Blanket | 49 lb | (22,22kg) | |
| Jet pipe shroud | 23 lb | (10,43 kg) | |
| Exhaust cone blanket | 4 lb | (1,8 kg) | |
| Graviner Firewire system (Mark 803D-11 engine change unit only) | 6 lb | (2,72 kg) | |

The following accessories which are not supplied by Bristol Siddeley

| | | | |
|---|---|---|---|
| Hydraulic pump, Lockheed Mark 9 | 8 lb | (3,6 kg) | ) ) Alternative units |
| Hydraulic Pump, French Messier | 8 lb | (3,6 kg) | ) |
| 4kW Labinal generator & cooling pipes | 45 lb | (20,41kg) | Mark 803 |
| 6kW Labinal generator & cooling pipes | 55 lb | (24,95kg) | Mark 803D-11 and alternative unit for Mark 80302 engine change unit. |

## PERFORMANCE OF THE ORPHEUS MARK 803

The nominal engine performance under I.S.A. sea level static conditions with no intake loss, air bleed, power take-off or ejector effect is as follows:-

| Condition | Percentage of Design Compressor Speed | Thrust | | Specific Fuel Consumption | |
|---|---|---|---|---|---|
| | | lb | kg | lb/lb thrust/hr | kg/kg thrust/hr. |
| Maximum | 100 | 5000 | 2270 | 1.08 | 1,08 |
| Intermediate | 96.5 | 4570 | 2070 | 1.06 | 1,06 |
| Max. Continuous | 94 | 4200 | 1905 | 1.05 | 1,05 |
| Ground Idling | 35 | 220 | 100 | Fuel flow 940 lb/hr. | Fuel flow 426 kg/hr. |

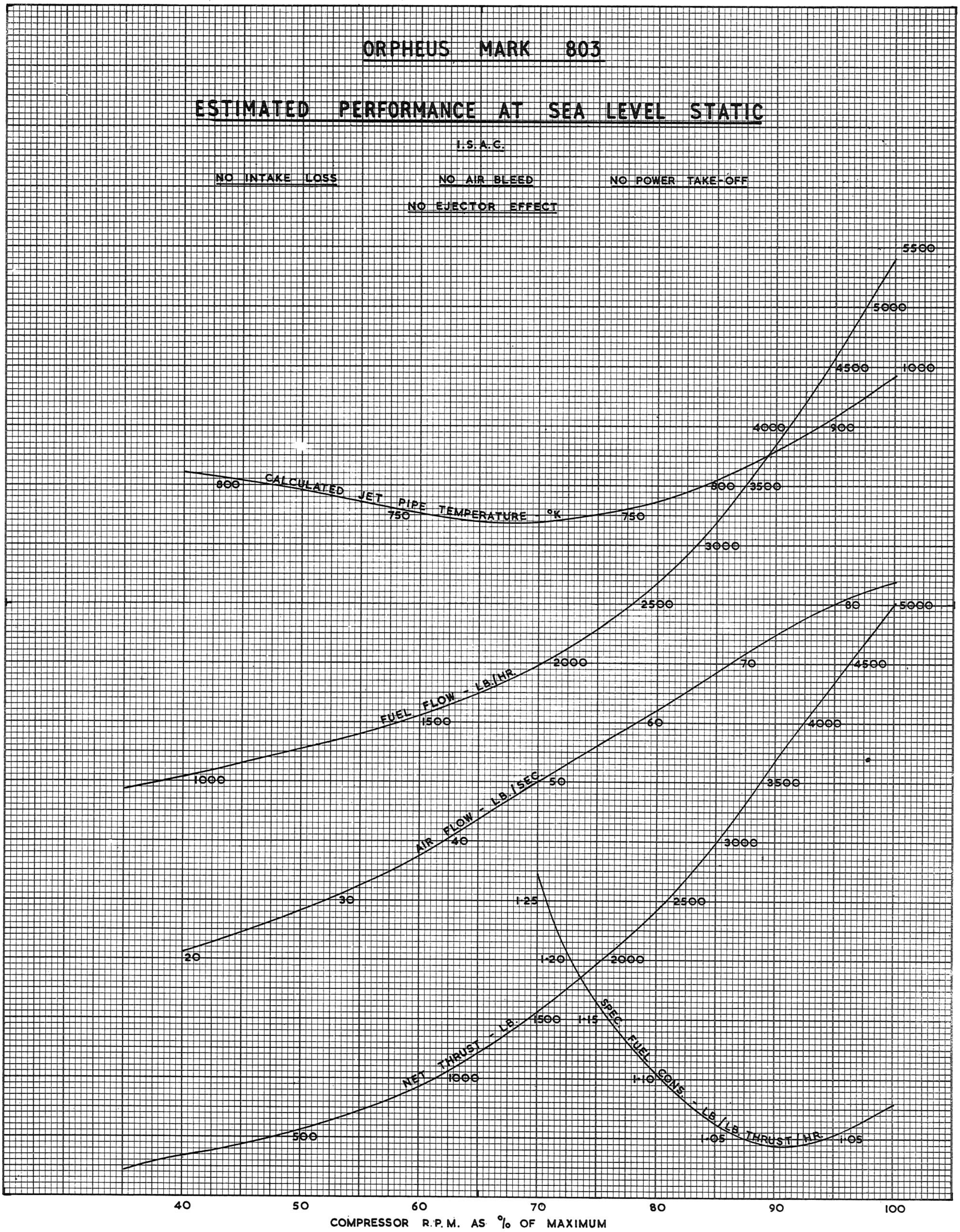
Typical cruising flight performance at Mach No. 0.9 and 36,000 ft. (11,000 m):-

Thrust 1480 lb (670 kg)

Consumption 1.32 lb/lb thrust/hr. (1,32 kg/kg thrust/hr.)

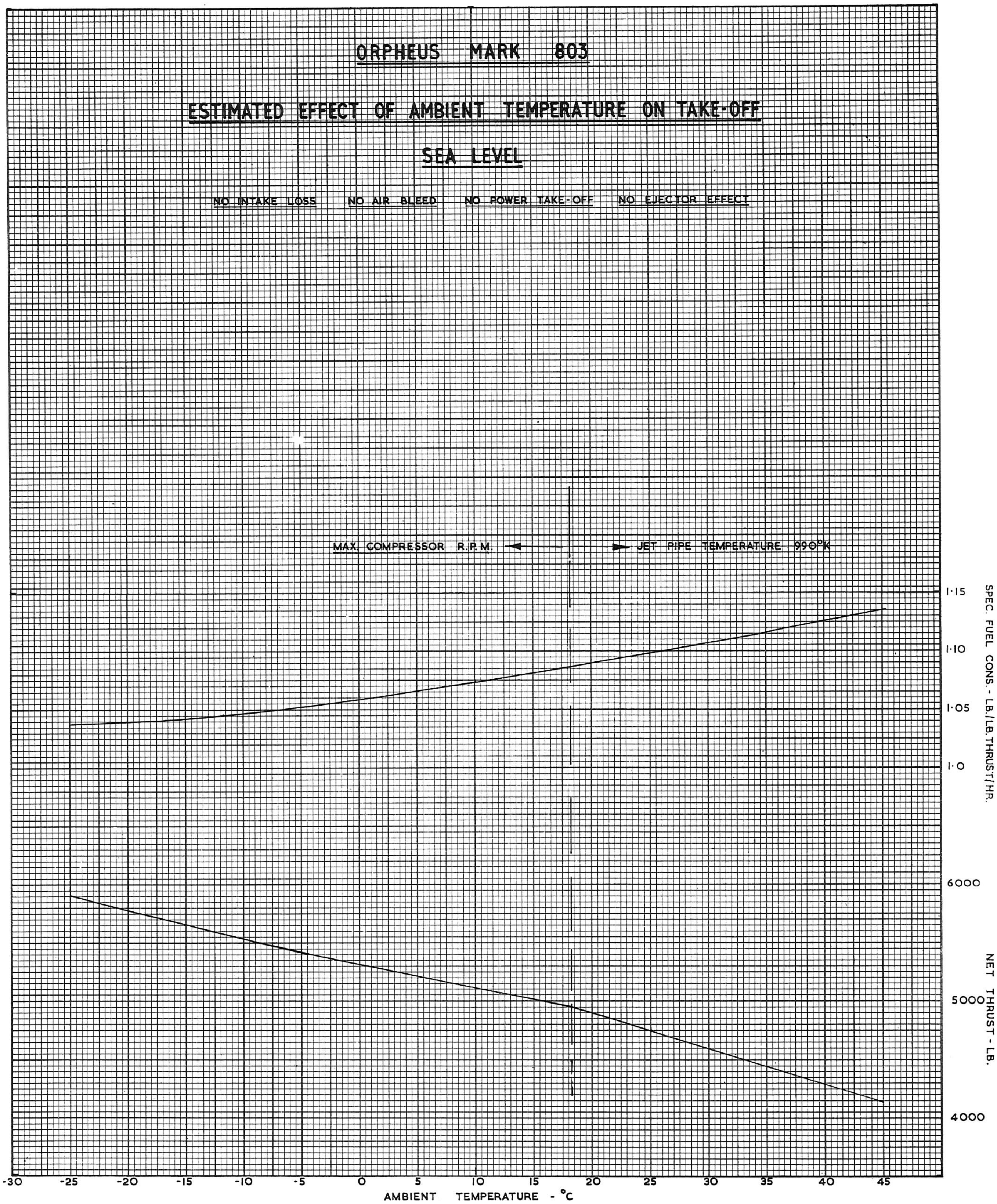
The performance of the Orpheus Mark 803 is given in detail on the following curves for a range of operating conditions. With the exception of B175465, which shows the effect of ambient temperature on the take-off thrust, all these curves are for I.S.A. conditions. If the engine performance is required in other ambient conditions reference should be made to Bristol Siddeley Engines Limited.

The stress boundary shown on the curves gives the limiting conditions at which engine life is unrestricted. Operation at higher Mach Numbers than those given by this boundary is, of course, possible but may lead to a reduction in the total life of some components. Reference should therefore be made to Bristol Siddeley Engines Limited if operation at these higher Mach Numbers is being considered.



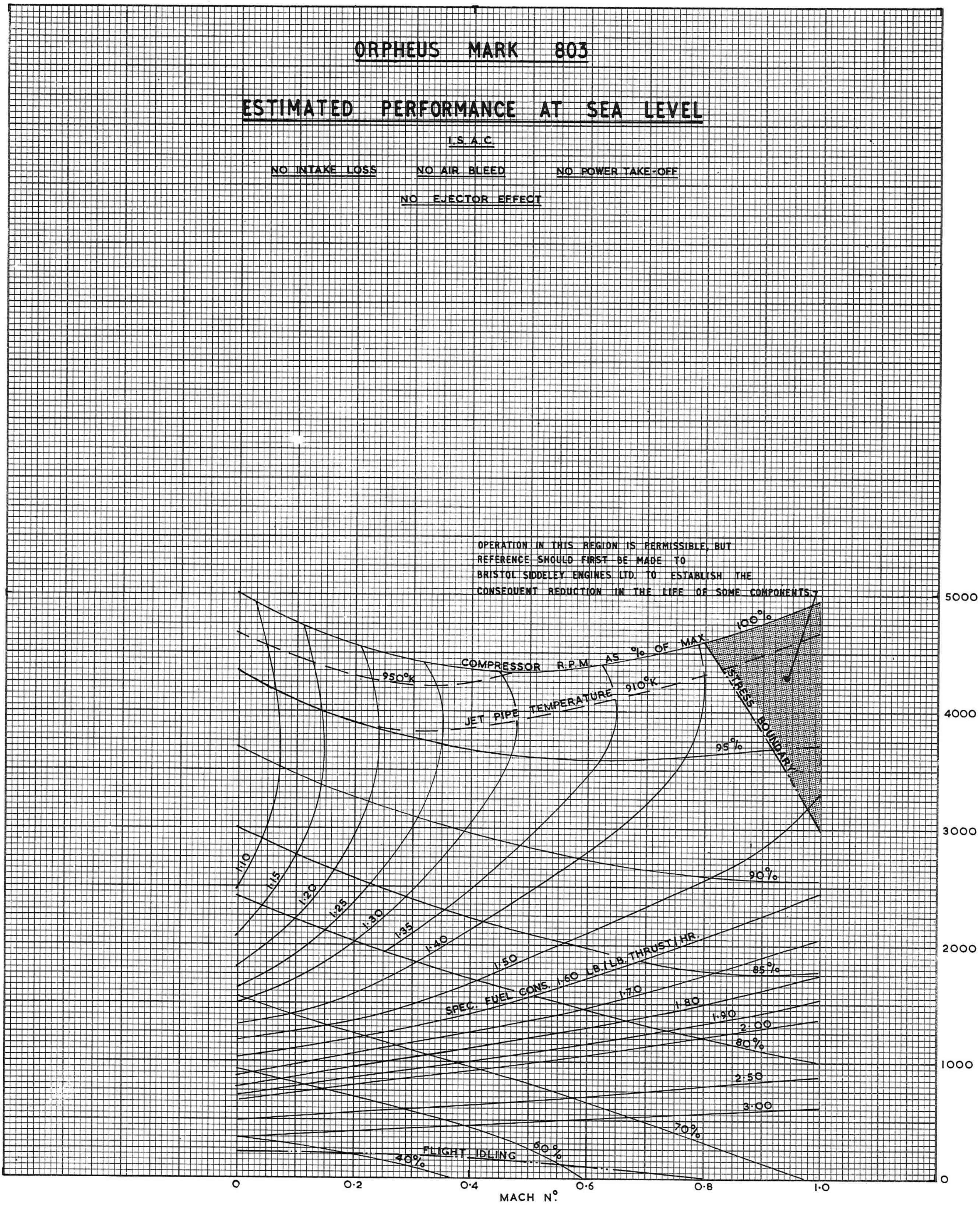

B.175464.A.

CURVE 1



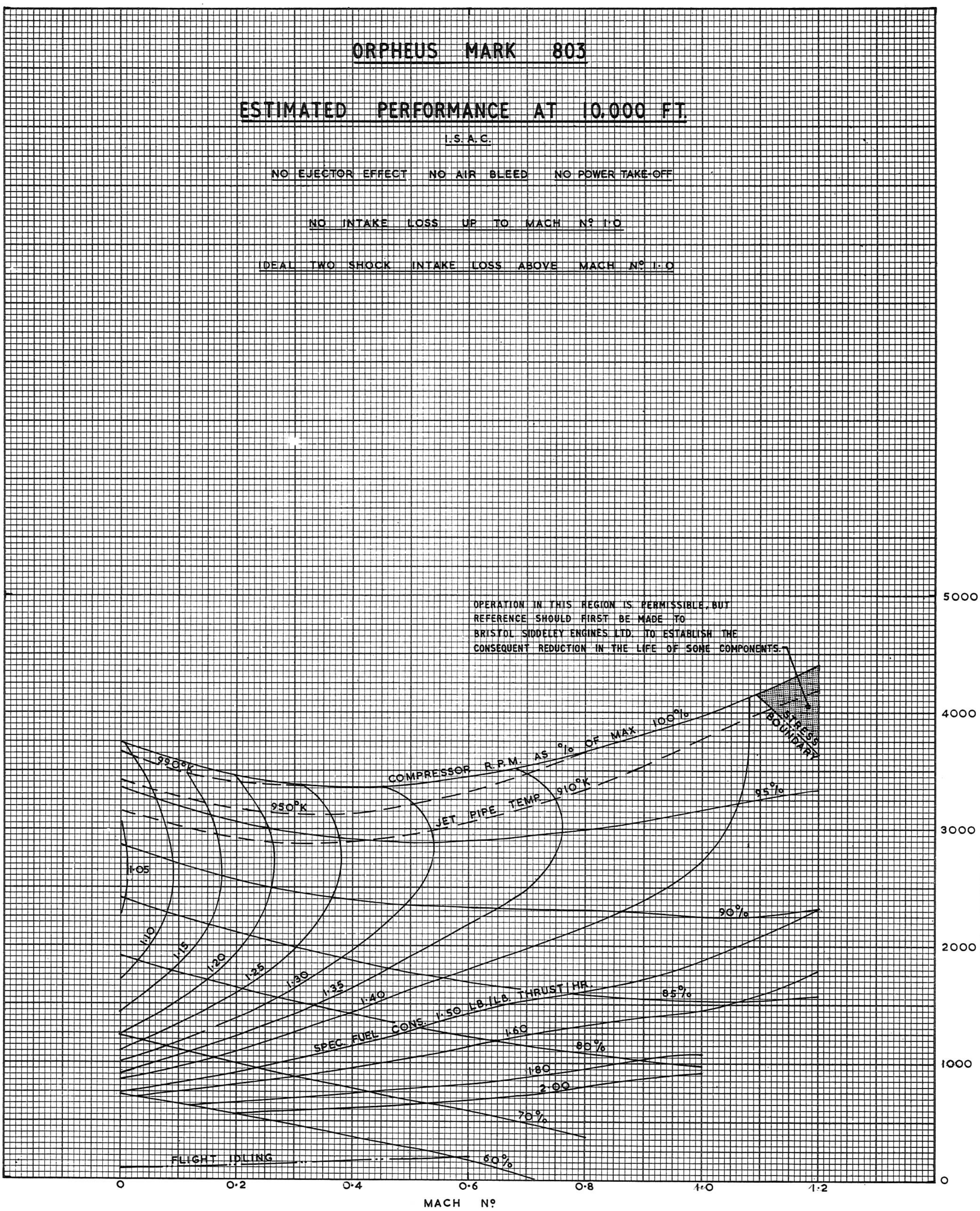

B. 175465. A.

CURVE 2



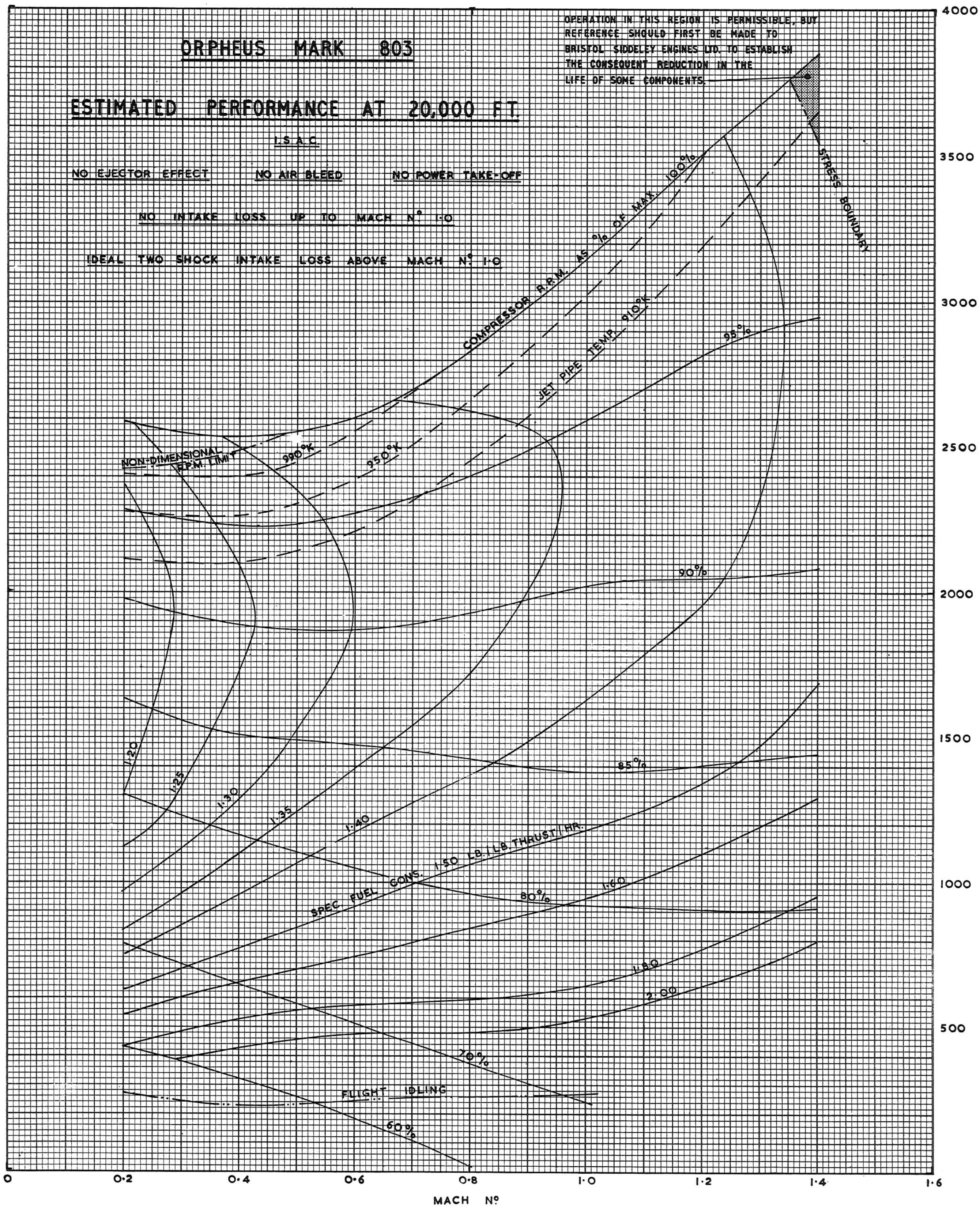

B.175466.D.

