

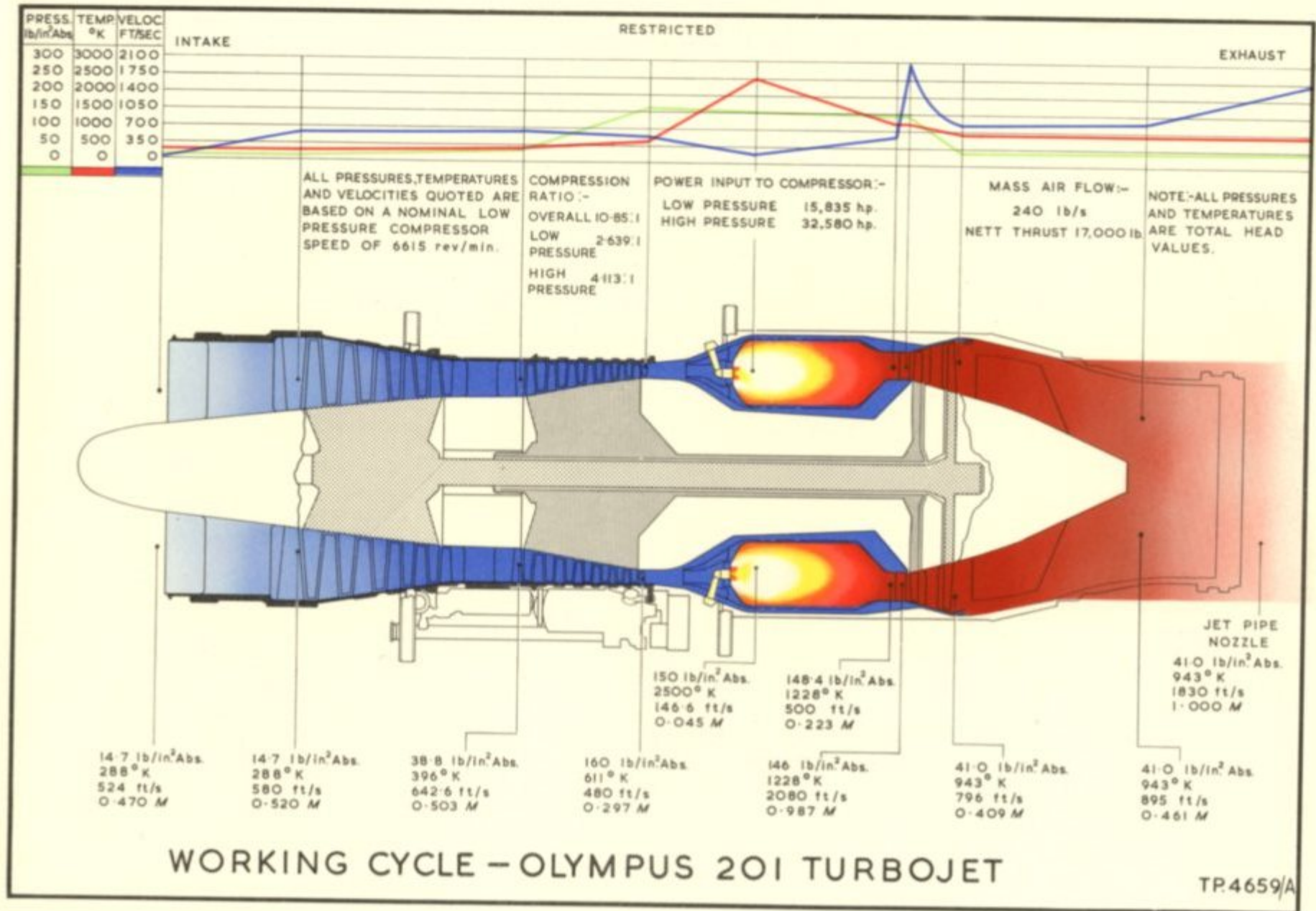
## SECTION 1

## BASIC GAS TURBINE

1.1 THERMODYNAMICS

1.2 GAS FLOW

1.3 ADVANTAGES OF A TWO SPOOL COMPRESSOR



WORKING CYCLE - OLYMPUS 201 TURBOJET

TP.4659/A

## AERO ENGINE SCHOOL

1.1. THERMODYNAMICSFirst Law of Thermodynamics

Broadly speaking this may be stated as follows:-  
Heat and mechanical energy are mutually convertible, and the 'rate of exchange' is constant and can be measured.