CURVE 3

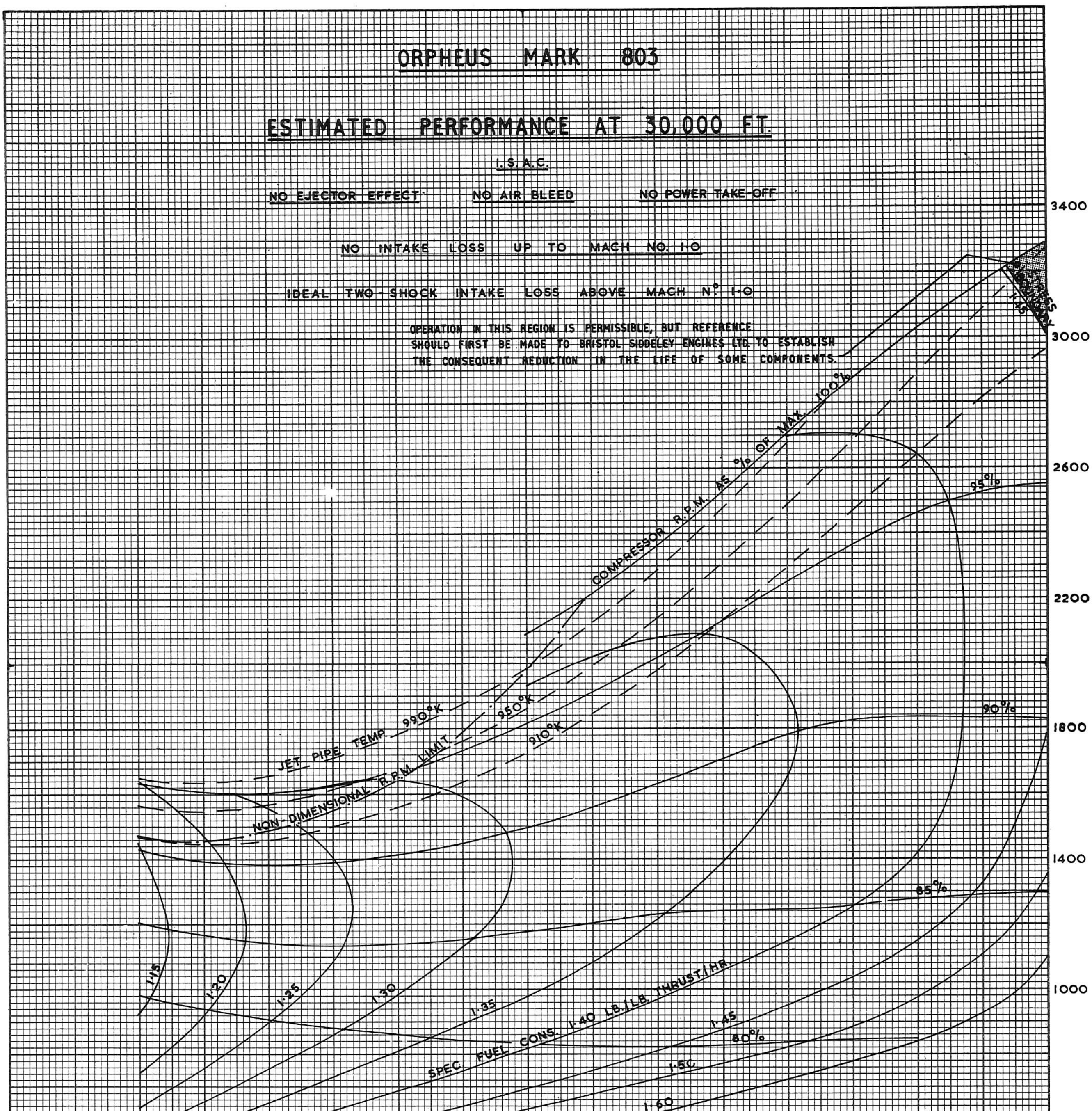



B.175467.C.

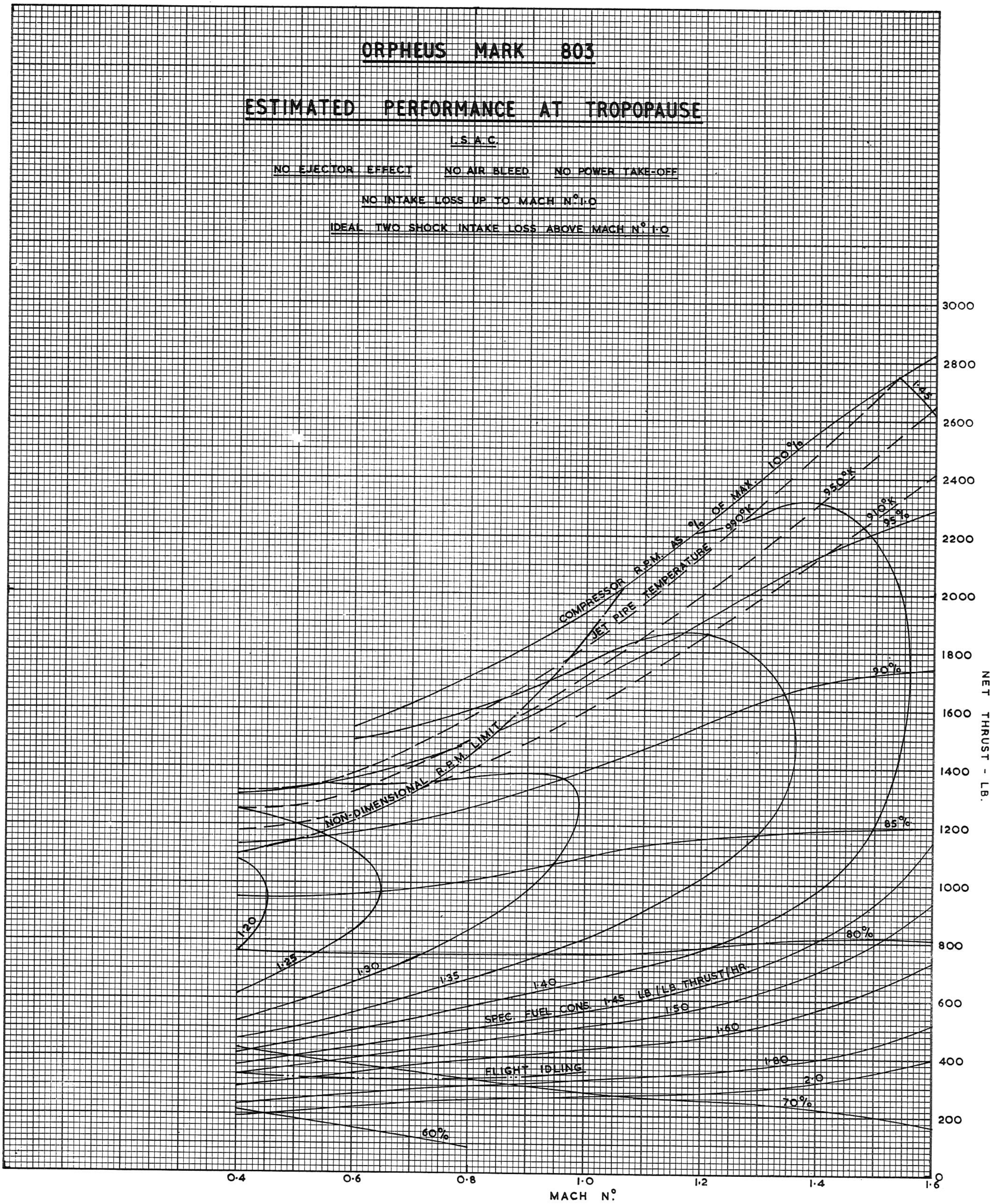
CURVE 4


ORPHEUS MARK 803
ESTIMATED PERFORMANCE AT 20,000 FT.
I.S.A.C.
NO EJECTOR EFFECT
NO AIR BLEED
NO POWER TAKE-OFF
NO INTAKE LOSS UP TO MACH Nº 1·0
IDEAL TWO SHOCK INTAKE LOSS ABOVE MACH Nº 1·0
OPERATION IN THIS REGION IS PERMISSIBLE, BUT REFERENCE SHOULD FIRST BE MADE TO BRISTOL SIDDELEY ENGINES LTD. TO ESTABLISH THE CONSEQUENT REDUCTION IN THE LIFE OF SOME COMPONENTS.
STRESS BOUNDARY
COMPRESSOR R.P.M. AS % OF MAX. 100%
JET PIPE TEMP. 910°K
950°K
990°K
NON-DIMENSIONAL R.P.M. LIMIT
95%
90%
85%
80%
70%
60%
1·20
1·25
1·30
1·35
1·40
SPEC. FUEL CONS. 1·50 LB./LB.THRUST/HR.
1·60
1·80
2·00
FLIGHT IDLING
NET THRUST – LB.
4000
3500
3000
2500
2000
1500
1000
500
0
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
MACH Nº
B.175468.C.

CURVE 5

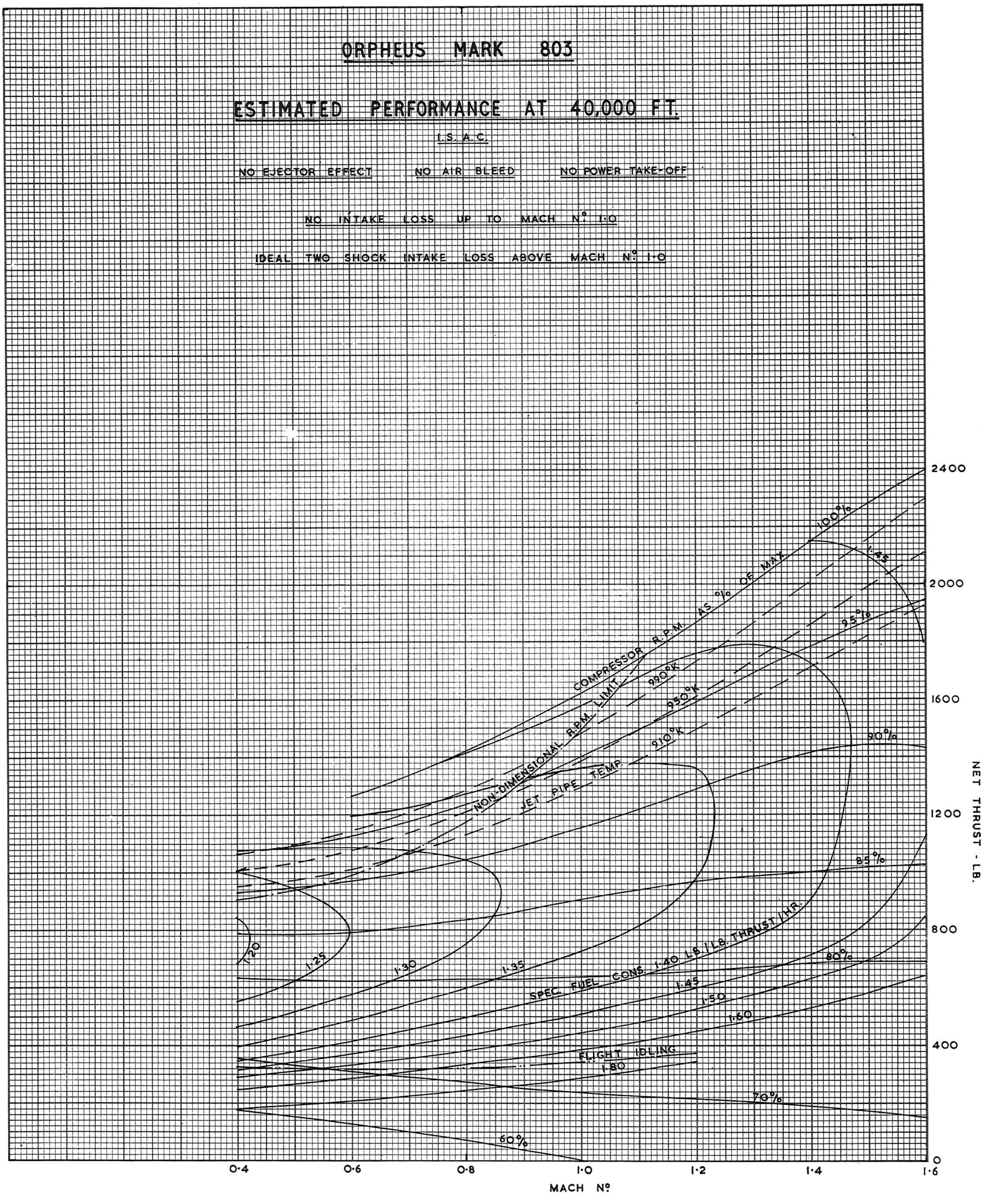

ORPHEUS MARK 803
ESTIMATED PERFORMANCE AT 30,000 FT.
I.S.A.C.
NO EJECTOR EFFECT
NO AIR BLEED
NO POWER TAKE-OFF
NO INTAKE LOSS UP TO MACH NO. 1·0
IDEAL TWO-SHOCK INTAKE LOSS ABOVE MACH Nº 1·0
OPERATION IN THIS REGION IS PERMISSIBLE, BUT REFERENCE SHOULD FIRST BE MADE TO BRISTOL SIDDELEY ENGINES LTD. TO ESTABLISH THE CONSEQUENT REDUCTION IN THE LIFE OF SOME COMPONENTS.
COMPRESSOR R.P.M. AS % OF MAX. 100%
95%
90%
85%
80%
70%
60%
JET PIPE TEMP. 990°K
950°K
910°K
NON-DIMENSIONAL R.P.M. LIMIT
SPEC. FUEL CONS. 1·40 LB./LB. THRUST/HR
1·15
1·20
1·25
1·30
1·35
1·45
1·50
1·60
1·80
2·00
FLIGHT IDLING
NET THRUST - LB.
MACH Nº
B.175469.C.

CURVE 6




B.175470.B.

CURVE 7


ORPHEUS MARK 803
ESTIMATED PERFORMANCE AT 40,000 FT.
I.S.A.C.
NO EJECTOR EFFECT
NO AIR BLEED
NO POWER TAKE-OFF
NO INTAKE LOSS UP TO MACH N° 1·0
IDEAL TWO SHOCK INTAKE LOSS ABOVE MACH N° 1·0
COMPRESSOR R.P.M. AS % OF MAX
100%
95%
90%
85%
80%
70%
60%
NON-DIMENSIONAL R.P.M. LIMIT
JET PIPE TEMP
990°K
950°K
910°K
SPEC. FUEL CONS. 1·40 LB/LB. THRUST/HR.
1·20
1·25
1·30
1·35
1·45
1·50
1·60
1·80
FLIGHT IDLING
NET THRUST - LB.
0
400
800
1200
1600
2000
2400
MACH N°
0·4
0·6
0·8
1·0
1·2
1·4
1·6
B.175471.A.

CURVE 8

# SECTION 2

# DESCRIPTION OF THE ORPHEUS MARK 803 INSTALLATION

## General

The design of the Orpheus engine and its installation has been kept as simple as possible, thus enabling a robust and efficient engine to be produced with an exceptionally low weight. No provision is made for anti-icing or any other features which are not required by lightweight aircraft but high pressure air may be bled from the compressor for aircraft services.

In order to simplify installation the engine is arranged for three point mounting and single lever control, while provision is made for embodying the oil supply system complete with integral oil tank, thus eliminating the necessity of a tank and piping in the airframe.

Orpheus engines can be supplied as complete self contained and interchangeable engine change units to suit particular airframe requirements.

## Engine Mounting

The accompanying diagram shows the three-point method of mounting the engine in the airframe. The engine is supported in the airframe mounting blocks by two trunnions, one on either side of the compressor casing, located near the centre of gravity.

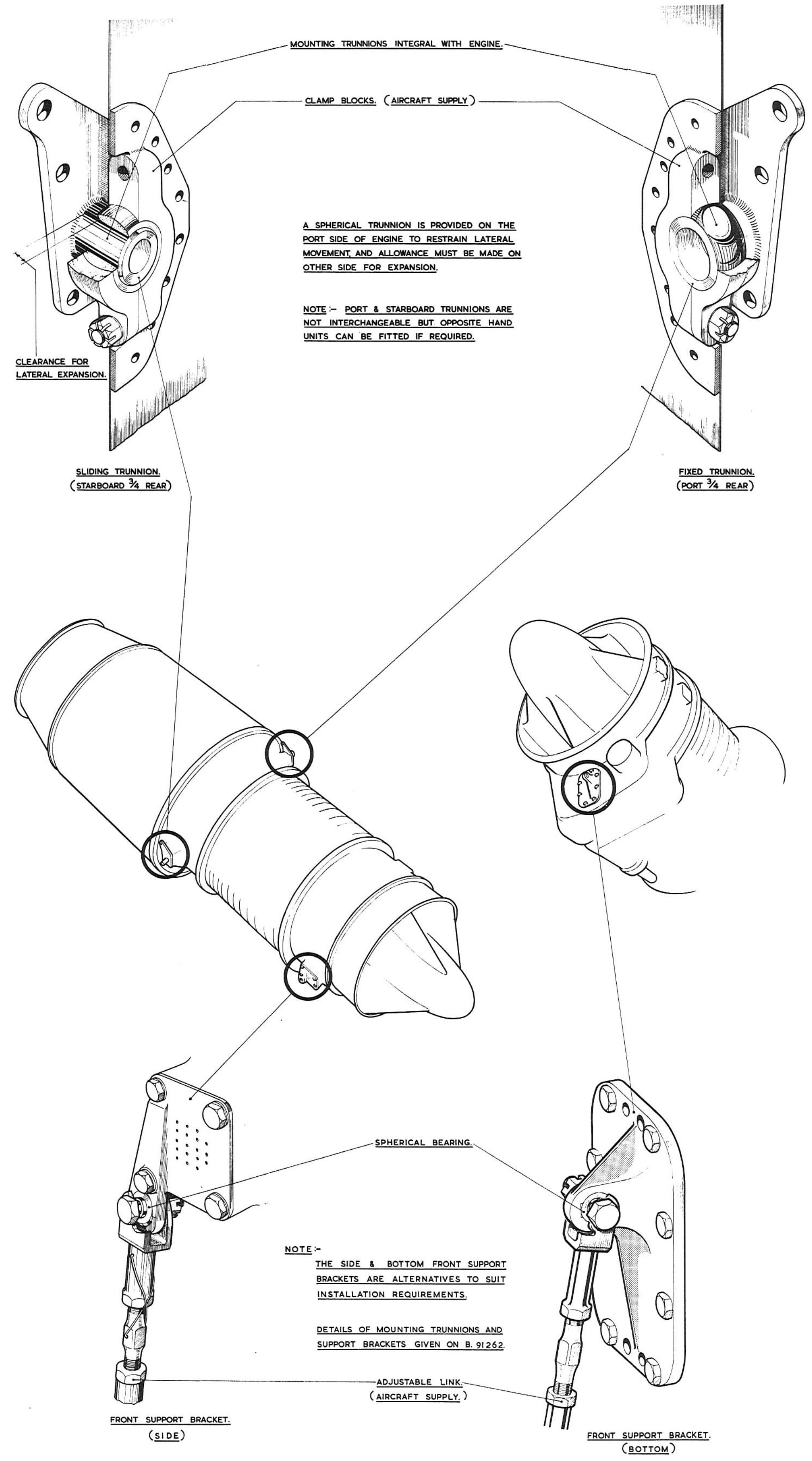
The forward end of the engine is steadied by a single adjustable forked support link bolted to a bracket provided alternatively on the side or underneath the compressor intake casing.

A spherical trunnion is fitted on the port side to provide lateral location for the engine. A parallel trunnion is fitted to the starboard side and the airframe block must be designed to allow for the lateral expansion of the engine. The two trunnions are not interchangeable, but opposite handed units can be fitted as required.

The single front support bracket is fitted with a spherical bearing for the attachment of the support link, which is free to swing to allow for the linear expansion of the engine forward of the trunnions.

## Air Intake

The air intake duct is not directly attached to the engine there-




Engine mounting details

EPD 32

by greatly simplifying the fitting or removal of the engine from the airframe. A synthetic rubber sealing ring is supplied with the engine and the mating duct is designed with a flange having a metal sealing plate which compresses this ring to form an effective seal between engine and duct.

No arrangements are made on the Orpheus for intake anti-icing, but passages in the intake nose fairing support vanes permit the following services:-

| | |
|---|---|
| Upper vertical and starboard vanes | : Gas from breeches to starter |
| Port vane | : Exhaust gas from starter |

Exhaust System

The jet pipe and shroud are supported from the engine and are designed to suit particular installations. The jet pipe is bolted to the turbine annulus flange, and the shroud is of stiff cantilever construction and is attached to the combustion chamber-turbine joint flanges.

A collector tray is provided towards the nozzle end of the jet pipe to drain away any fuel that may be present after a wet start.

Ventilation

The engine installation is divided into two compartments, the layout of the zoning and ventilating air inlets and outlets for a typical installation being shown on the accompanying diagram.

Details of the zones are as follows:-

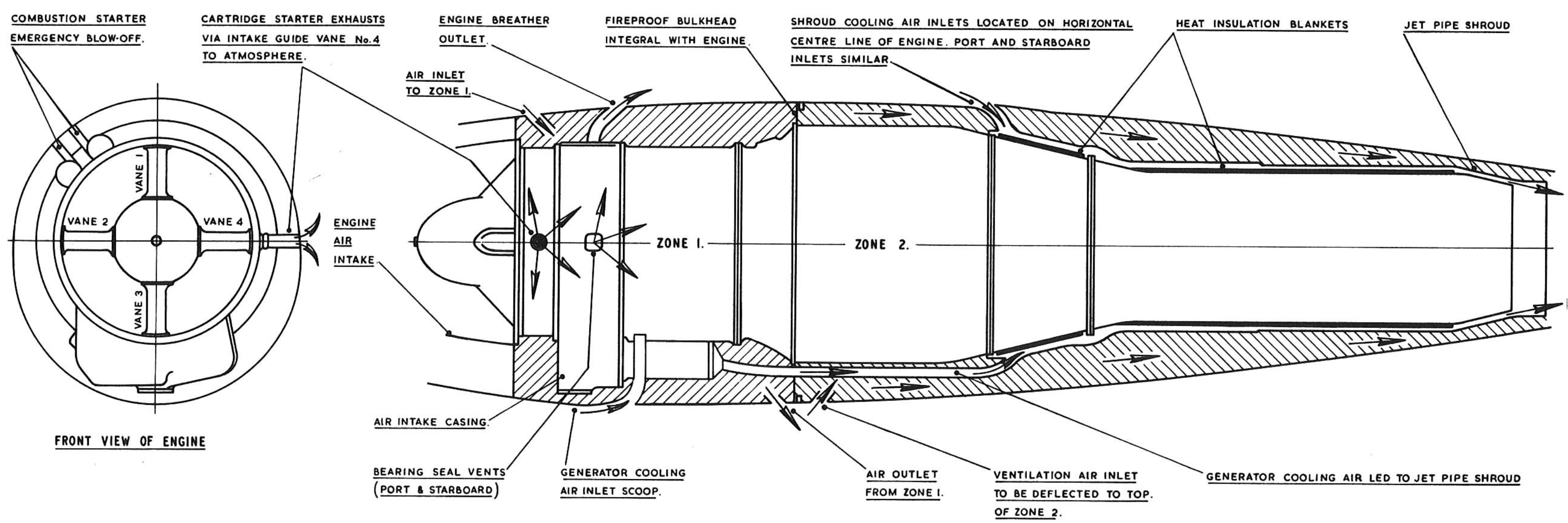
Zone 1

This is the compartment containing the engine fuel system and the electrical generator. It lies between the aircraft bulkhead adjacent to the air intake seal and the bulkhead mounted on the engine.

Zone 2

This zone is aft of the engine bulkhead and includes the combustion chambers, turbine and exhaust system. The zone is ventilated by ram air which is admitted at the forward end and is discharged to atmosphere at the tail end of the jet pipe.

To reduce heat radiation a shroud is fitted around the exhaust cone and jet pipe, thus forming an annulus into which ram air is fed from




NOTE :-

JET PIPE & SHROUD ARE ARRANGED TO GIVE EJECTOR ACTION TO ENSURE GENERATOR & SHROUD COOLING DURING GROUND RUNNING.

NOTE :-

TO COMPLY WITH FIRE PRECAUTIONS REGULATIONS THE FIREWALL IS TO BE EFFECTIVELY SEALED WITH THE AIRFRAME TO FORM ZONES OR COMPARTMENTS TO PREVENT THE PASSAGE OF LIQUIDS, FUMES OR INFLAMMABLE VAPOURS FROM ONE ZONE TO ANOTHER.

EACH ZONE IS TO BE VENTILATED SO THAT ANY INFLAMMABLE VAPOUR/AIR MIXTURE IS RAPIDLY DISPERSED TO ATMOSPHERE.

SEE DIAGRAM B.135045. FOR ALTERNATIVE VENTILATION SYSTEM.

FIRE EXTINGUISHER EQUIPMENT AIRCRAFT SUPPLY.

## ORPHEUS ENGINE CHANGE UNIT
## DIAGRAMMATIC LAYOUT OF TYPICAL ENGINE VENTILATION

B.135012.A.

an external scoop.

In order to ensure effective cooling of the shroud and generator during ground running the jet pipe and shroud are designed to give an ejector action.

Engine Air Supplies

The high air mass flows associated with gas turbine engines have led the aircraft designer to look to the engine for the supply of air at high pressure and/or high temperature which would otherwise have to be obtained from additional equipment. In this way a valuable weight saving and simplification of installation equipment is effected, especially if the particular service is for intermittent use only.

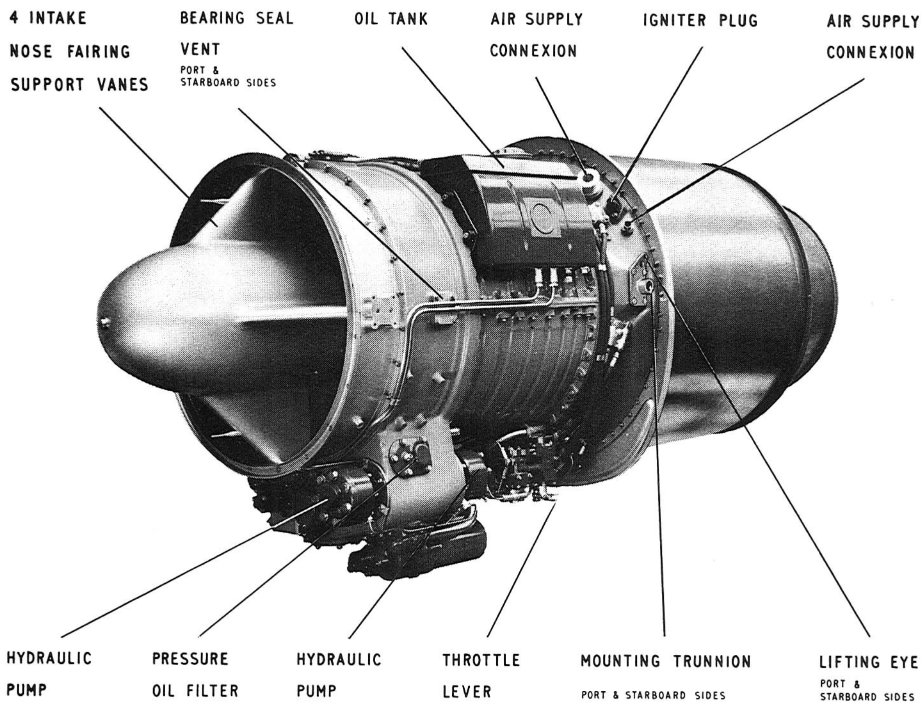
On the Orpheus arrangements have been made for high pressure air to be bled from the compressor delivery casing for aircraft services such as cabin pressurization, fuel tank pressurization, windscreen anti-icing and pressure suits.

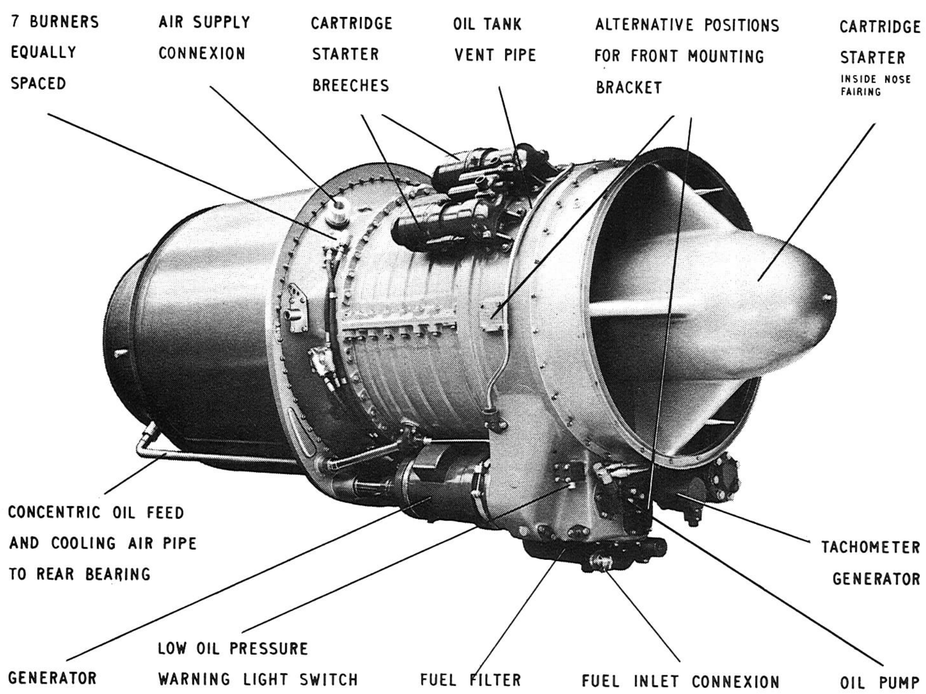
Oil System

The oil system is completely self-contained and consists of the following main elements :

(i) Oil tank - which is mounted on the port side of the compressor casing and is vented to the engine air intake casing. It has a total capacity of 15.5 pints and contains 13.75 pints of oil (usable capacity 5.5 pints in level flight). A filler tube, embodying a filter, and a graduated dip-stick are provided on the tank and a debris guard is built into the tank to prevent the entry of foreign matter when the filter assembly is removed. An increased capacity oil tank with a total capacity of 18.5 pints and containing 16.5 pints of oil (usable capacity 7 pints in level flight) is available to special order. The design of the oil suction pipe and tank vent pipe inside the tank allows for all aerobatic manouevres without loss of oil.

(ii) Main Pressure Pump - which is engine driven and mounted in the housing beneath the air intake casing. It incorporates a relief valve set to give a normal working pressure of 50 lb/sq.in.




Orpheus 800 Series showing NATO type accessories

B. 131763. A.

(iii) Metering Pump - which meters definite quantities of oil to the engine accessory drives and the rotor rear bearing.

(iv) Two Main Scavenge Pumps - one of which scavenges the oil from the rotor thrust bearings whilst the other scavenges oil from the accessory drives. Both these scavenge pumps and the main pressure pump form a single unit. The small quantity of drain oil from the rear bearing is not scavenged, but passes via the exhaust cone to the jet pipe.

(v) Auxiliary Scavenge Pump - which ensures complete scavenging of the oil from the rotor thrust bearings during certain aerobatic manoeuvres.

(vi) Filters - (a) A screwthread type which is fitted in the oil feed line to the rotor thrust bearings.
(b) a felt type in the line before the metering pump.
(c) two scavenge filters, one for each main scavenge pump.

<u>Engine Starter System</u>

The Orpheus 803 engine employs a gas-driven turbo starter, which together with a pair of single-shot breech units forms a self contained system.

The starter is located on the front of the engine and is totally enclosed in the air intake nose fairing. The starter unit is a single stage turbine driven by the combustion of the solid propellant charge in one of the breeches, which are connected to the starter by heat resisting alloy pipes passing through the starboard and upper-vertical intake nose fairing support vanes. Each breech is fitted with a poppet type relief valve, designed to open when gas pressure in the breech exceeds 1600 lb/sq.in., thus relieving excess pressure to atmosphere through an exhaust port in the side of the housing. The exhaust gases from the starter turbine are passed to atmosphere via a duct in the port intake guide vane.

The starter has a ratchet and pawl engaging mechanism. With the engine at rest the starter is engaged and disengagement takes place when the desired compressor speed has been reached following light-up of the engine. A special feature of this starter is the swinging turbine wheel which is moved into the gas stream by torque reaction. This provides a smooth engagement and acts also as a safety device to prevent overspeeding in the event of a fractured quill shaft.

The cartridges are fired electrically and are controlled by selector and time switches. The selector switch is operated automatically by the starter button and its functions are to ensure that each cartridge is fired alternately, and to earth the circuit to the cartridge not selected.

The time switch is fitted to prevent the second cartridge being fired until 30 seconds have elapsed from the firing of the first cartridge.

In connection with engine starting two high energy ignition units are required for each engine. These are connected to the igniter plugs and may be located in the aircraft or nacelle to suit the convenience of the particular installation.

## Engine Driven Accessories

Power for the engine driven accessories is taken from the front of the compressor. The main drive shaft is in the vertical plane and passes through one of the intake nose fairing support vanes to the underside of the engine where separate drives are provided in a housing integral with the air intake casing for the engine driven oil and fuel pumps, tachometer generator and aircraft services.

The drives provided for an electrical generator and a hydraulic pump are suitable for the following :-

(a) Generator

(i) Orpheus Mark 80302 Engine Change Unit

Labinal 4 kW type with a rated output of 150 amperes at 28 volts or alternatively a Labinal 6 kW type with a rated output of 210 amperes at 28 volts may be fitted if a modified cooling system is incorporated

(ii) Orpheus Mark 803D-11 Engine Change Unit

Labinal 6 kW type with a rated output of 210 amperes at 28 volts.

Cooling of the generators is obtained by air which enters an external scoop and is ducted to the generator casing. After circulating around the generator the cooling air is led via an exit duct to exhaust into the jet pipe shroud. To ensure adequate generator cooling during ground running the jet pipe and shroud are designed so that the efflux of the exhaust will create an air flow through the shroud and generator air duct by ejector action.

(b) Hydraulic Pump

Orpheus Mark 80302 and 803D-11 Engine Change Units

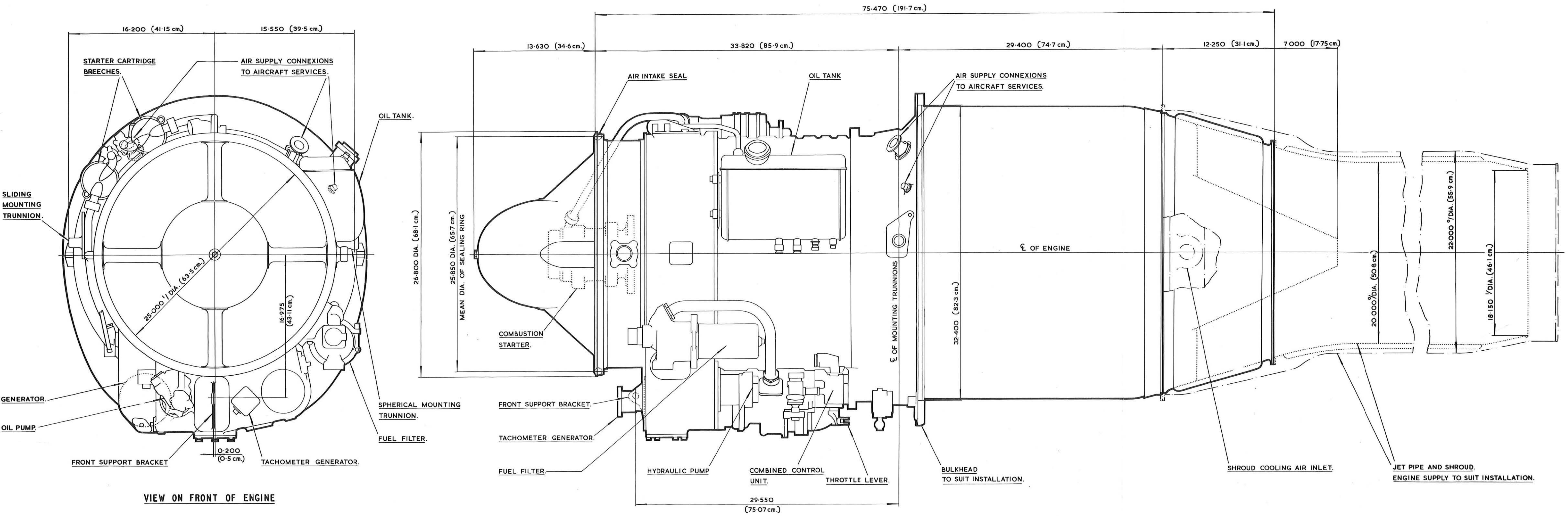
(i) A French Messier type 60 auto-regulation pump rated at 4.5 gals/min. at 3500 lb/sq.in. (20,5 litres/min. at 246 kg/sq.cm)

(ii) A Lockheed Mark 9 hydraulic pump rated at 3.25 gals/min. at 3500 lb/sq.in. (14,8 litres/min. at 246 kg/sq.cm)
Provision is made for fitting a second pump of either type, an associated internal drive modification being required.

## Fire Precautions

A fireproof bulkhead is provided on the engine at the plane of the combustion chamber entry. By sealing with the airframe, this bulkhead separates the main fuel system components from the rest of the engine.

Additional fire protection is provided on the Orpheus Mark 803D-11 engine change unit by Graviner Firewire detectors which form part of a complete fire-extinguishing system. The engine installation includes two separate fire-wire detector systems consisting of flexible fire-sensing elements disposed around the engine and jet pipe shroud respectively and connected to termination fittings mounted on the air intake casing and engine bulkhead. The fire-sensing elements consist of stainless steel capillaries each containing a central wire electrode separated from the wall of the capillary by a heat sensitive material, the electrical resistance of which varies with temperature. Excessive rise in temperature in the region of either the engine or jet pipe shroud produces a warning signal in the cockpit.




Bristol Siddeley Orpheus Mark 803 Engine Change Unit

B.175463.

# SECTION 3

## DEVELOPMENT OF THE ORPHEUS ENGINE

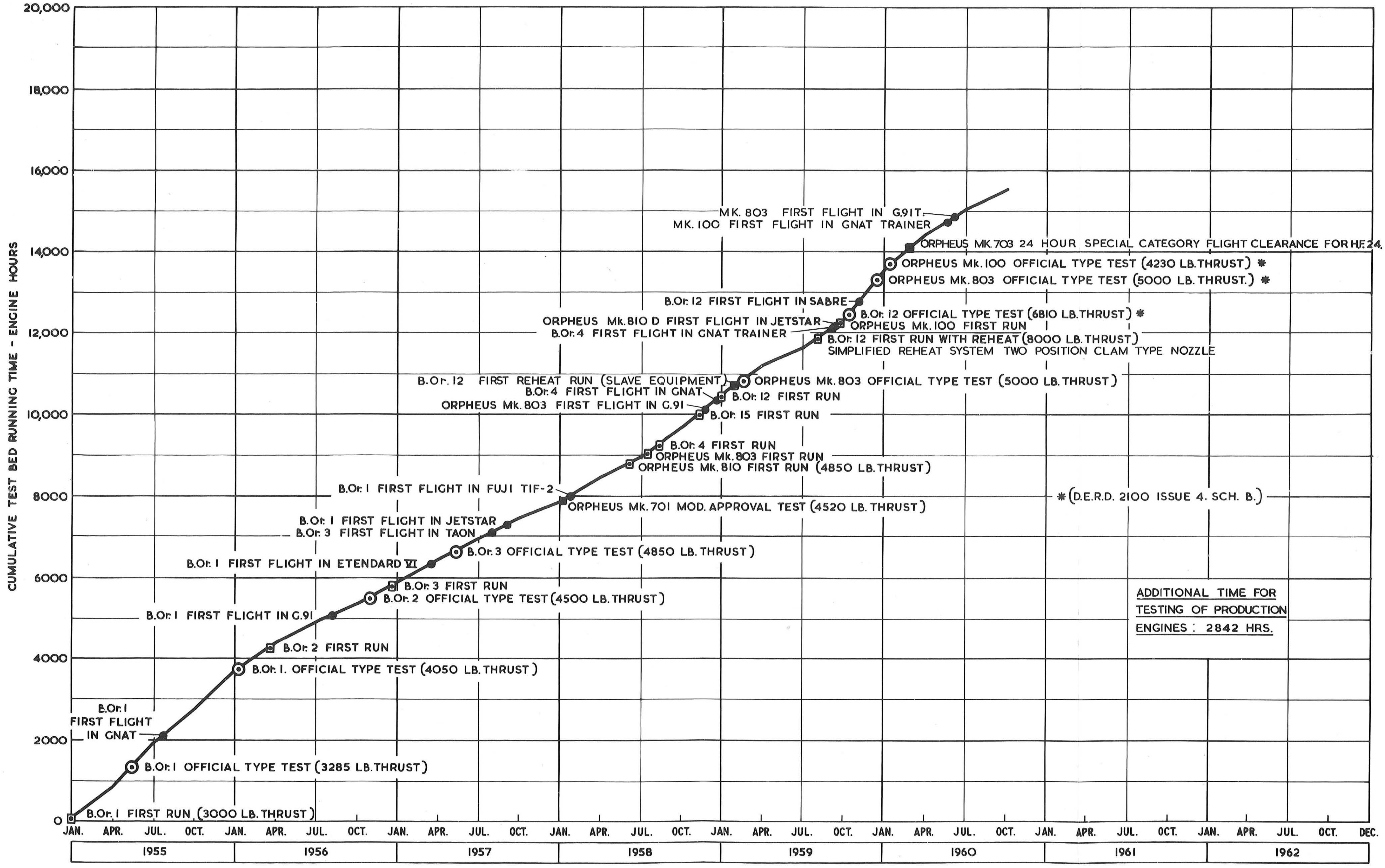
### Introduction

The Orpheus, in common with other successful aircraft engines, is the subject of a clearly defined development programme. The aim of this programme is not only the proving of the engine's mechanical reliability but also the establishment of performance improvements to meet the changing requirements of aircraft manufacturers and operators.

The programme is therefore characterized by the emergence of a family of engines differing either in accessories or in major components according to the requirements of a particular installation. The members of this family which have so far entered production are the Mark 701 for the Folland Gnat, the Marks 801, 803 and 803 D-11 for the Fiat G91 and the Mark 805 for the Fuji T1F-2. Production is also planned for the Mark 100 for the Folland Gnat Trainer and the Mark 703 for the Hindustan HF.24.

The first production version of the Orpheus Mark 800 series was the Mark 801. As will be described later in this Section the fundamental difference between this engine and the Orpheus Mark 701 for the Gnat lies in the design of the compressor blading. In the case of the Orpheus Mark 701 the engine employs a Phase 1 compressor which is more suited to the Gnat as this aircraft was primarily designed as a high altitude interceptor fighter. The N.A.T.O. lightweight fighters on the other hand were originally intended for ground-attack operations where the majority of the flying would be at low altitude. The Orpheus Mark 801 engine used in these aircraft therefore uses a Phase 2 compressor which is particularly suitable for this type of operation.