The rate of exchange is known as 'Joule's equivalent' and is usually denoted by the letter J. The value of J is 1,400 ft. lb. That is to say 1,400 ft. lb. of mechanical work would be required to raise the temperature of 1 lb. of water through one degree centigrade. This equals 1 C.H.U.

For example, if two rotating surfaces are in contact, and are not lubricated, the heat generated by the friction between them will soon raise their temperature by a measurable amount. Thus mechanical energy is converted into heat, but although this process is quite simple, it is far more difficult to convert heat to mechanical energy.

The latter indeed, is seldom accomplished without

considerable loss, as the comparatively low efficiency of the majority of heat engines amply demonstrate.

The Second Law of Thermodynamics

This may be stated as :- Heat cannot be conveyed from one body to another which is at a higher temperature, without the expenditure of energy supplied from an external source.

In other words, heat energy always runs down a temperature gradient, like water down a hill, and will not climb up a gradient unless forced to do so by the application of energy from an external source.

Boyle's Law

If the temperature remains constant, the volume of a given mass of gas varies inversely as the pressure exerted upon it.  $PV = \text{Constant}$ .

Charles Law ...

### Charles Law

If the pressure remains constant, a given mass of any gas expands one two hundred and seventy third of its volume at  $0^{\circ}\text{C}$  for each degree rise in temperature.

### Another Definition of Charles Law

If the pressure remains constant, the volume of a given mass of gas varies directly as the absolute temperature.

### Newton's Law of Motion

Law 1. A body remains in a state of rest, or of uniform motion in a straight line unless some external force is applied to change that condition.

This law states a principle sometimes known as "the Principle of Inertia", viz that a body has no tendency of itself to change its state of rest, or of uniform motion in a straight line, unless some outside force be applied to bring about such change.

For example: if , when travelling at speed in a car, the brakes are suddenly applied, the occupants are thrown forward, due to the tendency of a body to continue in a straight line of motion. If a car is driven round a bend so fast that the force tending to change its direction of motion (that is the grip of the wheels on the road) is overcome, the car will continue to travel in a straight line, or, in other words, will skid outwards from the periphery of the curve.

Law 2. The change of momentum in a body in a given time when acted upon by an external force is proportional to the applied force.

An aeroplane travelling in a straight line in still air has a certain momentum and direction. If a strong gust of wind (an outside force) suddenly strikes it from the right, it will no longer travel in a straight line but will move sideways to the left and the distance it travels in this direction will be in direct.....

## AERO ENGINE SCHOOL

be in direct proportion to the strength of the gust (or magnitude of the outside force).

Law 3. To every action there is an equal and opposite reaction.

BERNOULLI'S THEOREM

This states that when air is flowing in a convergent duct the velocity increases at the expense of the static pressure. When flowing through a divergent duct velocity decreases with a consequent rise in static pressure. In each case the change in pressure will be followed by a change in temperature.

Force and Mass

FORCE may be defined as anything which changes, or tends to change the state of rest, or uniform motion of a body. That which is capable of setting bodies in motion, or stopping them when they are in motion, or altering the direction or manner of their movement is called force.

The unit of force which is used generally in English-speaking countries is the weight of the standard pound. The standard pound is a piece of platinum kept in the Standards Department of the Board of Trade, which if suspended from a spring balance will deflect the spring and its indicator a certain distance, any other object which will deflect the spring the same amount when suspended from it is said to weigh one pound. Similarly, any force exerting a pull which will deflect the spring by this same amount is said to be the force of one pound.

MASS is defined as "the quantity of matter contained in a body". Any two bodies will have equal masses when they each weigh the same, irrespective of their size. A pound of lead would be comparatively small in volume when compared with a pound of aluminium, yet each

would be of ...

would be of equal mass. If, therefore, two bodies are of equal mass they will also be of equal weight (at the same place) and if one body contains two, three, four etc; times the mass of the other, that body will weigh two, three, four, etc; times as much as the other,

$$\begin{aligned} \text{THRUST (NET)} &= \frac{W(V - U)}{g} \\ \text{T.H.P. (FLIGHT)} &= \frac{\text{THRUST} \times U}{550} \end{aligned}$$

W = Airflow lbs/sec

M =  $\frac{W}{g}$  = Mass lb/sec.

F = Force = Rate of Change of Momentum

T = Thrust = Force lbs

T.H.P. = Thrust Horse Power

V = Velocity at Jet Ft/Sec:

U = Aircraft velocity Ft/Sec:

G = 32.2 ft sec/sec.