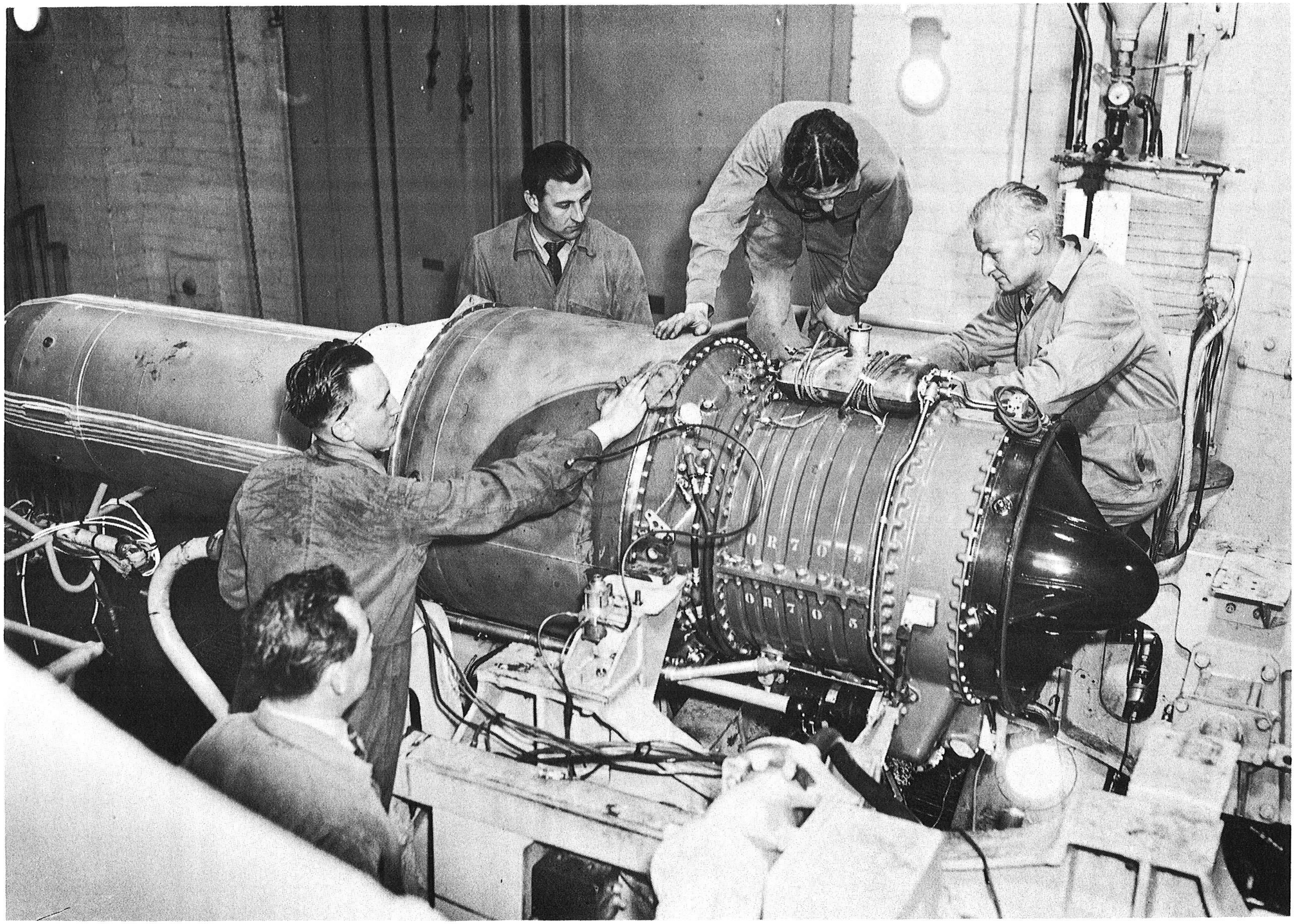
It has however now been decided to extend the function of the N.A.T.O. aircraft to include operation at high altitude and the Orpheus Mark 803 has therefore been introduced into production in replacement of the Mark 801.




# BRISTOL SIDDELEY ORPHEUS - ALL VERSIONS DEVELOPMENT TEST BED RUNNING

OCT.
1960

B.195829.C.




An Orpheus engine on the test bed

The Orpheus Mark 803 is an improved version of the Mark 801 and at sea level develops 5,000 lb. thrust instead of 4,850 lb. The engine reverts to the original Phase 1 compressor which, together with refinements to the control system, permits surge-free operation at high altitude, and also employs a cambered vane exhaust annulus to reduce the specific fuel consumption.

A further difference between the Mark 701 and the Mark 800 series engines is that the Mark 701 is fitted with a Lucas 'B' size fuel pump which limits the thrust at low altitude (the nominal sea level static thrust is 4,520 lb. although the average achieved thrust on the test bed is rather better than this - 4,725 lb.), whereas in the Mark 800 series a larger gearcase is fitted which can accommodate a Lucas 'D' size pump and allows the engine to develop the full thrust of 4,850 lb. at sea level in the case of the Mark 801 and 5,000 lb. in the case of the Mark 803.

Bench testing of the Mark 803 commenced in July 1958 and the engine completed its official 150-hour Type Test in February 1959. Flight testing of the engine began in November 1958.

## Early Orpheus Development

The first manufacturing instructions for development running of Orpheus engines were issued in January 1954 and all detail drawings had been cleared by the end of June 1954. The first engine ran on December 17th 1954, which by any standard is a remarkable achievement and testimony to the energy with which the design and manufacture of this engine was pursued at the Bristol factory.

In order to enable development to proceed rapidly and to permit flight experience to be obtained at the earliest possible moment, it was decided at the outset to divide the programme into two definite stages. In the first of these the thrust was restricted initially to 3,285 lb. for the early flight testing of the Gnat aircraft in the Summer of 1955 and in the second stage the thrust was increased firstly to 4,050 lb. for the prototype aircraft and then to 4,520 lb. and 4,850 lb. for production Gnat and N.A.T.O. fighters respectively.

In the implementation of this programme, as mentioned earlier, the engine manufacturing instructions were issued to the Shops during the first six months of 1954. Various test rigs were made and operated from February 1954 onwards and during the year wooden mock-ups of the engine were delivered to Folland for the Gnat installation and to Fiat and Breguet for the N.A.T.O. lightweight fighters. After the first engine run on December 17th, 1954, which was completely successful, development was promptly carried out under the Stage 1 Type Test conditions of 3,285 lb. thrust. The second engine was available for this development work in January 1955 and by April 27th five engines had been built and run. In the six months following the first run nearly 2,000 hours were completed on the test bed and the behaviour of the engine was in every way satisfactory. No major problems whatever were encountered, and in May 1955 an engine was able to carry out an official 150-hour Type Test. The performance of the engine was highly satisfactory and perhaps most outstanding of all was the fact that the weight was less than the design estimate. Even at 3,285 lb. thrust, the Orpheus has a higher thrust-weight ratio than any other fully type tested engine in the world.

The first flight of the Orpheus took place in July 1955 in the Folland Gnat aircraft at the thrust rating of 3,285 lb. and in this form was demonstrated at the S.B.A.C. Exhibition in September 1955. The flight testing of this Orpheus engine continued under a wide variety of conditions and demonstrated throughout the soundness of the design concept and its detailed execution.

## Official Type Test at 4,050 lb Thrust

Development running continued at higher ratings, and in January 1956 the Orpheus completed another official Type Test - this time at 4,050 lb. thrust. The test was completed almost without incident. The fact that the engine was on the test-bed for only 10 days, during which a total running time of 166 hours was completed is evidence of the trouble-free nature of the Type Test. The strip condition of the engine was excellent, particularly the combined flame tubes and turbine stators, which had then completed 670 hours running.

Engine ratings from the initial corrected curve were:-

| Condition | R.P.M. | Thrust lb. | Jet Pipe Temperature °C. | Turbine Entry Temperature °K |
|---|---|---|---|---|
| Take-off | 9400 | 4050 | 658 | 1111 |
| Intermediate | 9100 | 3610 | 616 | 1061 |
| Cruise | 8750 | 3110 | 571 | 1006 |

The Type Test was actually performed on the same engine which had already completed the earlier Type Test at the lower rating as well as a considerable amount of miscellaneous running.

## Test with Reduced Stator Cooling

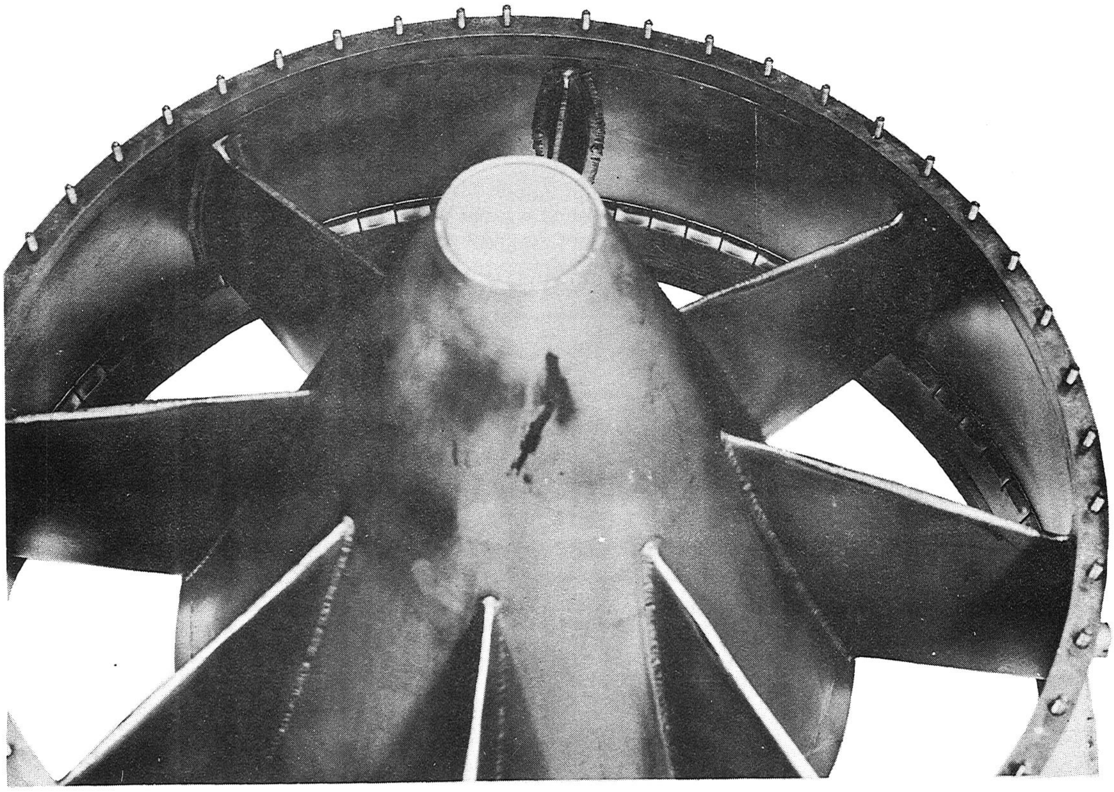
A 150-hour run to Type Test conditions at a take-off rating of 4,500 lb. was completed on an engine on which the cooling air through the turbine stators was restricted to about 10% of the amount used on the standard cooled-stator engine. Calibration tests showed that a very useful reduction in specific fuel consumption resulted whilst no ill effect on the turbine stators was detected. This reduction in stator cooling air was therefore standardized on all engines.

## Tests on the Orpheus B.Or.2 with Augmented Fuel Flow

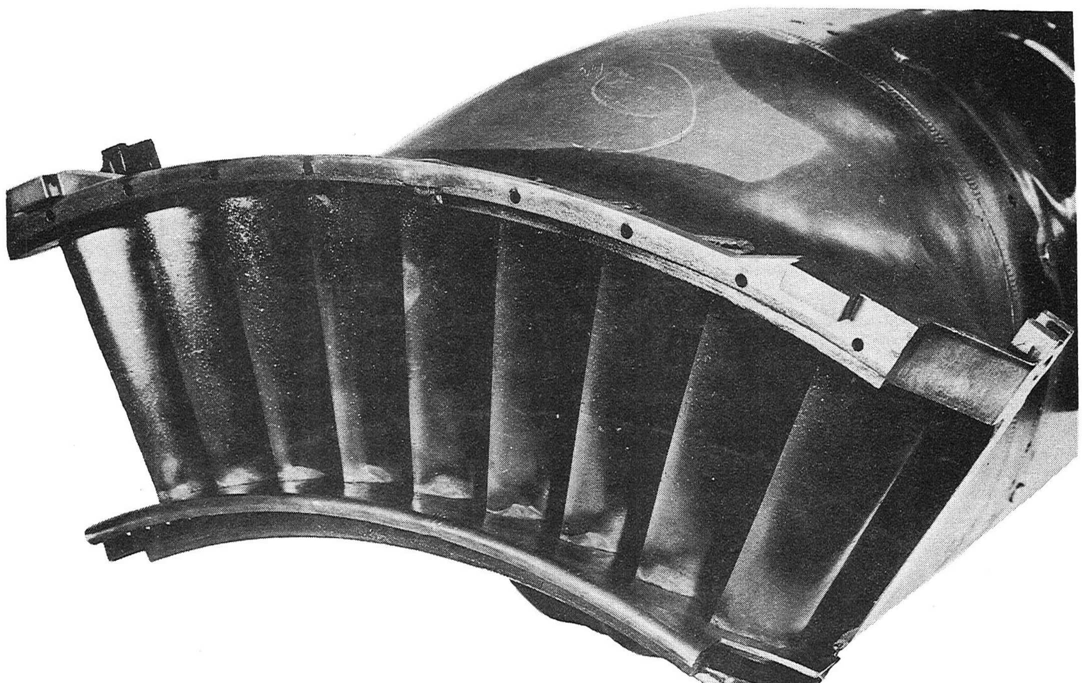
The Orpheus B.Or.2 (this is the development nomenclature of the Mark 701) as designed for the Folland Gnat, has a Lucas 'B' size fuel pump and the accessory gear casing was tailored accordingly. This pump limits the nominal engine take-off output to 4,520 lb. thrust although the average thrust of production engines is 4,725 lb. At altitude, of course, the thrust is not limited by the size of the fuel pump but is subject to the normal r.p.m. and jet pipe temperature limits.

Unlike the B.Or.2, the Orpheus B.Or.3 (development nomenclature of the Mark 801) was designed to be fitted with a Lucas 'D' size pump which would permit a take-off rating of 4,850 lb. thrust at sea-level. Orpheus B.Or.2 engines modified to use two 'B' size pumps were therefore used to clear the r.p.m. and temperature limits equivalent to a 4,850 lb. thrust take-off rating.

Components of Orpheus engine after the Official
150 hour Type Test at 4050 lb. thrust

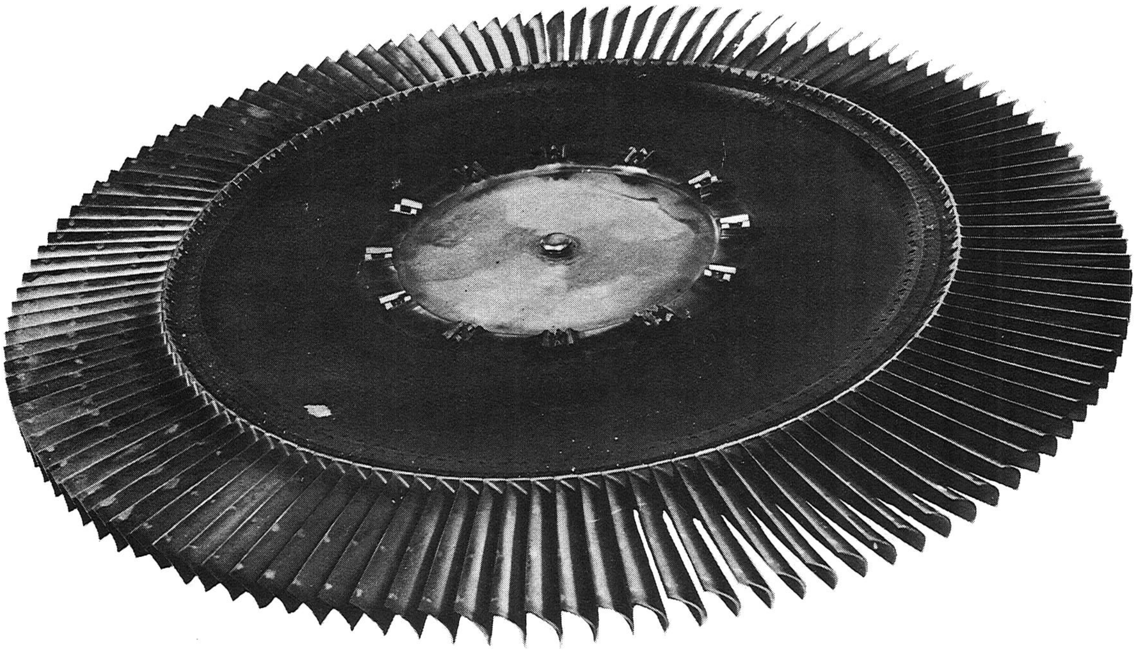


Exhaust cone.

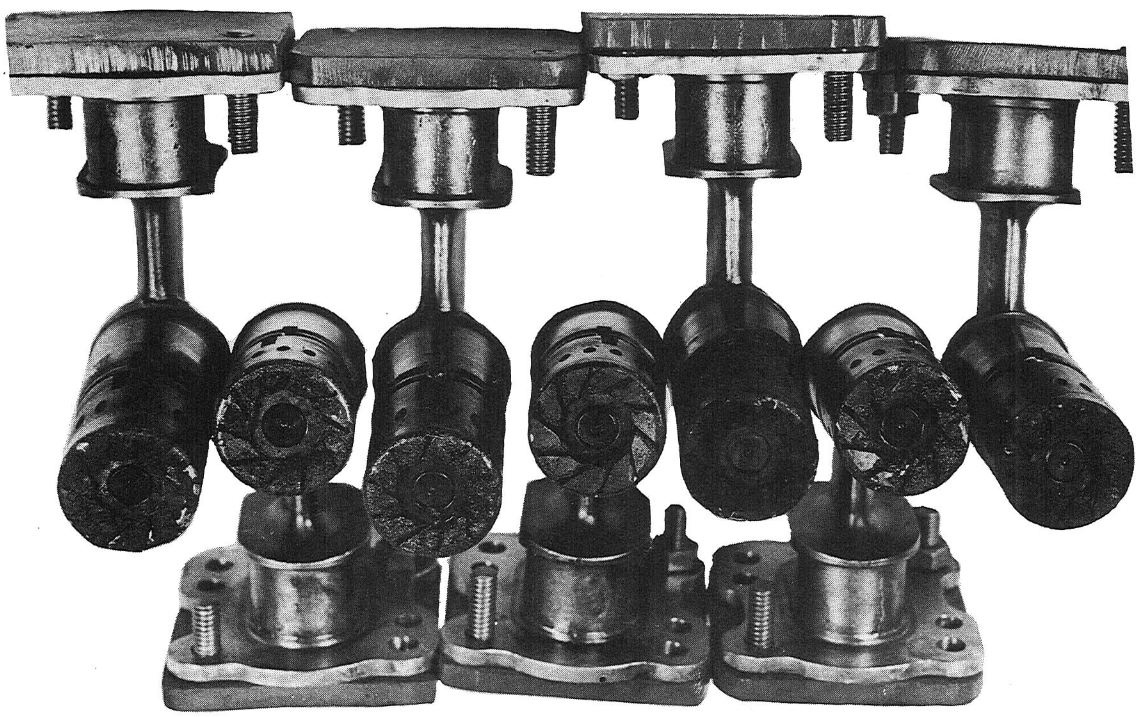


Combined Combustion Chamber and turbine stator blades

Components of Orpheus engine after the Official
150 hour Type Test at 4050 lb. thrust



Turbine wheel showing general good condition
with light carbon deposit on the rear face.



Burners showing general good condition and light
carbon deposits.

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The mechanical condition of the engine at these higher thrusts was outstanding, and after only 70 hours running as a type, the B.Or.2 with augmented fuel flow completed an unofficial 150-hour Type Test at the following rating:-

| Condition | R.P.M. | Thrust lb. | Jet Pipe Temperature °C. | Turbine Entry Temperature °K. |
|---|---|---|---|---|
| | | Initial corrected calibration curve | | |
| Take-off | 9900 | 4900 | 712 | 1157 |
| Intermediate | 9700 | 4560 | 665 | 1107 |
| Max. Continuous | 9450 | 4150 | 620 | 1057 |
| | | Mean observed figures throughout test | | |
| Take-off | 9900 | 4782 | 711 | 1160 |
| Intermediate | 9721 | 4466 | 672 | 1115 |
| Max. Continuous | 9480 | 4107 | 629 | 1062 |

Official Type Test of B.Or.2 Engine

In October 1956 an Orpheus B.Or.2 engine fitted with the twin fuel pump arrangement successfully completed an official 150-hour Type Test at the B.Or.3 rating of 4,850 lb. thrust. In order to obtain approval of the B.Or.2 fuel system with only one Lucas 'B' size pump a further 150-hour test was run, the full take-off speed being obtained by using a larger final nozzle on the jet pipe.

The general strip condition of the engine was highly satisfactory. All compressor and turbine blades were free from cracks, and the combined combustion chamber flame tubes and turbine stators were in excellent condition and entirely free from distortion. There were three minor cracks in the entry guide support ring and one of the exit guide blades inner fixing plates was cracked. Slight bowing of the exit guide blades themselves due to gas loading had occurred, but a new material of greatly improved strength at high temperature has now been introduced to overcome this.

The initial performance calibration of the engine is summarized in the following tabulation. It will be seen that because of the low ambient temperature during the period of the test the actual thrust obtained was over 5,200 lb.

| Condition | R.P.M. | Thrust lb. | Jet Pipe Temperature °C. | Turbine Entry Temperature °K. |
|---|---|---|---|---|
| | Initial corrected calibration curve | | | |
| Take-off | 9900 | 4880 | 693 | 1136 |
| Intermediate | 9700 | 4550 | 654 | 1090 |
| Max. Continuous | 9450 | 4160 | 615 | 1053 |
| | Mean observed figures throughout test | | | |
| Take-off | 9900 | 5221 | 713 | 1152 |
| Intermediate | 9702 | 4784 | 675 | 1106 |
| Max. Continuous | 9465 | 4451 | 630 | 1047 |

Declared Type Test at 4,850 lb. Thrust

The official Type Approval Test of the Orpheus B.Or.3 engine at a declared thrust of 4,850 lb. was completed on the 14th May 1957 within 9 days of its commencement, in a total running time of 178 hrs. 6 mins. Since it it scarcely possible to complete a Type Test in a shorter elapsed time, this shows how little trouble could have been encountered, and emphasises the complete reliability of the engine. In March 1955 this test had been scheduled for completion by the 1st June 1957 and the target date was therefore achieved.

The initial calibration curve corrected to I.S.A. conditions gave the following figures:-

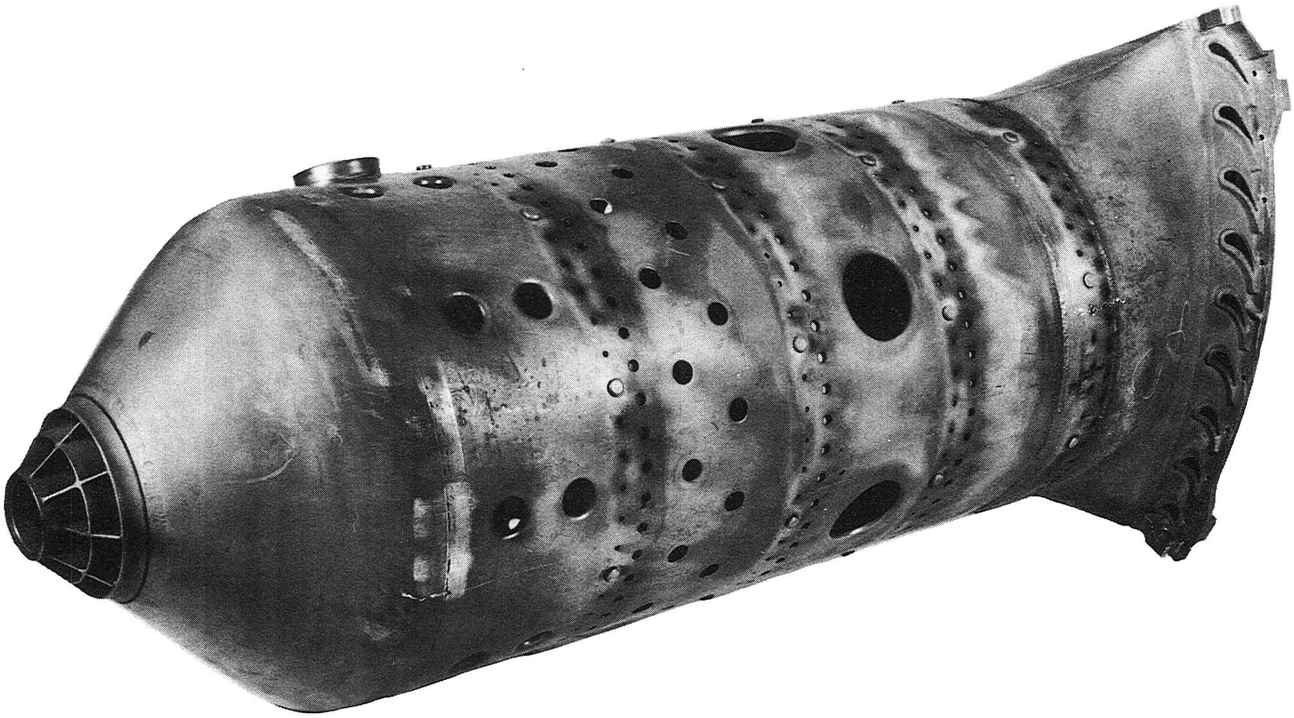
| Condition | R.P.M. | Thrust lb. | Jet Pipe Temperature °C. | Turbine Entry Temperature °K. |
|---|---|---|---|---|
| Take-off | 9900 | 4850 | 703 | 1130 |
| Intermediate | 9700 | 4530 | 654 | 1083 |
| Max. Continuous | 9450 | 4130 | 614 | 1035 |

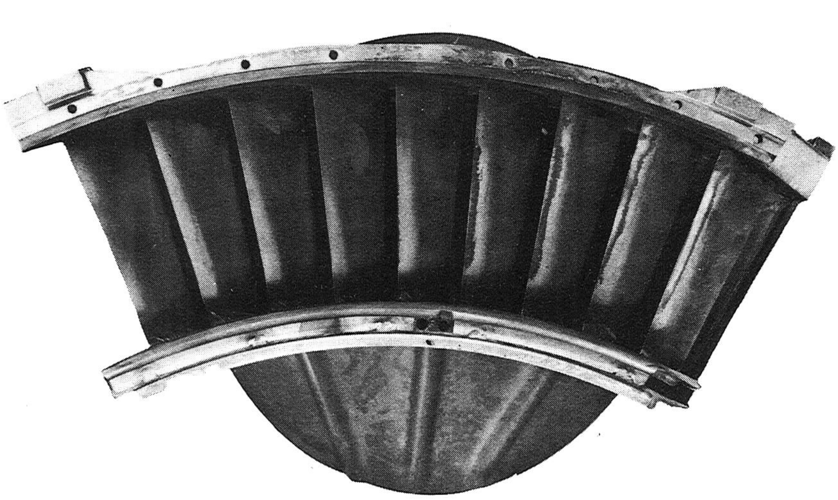
Further details of the initial calibration are given in the accompanying graph. The strip condition of the engine was good, as may be seen from the photographs of some of the components.

Test with Contaminated Fuel

A test has been carried out to investigate the effect of injecting varying quantities of water into the engine fuel system. The water, under

Components of Orpheus B.Or.2 after the Official
150 hour Type Test at 4850 lb. thrust





Combined flame tube and turbine stator blades

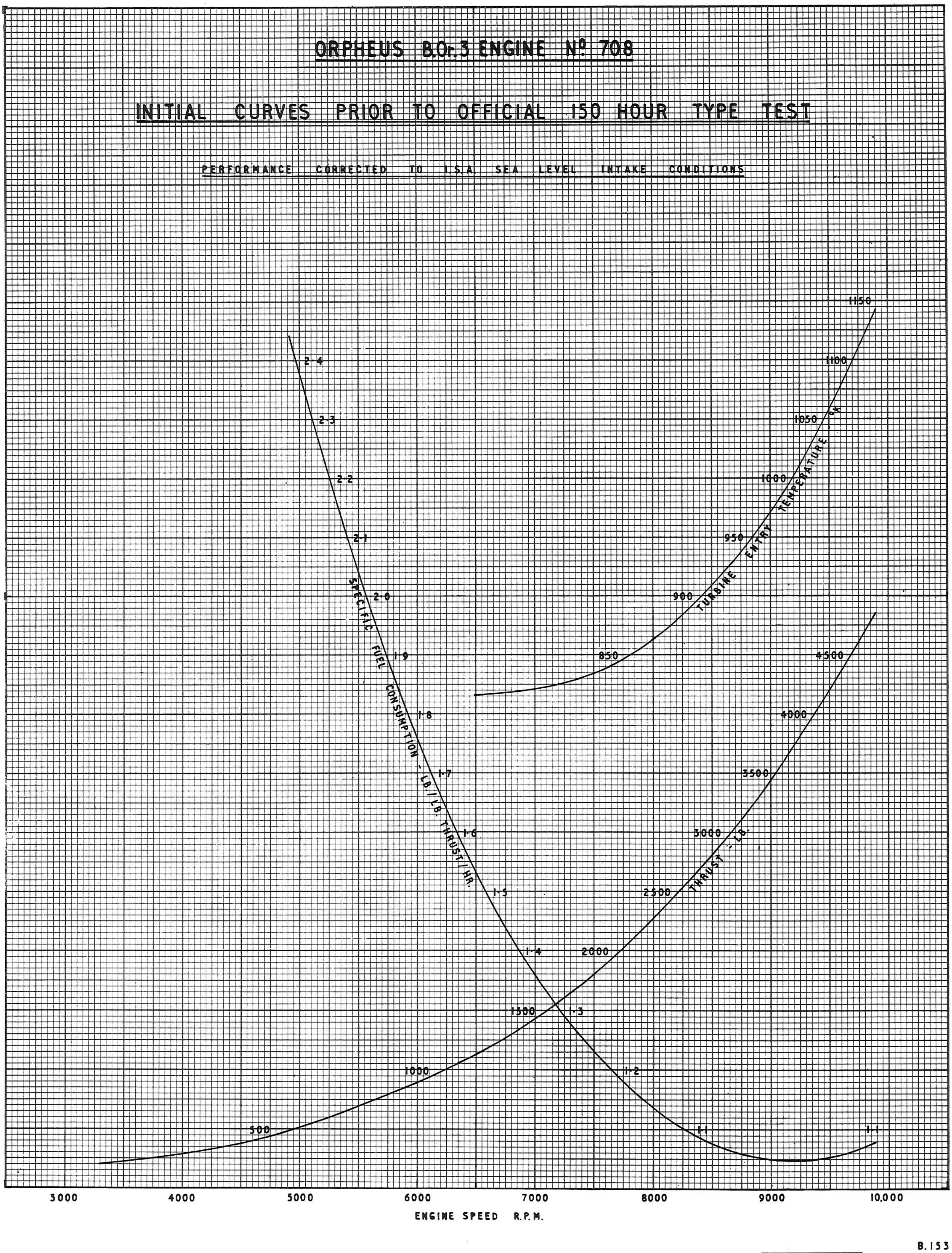
EPD 36

Components of Orpheus B.Or.2 after the Official
150 hour Type Test at 4850 lb. thrust

Burners showing good condition and light carbon deposits

Combustion chamber interconnections showing general good standard of the bores

EPD 37


ORPHEUS B.Or.3 ENGINE Nº 708
INITIAL CURVES PRIOR TO OFFICIAL 150 HOUR TYPE TEST
PERFORMANCE CORRECTED TO I.S.A. SEA LEVEL INTAKE CONDITIONS
SPECIFIC FUEL CONSUMPTION - LB./LB. THRUST/HR.
2·4
2·3
2·2
2·1
2·0
1·9
1·8
1·7
1·6
1·5
1·4
1·3
1·2
1·1
1·1
TURBINE ENTRY TEMPERATURE °K
1150
1100
1050
1000
950
900
850
THRUST - LB.
4500
4000
3500
3000
2500
2000
1500
1000
500
3000
4000
5000
6000
7000
8000
9000
10,000
ENGINE SPEED R.P.M.

B.153952.

mains pressure, was fed into the main fuel supply between the backing pump and the engine fuel filter inlet connection.

With the engine running at maximum continuous conditions, water was fed into the fuel system in increasing proportions until the engine cut. It was demonstrated that the engine combustion and running was satisfactory up to a water-fuel ratio of 25%.

## Tests with Simplified Reheat

A considerable amount of engine running has now been completed on Orpheus engines fitted with Simplified Reheat and the system has behaved extremely well. At present a thrust increase of 16% has been achieved and work is chiefly devoted to improving the combustion efficiency.

## Compressor Development

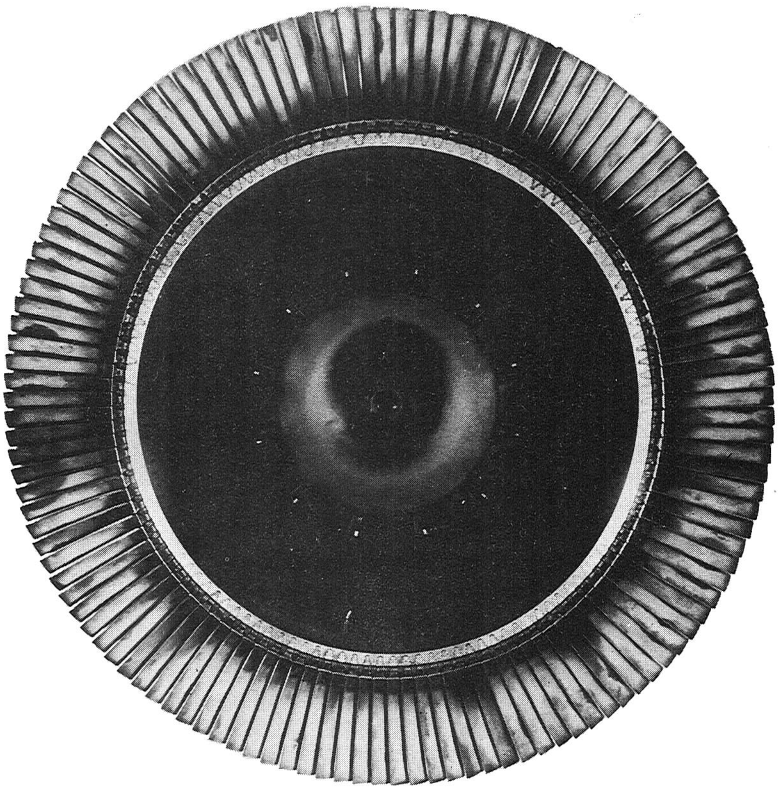
As a result of a detailed examination of the Phase 1 compressor used on the early development engines it was calculated that the efficiency could be usefully improved by a redesign of the blading. A new blading-called the Phase 2 - was accordingly designed and was incorporated in the B.Or.2 and B.Or.3 engines.

When the engine with the Phase 2 compressor ran on the test bed the anticipated improvement was achieved and the same improvement was also obtained on the initial flight tests. However, as the flight development programme of the Gnat proceeded it became apparent that at high altitude the improvement was not maintained and at these altitudes the performance of the Phase 2 compressor was definitely inferior to that of the Phase 1.

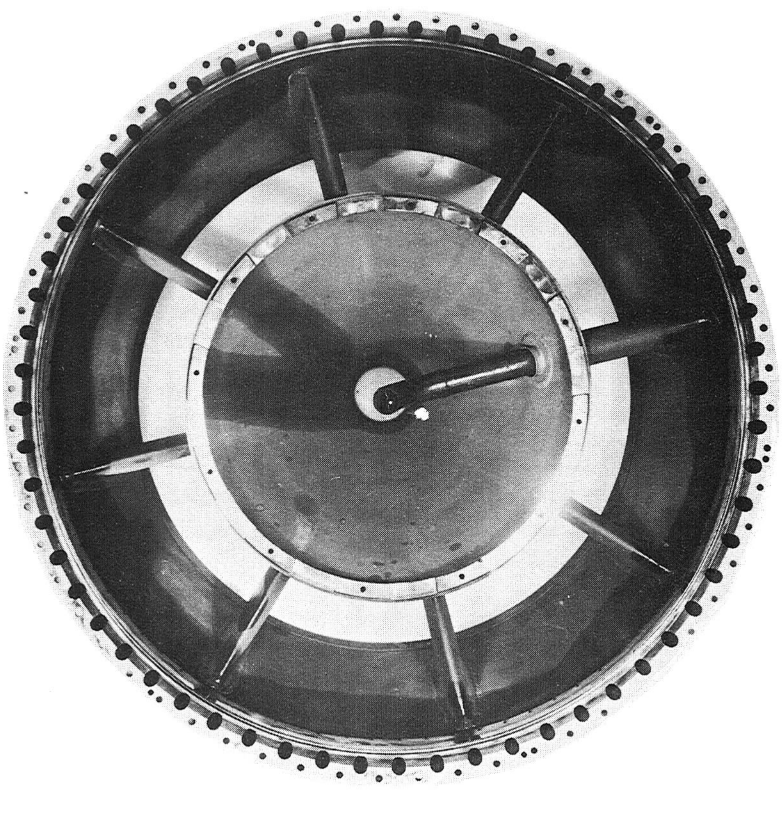
Since the Gnat was primarily designed as an interceptor fighter it was essential to have the highest possible performance at altitude. It was therefore decided to revert to the original Phase 1 compressor for this engine.

Meanwhile, as the N.A.T.O. lightweight fighters were primarily intended for ground attack operations in which the majority of flying takes place at low altitude, the Phase 2 compressor was retained in the production Orpheus Mark 801 engines since for this type of operation it was more efficient than the Phase 1.

Components of Orpheus B.Or.3 after the Official
150 hour Type Test at 4850 lb. thrust

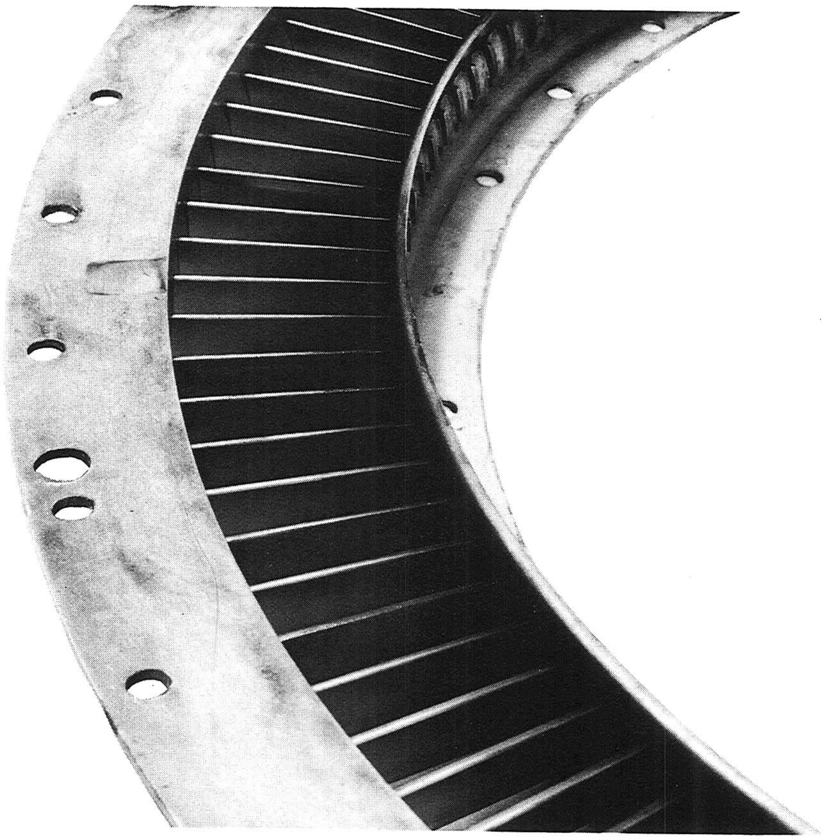


Turbine wheel showing good condition.

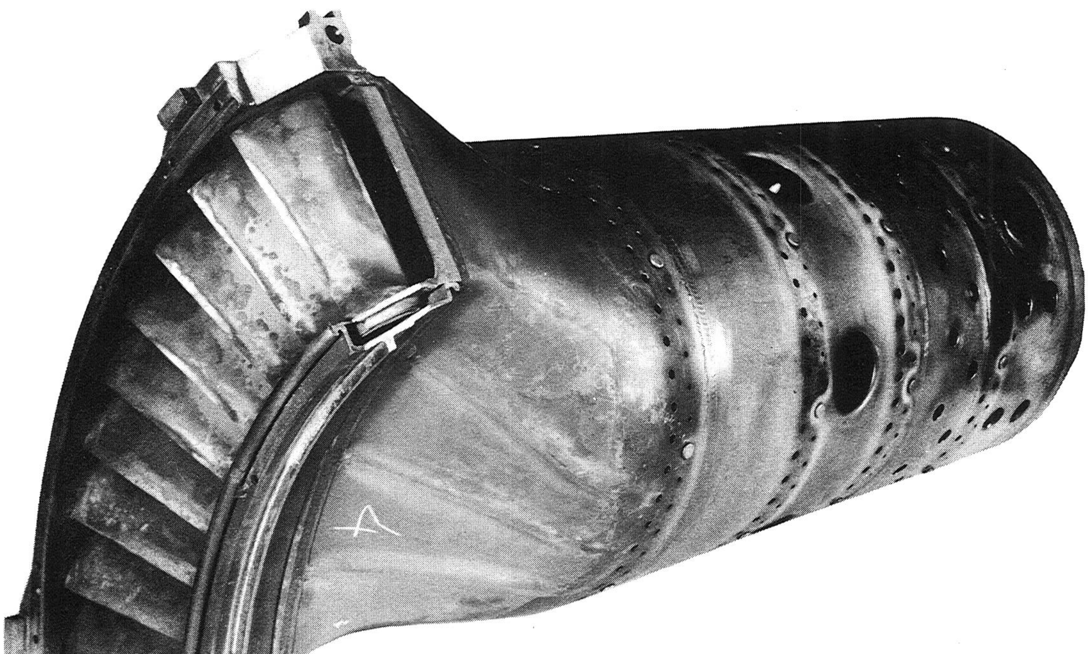


Exhaust cone showing good condition of vane units.

Components of Orpheus B.Or.3 after the Official
150 hour Type Test at 4850 lb. thrust



Compressor exit guide vanes showing complete absence of bowing



Flame tube showing general good condition

## Fuel System Development

The fuel system of the Orpheus was originally designed on the simplest possible lines, in conformity with the general philosophy behind the engine. As flight tests with the Gnat and later with the N.A.T.O. fighters proceeded, it became clear that refinements to the fuel system, even at the cost of some complication, would be necessary if the engine was to avoid surge at high altitude, particularly in violent manoeuvres and during gun-firing.

As a result of a steady development programme, a number of additions were made to the basic fuel system. The most important of these are the air/fuel ratio control and pressure ratio switch, which together prevent the engine being over-fuelled during acceleration; the pressure ratio limiter which prevents the engine exceeding the safe value of r.p.m. in any given ambient conditions and thus eliminating surge, and in the case of the Mark 701 only, the fuel dipping valve which, in conjunction with a pump stroke locking valve, slightly reduces the fuel supply to the engine when the guns are fired at altitude and thus prevents surge in these conditions. Further development of the fuel system for the Mark 701 is being carried out.

## Introduction of the Orpheus Mark 803

In view of the decision that the N.A.T.O. lightweight fighters should be capable of operating at high altitude in addition to their primary role of ground attack the Orpheus Mark 801 has been replaced in production for these aircraft by the Orpheus Mark 803.