## AERO ENGINE SCHOOL

1.2 OLYMPUS GAS FLOW

The turbo jet develops its thrust as a result of a continuous cycle of compression, combustion, expansion and exhaust, applied to the working medium; this is air or a product of combustion after the fuel has been burnt in it.

Physical changes taking place are important as an indication of the way the cycle works. With a piston engine we should be interested in Pressures, Volumes and Temperatures at critical points in the 4 stroke cycle. In the gas turbine, we are interested in conditions at entry and delivery from the compressor, before and after combustion, at entry and discharge from the turbines and finally at discharge from the exhaust nozzle.

The Olympus has two stages of axial compressor, the low pressure stage and the high pressure stage, which are driven by separate turbines.

The low pressure compressor is a five stage axial

unit and air entering the compressor is accelerated at each rotor stage and diffused at the stator stages, with the result that the pressure is raised through the system with an attendant temperature increase.

The flow continues via the exit guide blades in the intermediate casing, and from here it now enters the seven stage high pressure compressor, where a similar action to that of the low pressure compressor takes place with the result that pressure and temperature is raised still further.

On entering the compressor delivery casing the air is diffused, so that its velocity is reduced before entering the combustion chambers.

As a result of combustion, in the flame tubes, expansion takes place at constant pressure,

so that the .....

so that the velocity of the gas moving towards the turbines is considerably increased, the greater portion of the air delivered to the flame tubes enters after the primary zone, so that the gas temperature is reduced before entering the turbine region.

By flowing through the stator, the components of velocity and pressure are controlled before entering the H.P. turbine rotor, the work done on this rotor drives the H.P. compressor to which it is connected, and is accompanied by a reduction in temperature and pressure.

The gas is then caused to flow through the second turbine unit, where a further temperature and pressure drop occur and work is done to drive the low pressure compressor.

On leaving the turbine the gas is slightly diffused before reaching the jet orifice. Expansion across the jet pipe causes sonic velocity to be

achieved at the nozzle and the reaction to the high velocity jet of gas gives a large thrust in a forward direction.

## AERO ENGINE SCHOOL

1.3 ADVANTAGES OF THE TWO SPOOL COMPRESSOR

A jet propulsion engine employing compound axial compressors individually driven by separate single stage turbines in conjunction with an annular combustion chamber with eight separate flame tubes.

Advantage of a two Spool CompressorHigh Pressure Ratio

For pressure ratio above 5:1 blow off valves are required for single spool engines to avoid stalling of the early compressor stages at around 70% max. r.p.m.

For pressure ratios of 7:1 on single spool engines, blow off valves and variable intake vanes are necessary. With two spools the compressor speeds adjust their relative values at off - design conditions so that no blow off valves are required and the compressor is less sensitive to intake velocity patterns.

The higher pressure ratio obtainable with a two spool engine, results in the following advantages:-

a. Lower specific fuel consumption.

b. The pressure in the combustion chambers is higher so that efficient burning is possible to higher altitudes. The altitude limit for combustion blow out is also higher.

c. Smaller frontal area for the same thrust since for pressure ratios above 8:1 the combustion chambers can be accommodated in a diameter smaller than that of the compressor entry.

2. Improved Acceleration

Owing to the better part load component efficiencies (compressor and turbine) which results from the ability of the two spools to adjust their relative speeds automatically, the acceleration of the engine is markedly improved.

3. Easier Starting

Only the high pressure system has to be rotated for starting, so that a smaller starter motor.....

starter motor can be used.

#### 4. Weight Saving

- a. The low pressure compressor can be made of light alloy, and the high pressure compressor of steel. A single spool engine of comparable pressure ratio would be entirely of steel.
- b. Since the high pressure compressor can rotate at a higher r.p.m. fewer stages are required for a given pressure ratio (N.B. the high pressure compressor can rotate faster because the higher temperatures result in lower mach numbers).

#### 5. Improved High Altitude Performance

The ability of the two compressors to adjust their relative speeds to give high efficiencies, and better combustion efficiency, results in improved performance at very high altitudes, by comparison with a single spool engine.

#### 6. Base of Mounting Accessories

Accessories can be driven conveniently from the end of the low pressure compressor in a region where the temperature is not too high, so that heat passed to oil in the casing is kept to a low temperature. The positioning of the accessories makes for ease of maintenance.

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