This engine is fitted with the Phase 1 compressor similar to that used on the Mark 701 which, in conjunction with the refinements to the fuel system will enable the aircraft to be operated without engine surge at high altitude. The take-off thrust of the Mark 803 has been increased to 5,000 lb. at sea level, and at 40,000 ft. there is an increase in thrust of 9% and a reduction in specific fuel consumption of 5% compared with that obtained on the Mark 801.

The first run of the engine consisted of a 25-hour Special Category Test, the intitial calibration corrected to I.S.A. conditions being as follows:-

| Condition | R.P.M. | Thrust lb. | Jet Pipe Temperature °C | Turbine Entry Temperature °K. |
|---|---|---|---|---|
| Take-off | 10,000 | 5000 | 721 | 1180 |
| Intermediate | 9,700 | 4540 | 671 | 1121 |
| Max. Continuous | 9,450 | 4160 | 636 | 1078 |

The test was completed satisfactorily and Mark 803 engines have now accumulated over 3,000 hours running.

Official Type Test of the Orpheus Mark 803

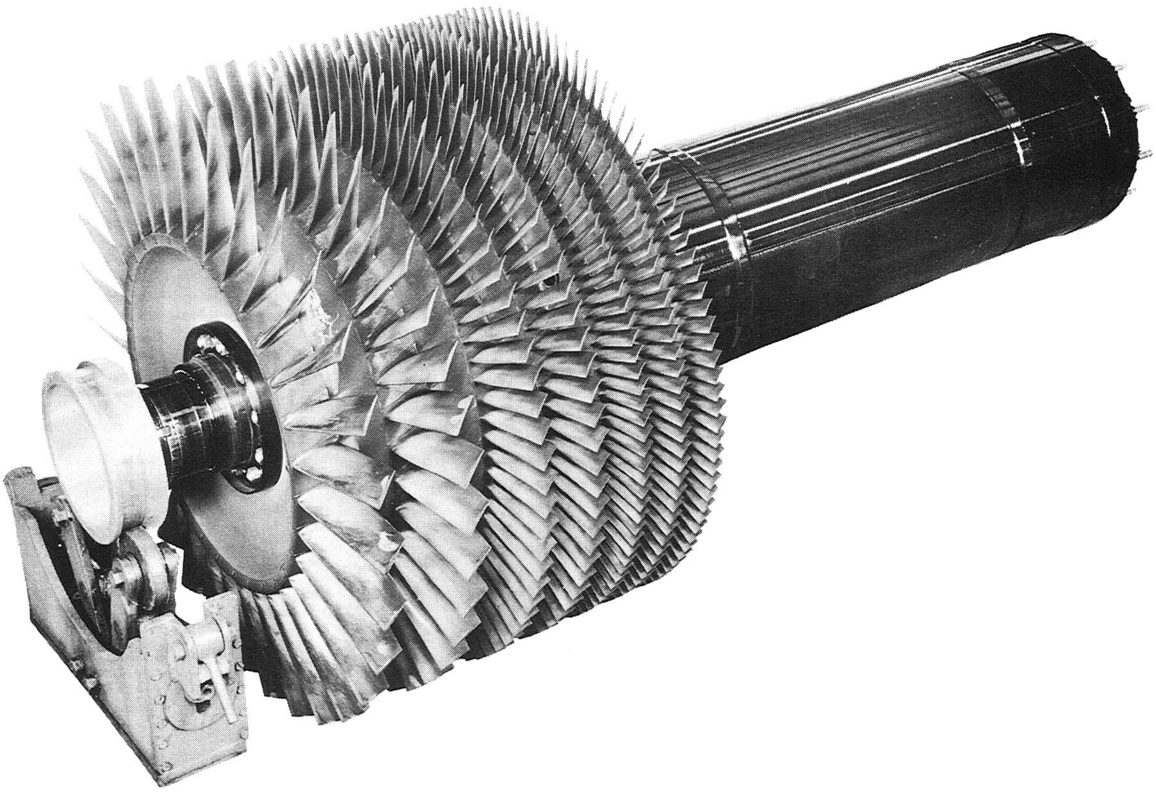
The official Type Approval Test for the Orpheus Mark 803 engine at 5,000 lb. thrust rating was successfully completed on the 2nd March 1959 in a total running time of 187 hrs. 27 mins.

As may be seen from the accompanying photographs of some of the components, the mechanical condition of the engine when stripped was excellent. The compressor and turbine assemblies were in good condition, the blades being free from cracks. The combustion chambers were of a good standard with a normal, uniform, carbon build-up on the inner flares. The amount of burnt oil deposited on the turbine wheel, generally .020" thick and locally .050" at the rim, was commensurate with the average oil feed of 1.4 pints per hour to the rear bearing. The latter was in good order, well lubricated, and exhibited central tracking in the outer member. Cracks were found at the outer leading edge and trailing edge vane welds of the exhaust cone but the general serviceability of the component would not be impaired after correction. However, design action, which includes a change of material, has been taken to eliminate these cracks.

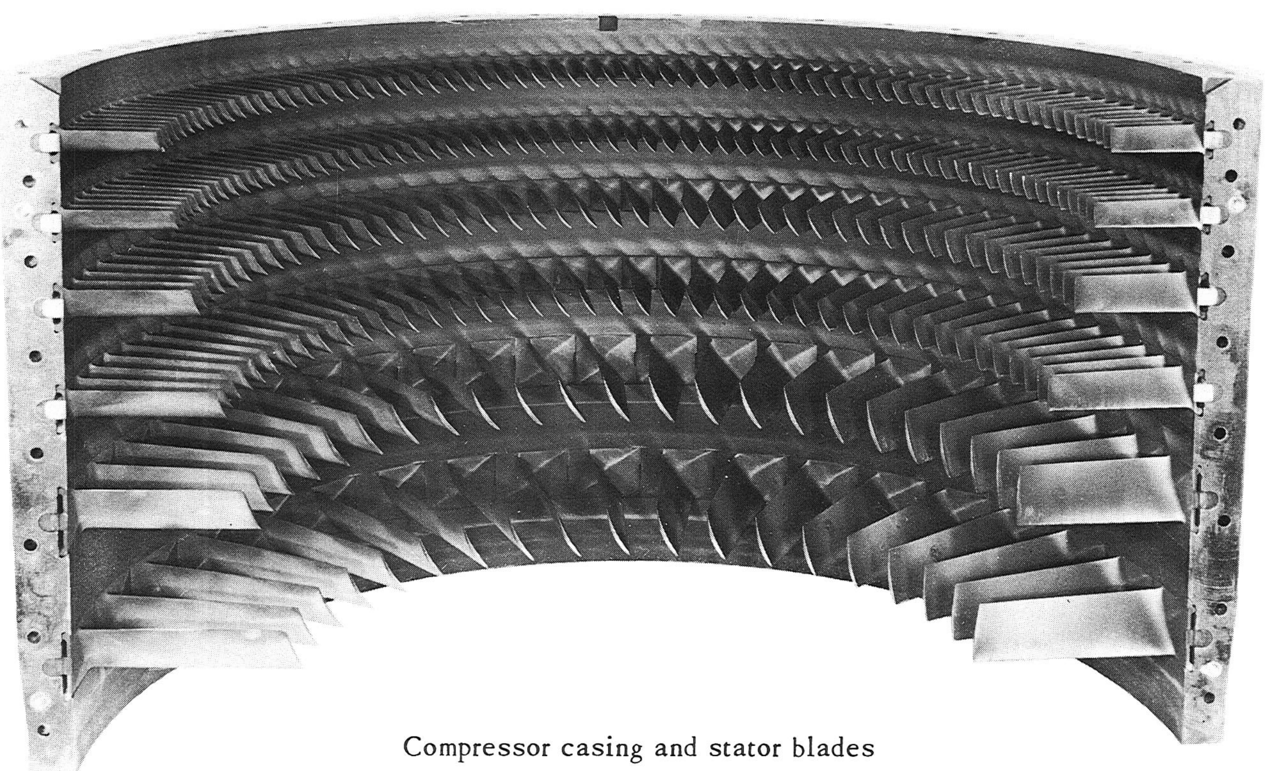
The initial calibration curve corrected to I.S.A. conditions gave the following figures:-

| Condition | R.P.M. | Thrust lb. | Jet Pipe Temperature °C. | Turbine Entry Temperature °K. |
|---|---|---|---|---|
| Take-off | 10,021 | 5060 | 707 | 1180 |
| Intermediate | 9,720 | 4590 | 657 | 1119 |
| Max. Continuous | 9,470 | 4210 | 623 | 1075 |

Components of Orpheus Mark 803 after the Official
150 hour Type Test at 5000 lb. thrust

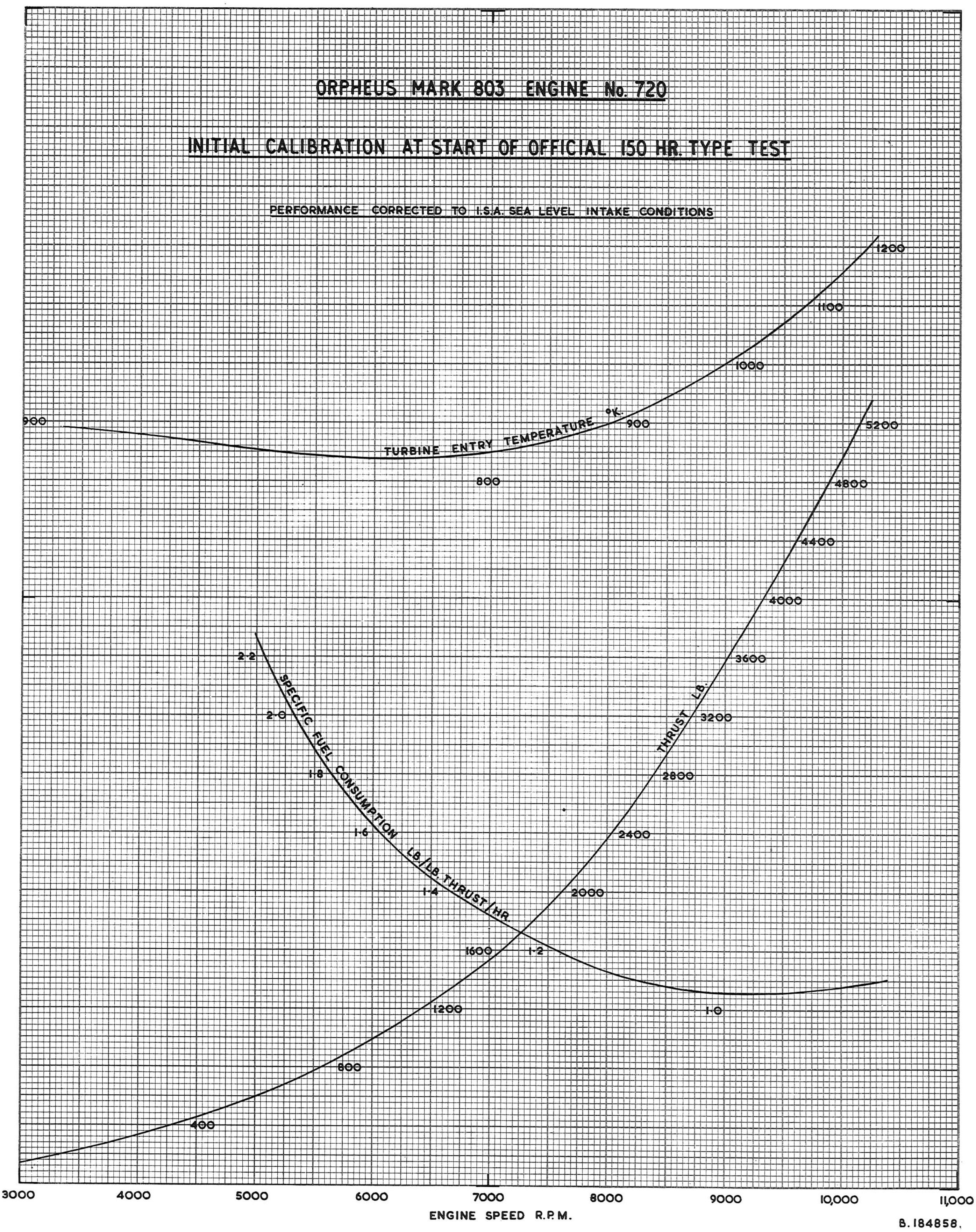


Compressor rotor



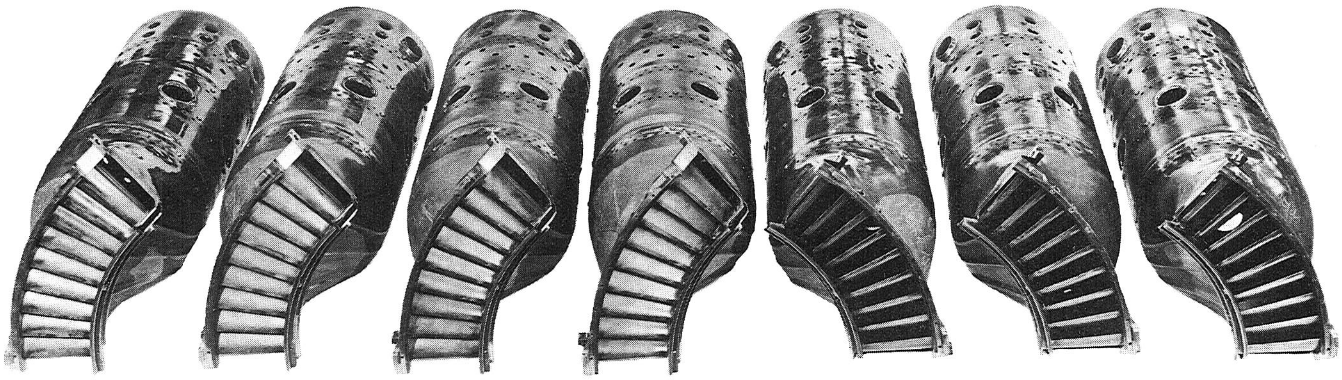
Compressor casing and stator blades

Illustrations showing the good condition of the compressor

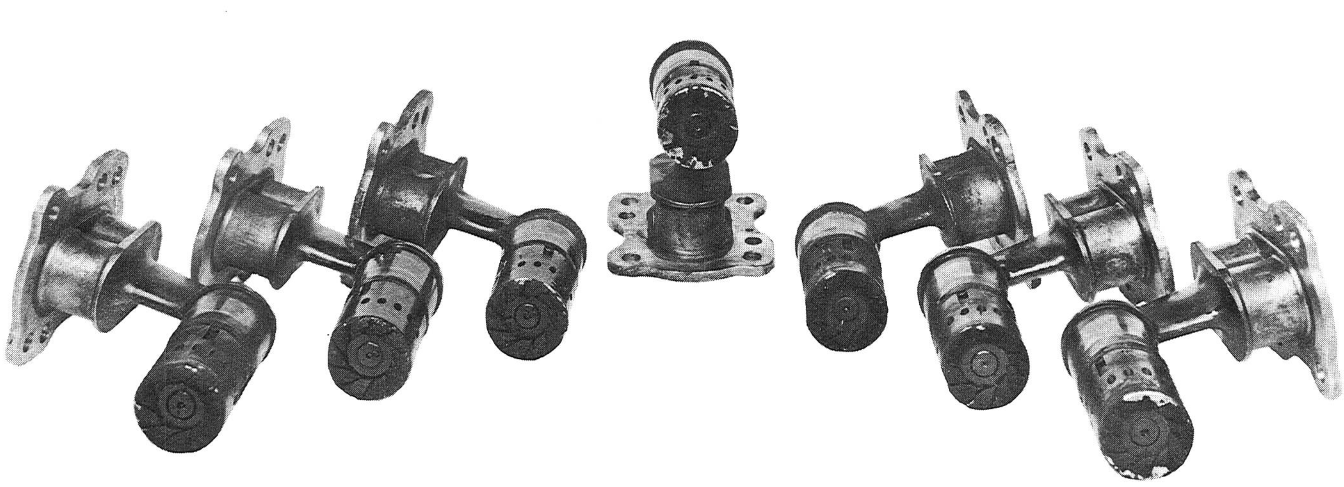

ORPHEUS MARK 803 ENGINE No. 720
INITIAL CALIBRATION AT START OF OFFICIAL 150 HR. TYPE TEST
PERFORMANCE CORRECTED TO I.S.A. SEA LEVEL INTAKE CONDITIONS
TURBINE ENTRY TEMPERATURE °K.
900
800
900
1000
1100
1200
THRUST LB.
400
800
1200
1600
2000
2400
2800
3200
3600
4000
4400
4800
5200
SPECIFIC FUEL CONSUMPTION LB./LB. THRUST/HR.
2·2
2·0
1·8
1·6
1·4
1·2
1·0
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
ENGINE SPEED R.P.M.

B. 184858.

Components of Orpheus Mark 803 after the Official
150 hour Type Test at 5000 lb. thrust



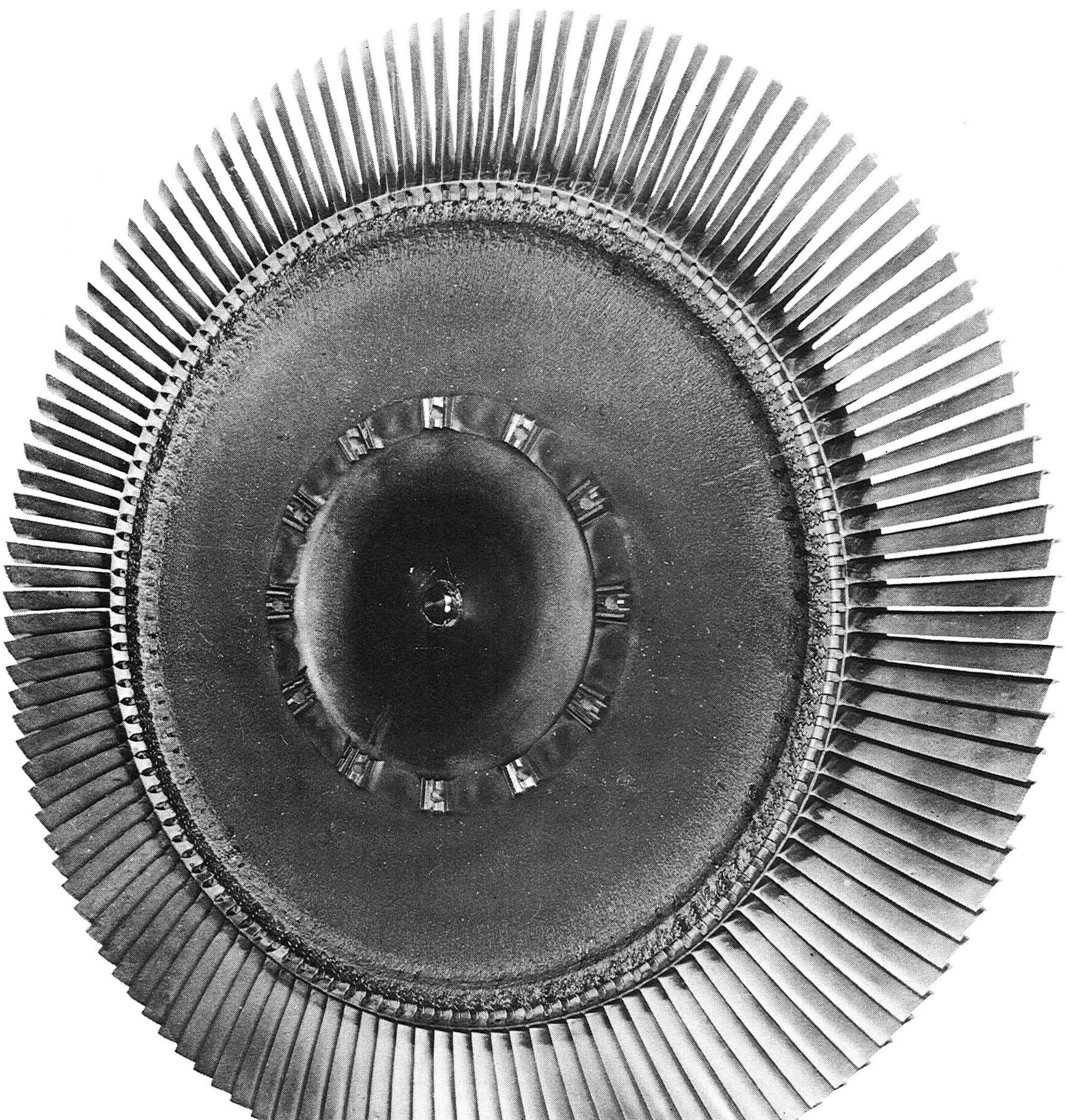
Flame tubes and turbine stator blades showing their excellent condition



Burners with light carbon deposits

EPD 41

Components of Orpheus Mark 803 after the Official
150 hour Type Test at 5000 lb. thrust



Turbine wheel showing the light carbon deposit on
the rear face and the good condition of the blades

EPD 42

## Second Official Type Test of the Orpheus Mark 803

The first official Type Approval Test for the Orpheus Mark 803 engine at 5000 lb thrust rating in March 1959 was run in accordance with the general requirements of Specification D.Eng.R.D.2100. Issue 3. Schedule B. In order to obtain type approval for the Orpheus Mark 803 engine to the more stringent requirements of the new Fighter Schedule, Specification D.Eng.R.D.2100. Issue 4. Schedule B, which necessitates operating the engine for 30 hours at take-off power, a second 150 hour Type Approval Test was successfully completed in November 1959.

The initial calibration curve corrected to I.S.A. conditions gave the following figures:-

| Condition | R.P.M. | Thrust lb. | T.E.T. °K | J.P.T. °C | Mass Flow lb./sec. | Specific Fuel Consumption lb/lb.thrust/hr. |
|---|---|---|---|---|---|---|
| Take-off | 100% (10020) | 5025 | 1173 | 718 | 83.5 | 1.09 |
| Intermediate | 97% (9720) | 4575 | 1110 | 691 | 81.2 | 1.07 |
| Max.Continuous | 94% (9470) | 4200 | 1062 | 627 | 79.0 | 1.065 |

## Flight Testing

Up to the end of August 1960 the Orpheus had completed a total of 15,500 engine hours flying in various aircraft under test and service conditions. This figure is made up as follows:-

| Aircraft Type | Flying Time - Engine Hours |
|---|---|
| Folland Gnat | 2858 |
| Fiat G91 | 9022 |
| Breguet Taon | 204 |
| Dassault Etendard VI | 236 |
| Lockheed JetStar | 2231 |
| Fuji TIF-2 | 830 |
| Ashton flying test bed | 70 |
| Sabre flying test bed | 50 |

The Orpheus was first flown in July 1955 in the Folland Gnat.

Reynolds number effects at high altitude have been investigated and these have been found to line up with predictions from tests on other engines.

The engine has been installed in a Sabre flying test-bed at Bristol and some flying has also been carried out in an Avro Ashton flying test-bed which was more fully instrumented than is possible with a single-seat fighter aircraft.

A considerable amount of the Gnat flying has been concerned with the development of control system refinements on the Orpheus Mark 701 to prevent engine surge at high altitude. The Orpheus Mark 803 directly benefits from this work because this engine incorporates most of the refinements.

One problem encountered resulted from the fact that the pressure ratio control was sensitive to effects of gravity so that its behaviour changed when the aircraft was undergoing certain manoeuvres. This has been corrected by suitable mass balancing, the initial development tests for which were performed in the Gnat.

In the Fiat G91, Dassault Etendard VI, Breguet Taon, Lockheed Jet-Star and Fuji TIF-2 the test flying has largely been concerned with aircraft development work. Although not experienced during the bench test development programme on the Mark 801, failures of the Phase 2 first stage compressor blades fitted to this engine occurred during development flying in the Fiat G91 due to a vibration induced in the blades at low r.p.m. by rotating stall. This was investigated at Bristol in a programme of flight strain gauging of the compressor blades using the Fiat G91. The failures have been overcome by replacing the aluminium first stage rotor blades on the Mark 801 engines with steel blades.

## Starting and Relighting Tests

Cold starting tests have been carried out in the refrigeration chamber at Bristol. Using D.Eng.R.D.2487 synthetic oil, lubrication and starting have been satisfactory in tests down to $-26^{\circ}$C. Tests down to $-36^{\circ}$C form part of a current test programme.

Considerable effort has been applied to the development of cartridge starter motors specified for the Mark 803 engine, resulting in the introduction of a number of improvements including a ratchet and pawl engaging mechanism and a roller turbine bearing.

The starters have been cleared for 250 shot lives and are now in Squadron service on the Fiat G91.

## The Bretigny Lightweight Fighter Trials

In October 1957, the Fiat G91, Dassault Etendard VI and Breguet Taon lightweight fighters powered by Orpheus Mark 801 engines were submitted to an exhaustive programme of operational missions to determine their suitability for N.A.T.O. military requirements. These tests provided the first opportunity for assessing the operational characteristics and behaviour of the Orpheus engine under simulated service conditions. The experience gained during these trials was extremely valuable because they demonstrated the soundness of the Orpheus engine's conception and the ease of maintenance which results from its basic simplicity.

Prior to these trials, two of the aircraft - the Dassault Etendard VI and the Breguet Taon - had done very little development flying so it would not have been surprising if their maintenance requirements had been of a rather extensive nature. Experience showed, however, that the maintenance of all the Orpheus engined aircraft was at an exceptionally low level - a feature which augurs well for the future of Orpheus-powered aircraft in service.

## The Italian Lightweight Fighter Trials

In May 1959 tactical trials of ten Orpheus powered Fiat G91 aircraft were held in Northern Italy under the auspices of the Italian Ministry of Defence. During these trials the remarkable record of one hundred per cent reliability was achieved.

Operating under both muddy and dusty conditions from a series of grass landing strips, the aircraft carried out three times the number of daily sorties normally expected of them under optimum conditions. During the five-day exercise nearly 170 sorties were completed in a total flying time of some 150 hours. Operating in groups of four, the aircraft were put through all types of firing exercises, including ground strafing, rocket firing and also the dropping of 500 lb bombs.

The entire programme was carried out under strictly operational conditions and all servicing of engines and airframes was done in the field. During an engine-change demonstration, an engine was removed and a replacement fitted within 45 minutes.

## Other Orpheus Developments

Although the granting of Type Approval Certificates to the Orpheus 701 and 801 engines marked the successful conclusion of the preliminary development programme, the remarkable progress of the Orpheus has created a demand for further applications of the basic type. Apart from the introduction of the Mark 803 described in this brochure, other members of the Mark 800 series are the Mark 805 of 4000 lb. thrust for the Fuji TIF-2 trainer and the Mark 810D of 4850 lb thrust for the Lockheed JetStar prototype. In addition to these engines, development has been actively pursued on a number of other main lines.

One of these lines of development concerns the Orpheus Mark 100 which has been developed primarily for the trainer version of the Gnat. This aircraft does not require the full thrust available from the Orpheus and it has therefore been possible to reduce the maximum rating to 4230 lb thrust, with a consequent improvement in potential overhaul life. In addition to this, the use of a more efficient turbine has resulted in a corresponding reduction in specific fuel consumption. The Mark 100 and the Mark 810D are equipped for the anti-icing of the air-intake and entry guide vanes.

Bench testing of an early version of the Mark 100(the Orpheus B.Or.4) began in January 1958 and over 1400 hours running on the test bed and 400 hours flight testing in the Gnat trainer have so far been completed. The tabulation following shows that the performance achieved on the test bed is in very close agreement with that quoted in the Bristol Siddeley brochure for this engine.

| Condition | Thrust lb. | Specific Fuel Consumption lb/lb. thrust/hr. | |
|---|---|---|---|
| | | Brochure s.f.c. | Achieved s.f.c. |
| Maximum | 4230 | 0.964 | 0.966 |
| Max. Continuous | 3600 | 0.943 | 0.953 |

The Orpheus Mark 100, which will shortly be in production, first ran in September 1959 since when it has completed over 560 hours bench running and 5 hours flight testing in the Gnat. It successfully completed its 150 hour official Type Approval Test to the conditions of specification D.Eng.R.D. 2100 Issue 4. Schedule B. at the brochure rating in January 1960.

The performance from the initial curve corrected to I.S.A. conditions was as follows:-

| Condition | R.P.M. | Thrust lb | T.E.T. °K | J.P.T. °C | Mass Flow lb./sec. | Specific Fuel Consumption lb./lb.thrust/hr. |
|---|---|---|---|---|---|---|
| Take-off | 10000 | 4285 | 1016 | 549 | 84.0 | 0.990 |
| Maximum Continuous | 9500 | 3680 | 945 | 488 | 79.8 | 0.970 |

Flight testing is now proceeding with the engine installed in a Gnat trainer aircraft.

A further important main line of development is to increase the performance by adding an extra 'zero' stage to the front of the basic seven-stage compressor, thus raising the air mass flow and the compressor pressure ratio.

The first engine with the zero-stage compressor was the Orpheus B.Or.11D which ran on the test bed for the first time on 29th April 1958, and had a take-off rating of 6,015 lb thrust. Since then the compressor zero-stage blades have been redesigned to give an increased air flow, and the engine in this form is known as the Orpheus B.Or.15. The first run of the Orpheus B.Or.15 took place on 16th October 1958 at a take-off thrust of 6400 lb corrected to standard conditions.

A slightly more powerful version with considerably better fuel consumption is the Orpheus B.Or.12 rated at 6810 lb thrust. This engine uses the same compressor as the B.Or.15 together with a two-stage turbine. It first ran on the 30th December 1958 and has already completed over 600 hours development running on the test bed and 15 hours initial flight testing.

A 150 hour official Type Approval Test to the condition of specification D.Eng.R.D.2100 Issue 4 Schedule B was successfully completed during October 1959 at the following ratings:-

| Condition | R.P.M. | Jet Pipe Temperature °C | Turbine Entry Temperature °K | Thrust lb | Specific Fuel Consumption lb/lb.thrust/hr. |
|---|---|---|---|---|---|
| Maximum | 10020 | 690 | 1145 | 6810 | 0.950 |
| Maximum Continuous | 9620 | 612 | 1056 | 5825 | 0.915 |

The thrust was equal to that given in the engine's performance brochure whilst the achieved specific fuel consumption was 2% better. The strip condition of the engine after this test was very good.

An Orpheus B.Or.12 was installed in a Sabre flying test bed and its first flight took place on the 10th November 1959. During this and subsequent flights the mechanical behaviour of the engine has been extremely satisfactory.

The addition of Simplified Reheat to the engine enables the thrust to be increased to 8000 lb. Simplified reheat development on Orpheus engines has a background of 228 hours bench running of which 67½ hours is with reheat in operation. The overall running time includes 84½ hours on the Orpheus B Or.12, of which 14½ hours was with reheat operating. A 24 hour Special Category Test, using reheat in the scheduled take-off periods, was completed in December 1959 the average observed thrust being slightly in excess of 8000 lb.

A thrust reverser of the S.N.E.C.M.A. pattern has also been built and calibrated on an Orpheus engine. A reverse thrust of 54% has been achieved. The weight increase for a flight type reverser will be under 100 lb. The reverser can be applied to all marks of Orpheus engine, and the basic design has a substantial background of bench and flight development on a variety of engines and aircraft. Designs are also available for a clam-shell type thrust reverser should this be required.

Silencing nozzles have been developed by Bristol Siddeley, which give a reduction in overall noise level, at a point 30 degrees and 150 feet rearwards of the jet nozzles, of between 5 and 6 decibels with no measurable effect on the engine performance. These can be fitted if required. The additional weight for a silencing nozzle is approximately 50 lb.

If it were required, water injection could be fitted to the Orpheus. The system would be similar to that type tested on the Bristol Siddeley Proteus Mark 255, and consists of injecting distilled water into the engine intake from a tank pressurized by a compressor delivery tapping. The weight of the system would be 5 lb apart from the weight of the tank and water. The use of water injection should result in a 7% increase in take-off thrust. Engine tests to date have shown a 7% thrust increase for a 10 gallon per minute water flow.

It will be seen therefore that the development of the Orpheus family of engines is being pursued with vigour and that improved performance and design features are continually being evolved to meet the growing requirements of aircraft constructors.

# SECTION 4

## CONTROL SYSTEM FOR THE ORPHEUS MARK 803

## THE CONTROL SYSTEM REQUIREMENTS

Engine control requirements may be divided according to the two basic engine conditions of running at a set speed, (steady state control), and running under conditions of acceleration or deceleration (variable state control).

These conditions are fully met by the Orpheus Mark 803 control system which is entirely hydraulic and mechanical, and is manufactured by Joseph Lucas (Gas Turbine Equipment) Limited.

### Steady State Control

The basic steady state control is provided by the barometric pressure control and the throttle valve which together regulate fuel flow according to air intake total pressure and the setting of the pilot's throttle lever.

The engine is controlled so that it runs at approximately constant compressor speed at the normal operating condition. The control is so arranged that for a given throttle lever position approximately constant engine conditions are maintained during a climb to altitude. It is possible to select any compressor speed in the range between idling and maximum by means of the throttle lever.

At take-off conditions the throttle valve is opened fully and the engine is controlled by the pump governor set at the maximum compressor speed.

### Variable State Control

During accelerations the supply of fuel to the engine is regulated by the air-fuel ratio control, which incorporates a pressure ratio switch. This control gives a maximum fuel flow in accordance with the compressor delivery pressure and atmospheric pressure, permitting safe, rapid and surge-free accelerations at all altitudes. No special control during rapid deceleration is needed because the barometric pressure control and the throttle idling characteristics ensure that dangerously low fuel flows cannot occur when throttling back.

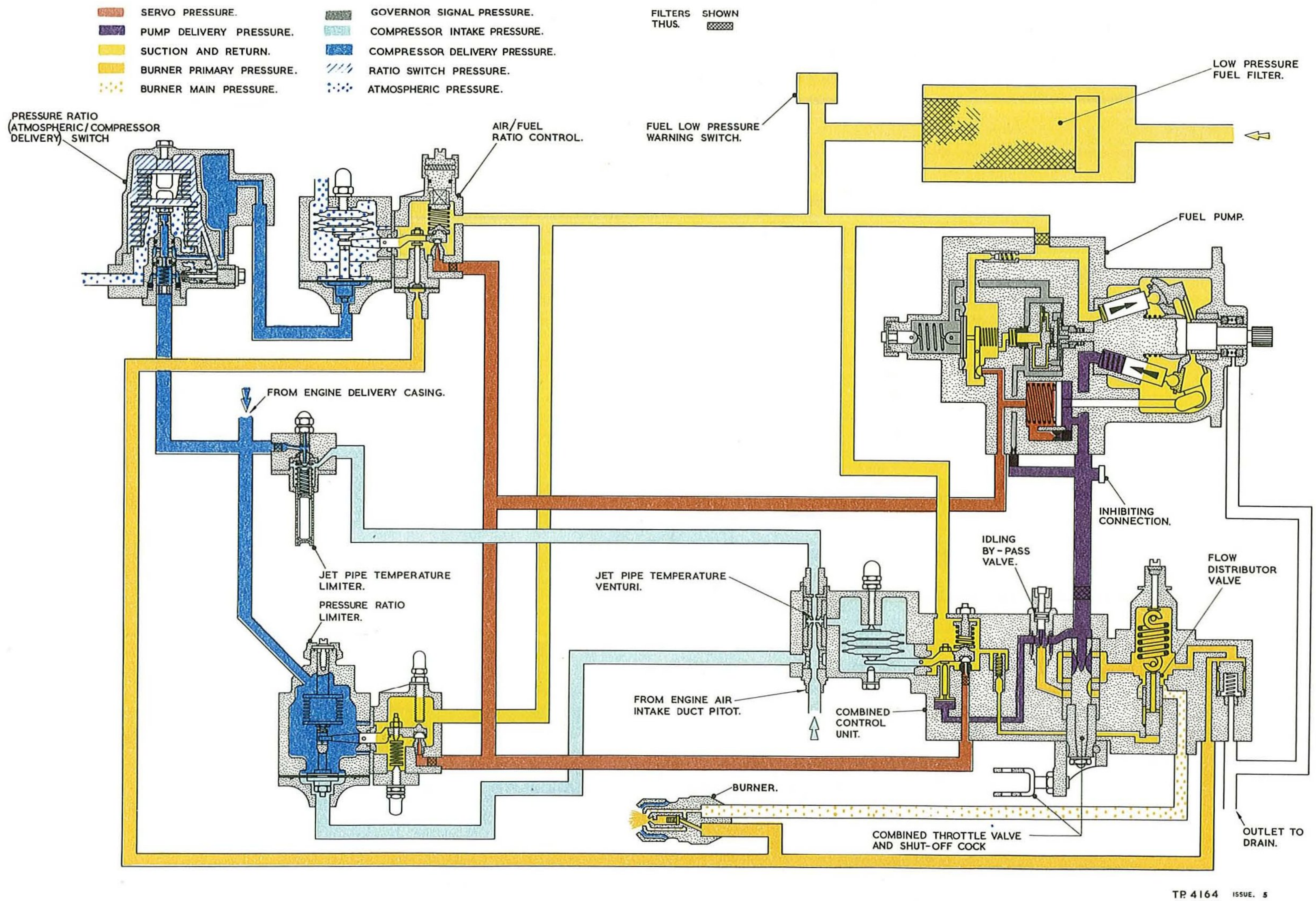



Diagram of fuel system.

A jet pipe temperature limiter of the pneumatic type is incorporated into the control system to prevent the maximum turbine entry temperature being exceeded.

A compressor pressure ratio limiter is incorporated in the control system to eliminate the possibility of the maximum permissible running point of the engine being exceeded in conditions of high engine speed and low ambient temperature at high altitude.

## DESCRIPTION OF FUEL SYSTEM COMPONENTS

### Fuel Pump

The fuel pump is a Lucas 'D' size high-pressure unit of the positive displacement variable stroke type. It is driven by the engine compressor and delivers fuel from the downstream side of a low-pressure filter to the combined control unit. Each of the major items in the control system can influence the pump by operating a bleed valve in the servo line.

The pump is fitted with a hydro-mechanical governor. The centrifugal force of the governor weight tries to close a control orifice, and this force is opposed by the pressure difference across the control orifice acting on a diaphragm until equilibrium is reached. The pressure difference across the orifice varies with the square of the rotational speed only (it does not depend on fuel density) and this pressure difference is fed to a diaphragm controlling a half-ball valve in the pump servo line, so that, when the governed speed is reached the half-ball valve opens and reduces the pump stroke. Fuel is fed to the governor from pump delivery through a fixed orifice.

### Combined Control Unit

The combined control unit contains the barometric pressure control unit, the throttle valve and high pressure shut-off cock, the dump valve, and the flow distributor.

The barometric pressure control is the basic metering unit of the control system. It senses intake total pressure and pump delivery pressure and acts on the fuel pump delivery through a servo valve to maintain the delivery of the fuel at a fixed relationship between these two pressures. The law chosen is of the form:- $P_p = A P_1 + B$
where A and B are constants, $P_p$ is pump delivery pressure and $P_1$ is intake total pressure.

With this law and the appropriate fixed throttle angle, a substantially constant compressor speed is maintained as the intake conditions vary.

The throttle valve and high pressure shut-off cock are combined in this unit. The throttle valve is of the barrel type which is rotated by a lever arm splined to one end. The first $20^{\circ}$ of throttle valve movement opens the shut-off cock, the next $70^{\circ}$ opening the throttle valve.

The dump valve drains the fuel lines from the throttle to the burners when the pressure in the lines falls below a minimum value.

The flow distributor functions firstly to keep the main burner lines closed until the primary opening pressure of about 350 lb/sq.in. is reached and secondly, to ensure even distribution to all seven main burner atomizers.

Air-Fuel Ratio Control and Pressure Ratio Switch

The air-fuel ratio control operates to limit the fuel flow to a pre-determined maximum value for any value of compressor delivery pressure. Its function is to permit rapid engine acceleration and to avoid either engine surging or overheating if the throttle is moved quickly.

The control compares the primary burner pressure - which is proportional to fuel flow - with compressor delivery pressure. $P_2$ The device thus provides a fuel flow according to a linear law of the type :

$$P_B = C\,P_2 + D$$

where $P_B$ is burner pressure

$P_2$ is the compressor delivery pressure

C and D are constants

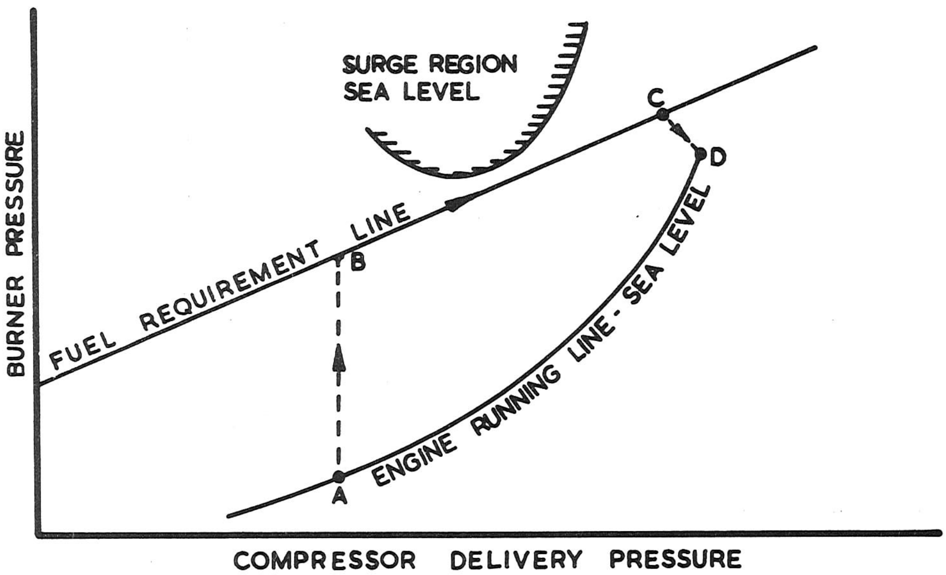



Fig.1.

The operation of the air-fuel ratio control is shown in Figure 1. The fuel requirement line is seen to lie between the engine running line and the surge region for the same altitude. If the throttle is opened from point A, the fuel flow to the engine will rise rapidly to the value B and then rise steadily as the delivery pressure increases to a point C at which the fuel pump governor becomes operative and brings the fuel flow to the value appropriate to maximum compressor speed at point D.

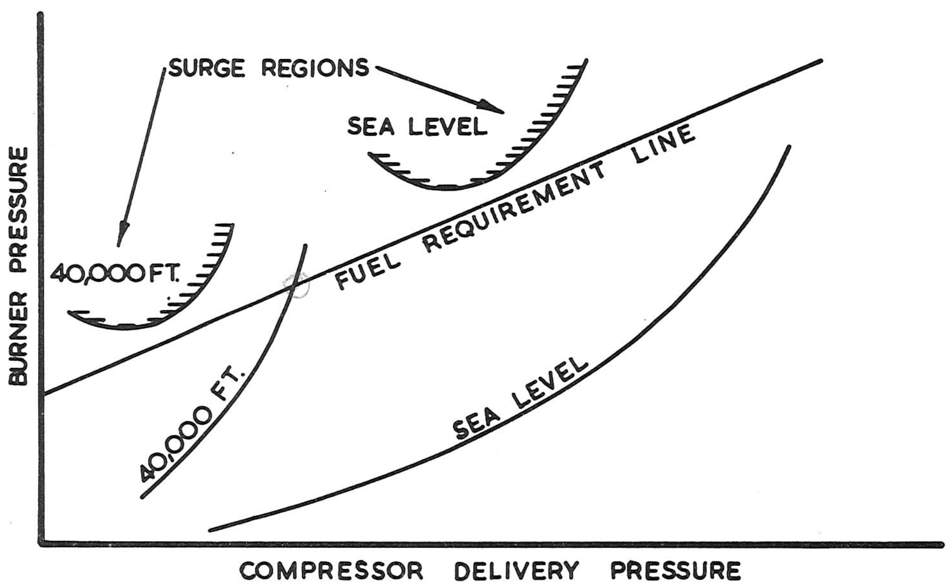



Fig.2

EPD 49

This simple type of air-fuel ratio control, however, has certain disadvantages. Figure 2 shows engine operating characteristics and typical surge regions for sea level and high altitude. It is seen that the fuel requirement line cuts the engine altitude characteristic at an r.p.m. less than maximum. This means that at altitude, the engine could not be accelerated to maximum r.p.m. with the air-fuel ratio control in circuit.

To overcome this disadvantage, a pressure ratio switch is incoporated in the air-fuel ratio control. The pressure ratio switch consists essentially of two orifices in series with a tapping between them to the air-fuel ratio control. The compressor delivery pressure is fed to the first orifice and, according to whether the second orifice is open or closed, so the intermediate tapping conveys a fraction or the whole of the compressor delivery pressure to the air-fuel ratio control. The second orifice closes at a predetermined value of compressor pressure ratio. $P_1/P_2$

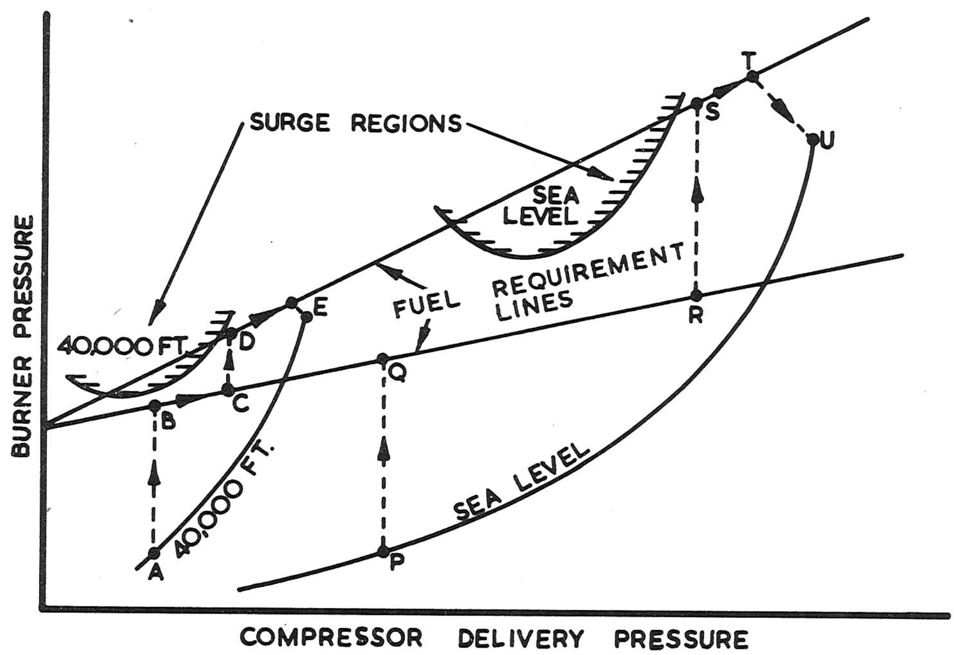



Fig.3

EPD 50

The effect of the switch is to provide two datum requirements for the air-fuel ratio control as shown in Figure 3. The important feature to notice is that the upper requirement line now lies above the maximum r.p.m. point of both the sea level and high altitude operating characteristics. The surge regions may or may not be cut by this upper line.

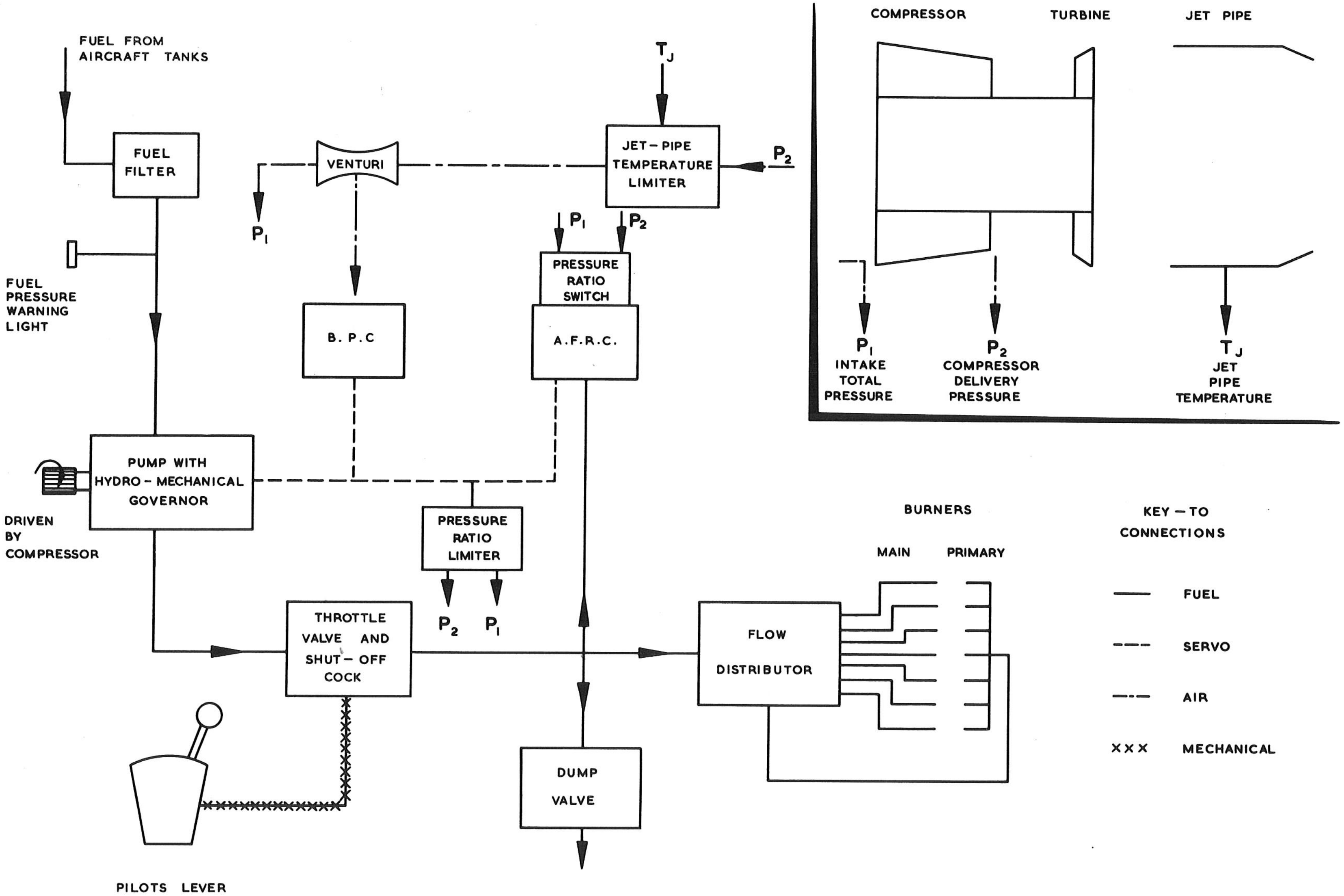
Now consider an acceleration from point A on Figure 3 on the high altitude characteristic. The engine will be operating at a low compressor speed initially and hence the compressor pressure ratio will be low. Therefore the lower requirement line will be in use and the fuel flow will at first increase only to point B. The fuel flow will then increase progressively along the line until at point C the engine r.p.m. and compressor ratio will have increased to the pre-determined value at which the pressure ratio switch operates and the upper line becomes effective. The fuel flow will therefore increase to point D and advance along the upper line until the fuel pump governor trims it to the desired value at E. The pressure ratio at which the transition from points C to D takes place is chosen both to ensure that the path BCD lies wholly outside the surge region and to prevent excessive temperatures during acceleration.

Similarly at sea level, the line PQRSTU shows the path of a typical acceleration. Again the point R at which transition from the lower to the upper line takes place, is chosen to avoid the surge region and excessive temperatures during accelerations at sea level. The air-fuel ratio control with its pressure ratio switch permits slam accelerations at all altitudes up to 50,000 ft.

Jet Pipe Temperature Limiter

This consists of a quartz rod inside a Nimonic tube and fixed to it at one end. This end of the tube is in the hot gas stream part way along the jet pipe. The differential expansion between the quartz rod and the Nimonic tube opens a valve in an air line connecting compressor delivery pressure to a venturi which vents to the intake pressure. A static pressure tapping at the throat of this venturi is connected to the capsule chamber of the barometric pressure control.

Normally the air valve is shut, the air in the venturi is stationary and the full intake pressure is applied to the barometric pressure control. If the maximum jet pipe temperature is exceeded, the valve opens, and air flows through the venturi. This reduces the static pressure in the venturi throat and hence lowers the pressure in the barometric pressure control, which, in turn opens the half-ball valve in the pump servo system and reduces the fuel flow.




Block diagram of fuel system.

TP.4096

## Pressure Ratio Limiter

This device is, in effect, a surge control which relieves the pilot of the responsibility of ensuring that the maximum permissible running point of the engine is not exceeded. The maximum permissible running point of the engine is defined by a maximum value of non-dimensional compressor speed $\left(\frac{N}{\sqrt{\theta}}\right)$ beyond which the compressor will surge. The device consists of a system of levers and capsules which are so balanced that when a predetermined value of compressor pressure ratio is obtained, a valve is opened to bleed the fuel pump servo line and hence reduce the fuel supply to the engine. This prevents the engine speed increasing beyond the value which, for the relevant ambient conditions, corresponds to the maximum permissible $\left(\frac{N}{\sqrt{\theta}}\right)$

## Burners

Seven Duplex burners are fitted for injecting the fuel into the combustion chambers. These burners each contain a primary and a main atomizer arranged concentrically. At low fuel flows the primary atomizers only are in circuit and they are sufficiently small to ensure adequate atomization of the fuel under these conditions. All the primary burner lines are fed from one manifold, but the main burner atomizers are fed from individual outlets in the flow distributor.

## SERVICE ORGANISATION

### Introduction

At the present time Bristol Siddeley aero-engines are being used in every continent in the world, and the purpose of this Section is to describe the service facilities which exist for the benefit of the numerous operators. Arrangements will be made for the extension of these facilities as required to deal with service requirements.

Bristol Siddeley provides technical training facilities for air-crew and ground staff, planning assistance before aircraft delivery, and service engineers after delivery, together with all of the usual maintenance and repair publications, augmented by Bulletins, Modification Leaflets, Repair Notes, Component Salvage Instructions and Overhaul Schedules.

The Service Department has a section devoted to assisting operators in planning and equipping a new overhaul shop, or in adapting an existing piston or turboprop overhaul shop to deal with the latest type of turbine engine. Their recent exercises have included repair bases in Canada, Mexico, Israel, Japan, India, Italy and Australia.

There is also a special section of the Department to handle A.O.G. (Aircraft on Ground) demands, whose duties include the progressing of modifications and the provision of assistance in the form of working parties, if and when required.

A statistical and records section maintains a complete history of every engine made and issues periodic summaries for use by the operators, as well as for internal use in the Engineering and Supplies Departments.

The Company has acquired a reputation, not only for good service on orthodox lines, but also for maintaining very close touch with the operators' special requirements. The internal organization is arranged to ensure that technical problems are immediately brought to light at high level to ensure quick and comprehensive action. The Engineering Department, in conjunction with the Service Department, maintains a close liaison with operators of Bristol Siddeley Engines. Within the normal Development Department there is a large Service Development section whose activities are centred on providing quick technical solutions to any service problems and on continually improving engines in service to provide greater reliability, longer overhaul life and more economical operation and maintenance.

## Technical Liaison Service

Under the Chief Service Engineer (Turbine), skilled technicians are employed to ensure the satisfactory operation of Bristol Siddeley turbine engines. They are responsible for all technical liaison with the operator on matters affecting service, maintenance and operation of the engine.

The pooling of experience is ensured by the continuous review maintained by this Technical Liaison Service, who also alert the Development team to service difficulties, and then progress the remedial action. Technical liaison meetings are held with the operator and joint meetings of all operators of a particular engine type have been and will be arranged.

Technical Bulletins dealing with specific problems of service, maintenance or operation are prepared by the Service Department and issued by the Technical Publications Department.

A News Letter covering Orpheus engine experience and progress is issued each month. This letter gives an analysis of the previous month's world-wide experience, and draws attention to any methods of improving the operation or maintenance of the engine.

Operators' questions are answered as appropriate by telephone, cable or letter, and each member of the Technical Liaison Service holds a current passport and medical certificate to allow visits to operators' home bases or elsewhere at short notice. Regular visits by the Service Manager or Chief Service Engineer are made to all operators.

Most members of the Technical Liaison Service have spent a considerable time on development and training flights with the engine type on which they are engaged, and they are available to assist operators during their initial training period if required.

## Service Engineers

These engineers are located for long periods with the operators, and their function is to ensure that the Bristol Siddeley engines in their charge are giving the best possible service. This entails advising the operator's staff on the correct methods of maintenance, and dealing with any day to day problems which may arise.

## Investigations

The Service Department arranges the investigation by a specialist team and subsequent issue of a technical report on all engines and components returned as defective, whether these are still under warranty or not. A copy of such reports is sent to the operator.

## Organisation of Overhaul Facilities Overseas

With the increasing use of Bristol Siddeley engines throughout the world it has been necessary to set up a large number of engine repair and overhaul bases in various countries overseas. The co-ordination of the activities of all these repair bases is undertaken by a specialized section, which sends representatives to the various countries in order to give advice and, where necessary, practical assistance either to Bristol Siddeley personnel located there in established bases or to an operator who is about to set up his own repair base. They are thus able to smooth out any difficulties which may have arisen and advise and assist in the setting up of the base. These visits also ensure that the latest Bristol Siddeley techniques are also used overseas. Bristol Siddeley Engines Limited is prepared to assist in setting up additional bases as these become necessary in the future.

Extensive facilities are also available in the Company's factories for training the operator's own personnel in all aspects of engine stripping, overhauling, rebuilding and testing.

## Records and Statistics

Arrangements are made for the collation of all the various statistics which emerge from the reports received from service engineers and operators, and a history is maintained of every engine in service together with any defects experienced. The co-ordination of all these facts makes it possible for each operator of Bristol Siddeley engines to benefit from the combined experience of all other operators.

## Emergency Services

The Company recognises the necessity for special facilities to be available in order to reduce to a minimum the possibility of an operator having to curtail services for lack of spare parts or of technical assistance in an emergency. In consequence a special section has been built up solely to deal with all the emergency requirements of operators at home and abroad. Thus any operator who may find himself in a position where his aircraft are likely to be grounded for want of some component or assistance can invoke the help of this special A.O.G. or "Aircraft on Ground" service.

Special facilities exist for meeting priority demands for spares, equipment or tools in instances where aircraft are grounded or such a situation is threatened. This service, which is given priority treatment throughout the Company, operates during normal working hours and evenings and also during week-ends and holiday periods. Being separate from the normal spares organisation this service is authorised to by-pass the normal channels in cases of emergency so as to ensure speedy delivery to the operator in accordance with his requirements.

In addition, the Company is equally appreciative of the necessity to provide as quickly as possible working parties for the purpose of effecting repairs, rectifications, or modifications to engines in the field whenever such services are requested by operators.

## Technical Publications

The operator is provided with detailed technical literature covering the maintenance and overhaul of the engine, its power plant and accessories. This information is presented in detailed form including diagrams covering all systems.

Large sized instructional diagrams are provided as a supplement to the information contained in the Maintenance Manuals and these are particularly helpful to the operator in providing his personnel with essential information. All these publications are amended and expanded as required, and in addition Technical Bulletins are issued to cover specific cases of servicing or operation on each engine type.

Modifications to improve the reliability and to assist in extending the overhaul life are notified to the operator by means of detailed leaflets explaining the reasons and providing an indication of the availability and cost, together with instructions covering the fitting of the modifications in the field.

## The Aero-Engine School at Bristol

The object of the School is to instruct customers' technical and operational staff in the maintenance and handling of Bristol Siddeley engines. The instruction given satisfies the standards required by the A.I.D. for military engines and by the British Air Registration Board for civil engines.

The School is well equipped with both lecture and exhibition rooms, and includes sectioned engines and components and working models to provide any kind of instruction required by the customer.

The courses of instruction, which are free of charge to customers' personnel, cover all types of Bristol Siddeley engines. The number of students attending has increased steadily since the end of the war and is now a thousand per year.

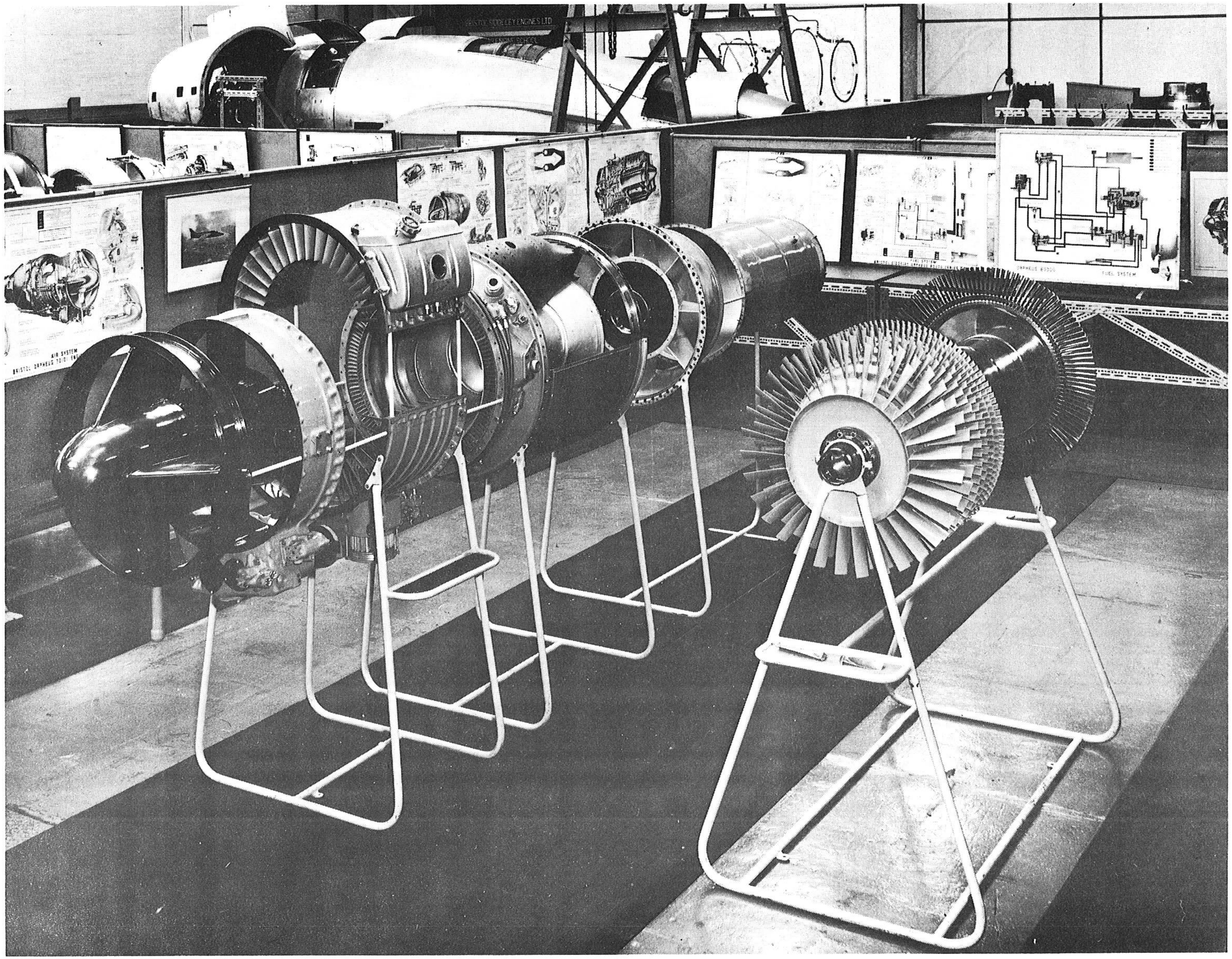
## Spare Parts Organization

The Bristol Siddeley organization for spare parts embraces the co-ordination of forward provisioning, manufacture, storage, packaging and supply of all Bristol Siddeley spares both for military and civil use.

An essential feature of a satisfactory supply of spares is an adequate plan of long term forward provisioning. The Spares Department, from its knowledge of world-wide operations of Bristol Siddeley engines, is able to forecast for several years ahead the probable consumption of overhaul and maintenance spares, upon which is based the bulk manufacturing orders issued to the factories for stock spares. By this means the most economical manufacture is assured and adequate stocks are always available.

An important responsibility of the Spares Department is to advise operators on their operational spares requirements so that in consultation with the engineering branches of the airlines, spares orders and stocks are matched in the most economical manner.

Fully illustrated and indexed spares catalogues are issued by the Spares Department together with price lists. A thorough and practical information service is provided to operators about modifications and alterations. This gives details of new modifications, their effect on maintenance, overhaul and existing stocks of spares, and recommendations for action. The information is simultaneously passed to the Bristol Siddeley service engineers whose responsibility is to assist airline operators with advice on the spot.



The Orpheus Section Of The Bristol Siddeley Aero-Engine School

The preservation, packing and despatch of spares for military and civil use is carried out in a large spares packing organization under the direction of the Spares Department. Spares are preserved and packed according to the climate of the destination and the storage conditions there; the standard throughout is fully approved by the British civil and military authorities.