SECTION 1
CONTENTS

ALTITUDE CONDITIONS

Height Feet	Height Metres	Pressure Lb/sq.in.	Density Lb/cu.ft.	Pressure Milli-bars	Density Grm. per Cu. metre	Relative Pressure -	Relative Density -	Temp. °F	Temp. °C	Speed of Sound M.P.H.	Speed of Sound Ft/sec.	Unsupercharged Aircraft Engine H.P.	Correction to convert I.A.S. to True A.S. Multiply by
80.000	24,420	0.36	.002	25	35	.0247	.03	-70	-56.5	660	971	20	5.775
75	22,880	.50	.003	35	52	.0344	.04	-70	-56.5	660	971	25	5.000
70	21,350	.66	.004	46	70	.0414	.05	-70	-56.5	660	971	35	4.470
65	19,830	.83	.005	58	87	.0572	.07	-70	-56.5	660	971	45	3.782
60	18,310	1.04	.007	72	110	.0711	.09	-70	-56.5	660	971	60	3.335
55	16,780	1.31	.009	91	147	.0898	.12	-70	-56.5	660	971	78	2.892
50	15,240	1.68	.011	116	184	.1142	.1517	-70	-56.5	660	971	100	3.567
45	13,720	2.14	.015	147	233	.1450	.1926	-70	-56.5	660	971	135	2.275
40	12,190	2.72	.019	187	307	.1844	.2447	-70	-56.5	660	971	170	2.023
35	10,660	3.46	.024	238	381	.2347	.3098	-67	-54.3	661	973	225	1.800
30	9,144	4.37	.029	301	460	.2968	.3740	-49	-44.4	677	997	280	1.634
25	7,620	5.46	.034	376	552	.3709	.4480	-31	-34.5	693	1,013	360	1.494
20	6,096	6.77	.04	465	656	.4594	.5327	-13	-24.6	707	1,035	454	1.369
15	4,572	8.31	.048	572	774	.5642	.6291	5	-14.7	723	1,058	567	1.261
10	3,048	10.08	.056	697	908	.6876	.7384	23	- 4.8	739	1,081	693	1.164
5	1,524	12.23	.066	843	1.055	.8320	.8626	41	5.1	755	1,105	838	1.077
SEA LEVEL	SEA LEVEL	14.69	.077	1.013	1.226	1.0000	1.0000	59	15.0	771	1,128	1,000	1.000

ATMOSPHERIC TEMPERATURE REMAINS A CONSTANT VALUE ABOVE 36,090 FEET

First 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 poor efficiency of the majority of heat engines amply demonstrates.

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.

If the ....

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.

If the pressure remains constant, a given mass of any gas expands one two hundred and seventy-third of its volume at $0^\circ C$ 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 Laws 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 it 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.

The change ....

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 and takes place in the direction of that 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 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.

Bernouilli's Theorum

As velocity increases the pressure decreases. Pressure gradient in direction of flow.

As velocity decreases the pressure increases. Reverse flow gradient tends to cause flow in opposite direction.

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.......

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 by 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 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 another, that body will weigh two, three, four etc. times as much as the other.

W = Airflow (lbs/sec)

$M = \frac{W}{g}$ = Mass

F = Force = Rate of Change of Momentum

T = Thrust = Force lbs

T.H.P. = Thrust Horse Power

V = Velocity at Jet FT/SEC

U = A/C Velocity FT/SEC

g = 32.2 ft/sec.

$$\text{THRUST (GROSS)} = \frac{W \times V}{g}$$

$$\text{THRUST (NETT)} = \frac{W(V - U)}{g} \qquad = 32.2 \text{ ft./sec.}$$

$$\text{T.H.P.(FLIGHT)} = \frac{\text{THRUST} \times U}{550}$$

$$\text{T.H.P.(STATIC)} = \frac{T}{2.6}$$

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; as 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 Compressor

Whenever a compressor does work on the air flowing through it we should expect to see a rise in the pressure, or increase in the velocity of the flow or both. As it is the rise in pressure that we are interested in, the increase in velocity should be small and most of the work done on the air will produce a pressure rise. The accompanying rise in temperature is a measure of the amount of work done. Incidentally, if this rise is compared with the rise we ought theoretically to obtain for that pressure, we should be measuring the compressor efficiency.

The Combustion Chamber

If we prevent the pressure rising at all, in the combustion process, during the addition of fuel or heat energy to the air, all the heat energy added will go toward an increase in temperature and consequent increase in velocity.

These two,.......

These two, added together constitute the increase in the total head of energy that the stream now possesses.

The pressure in the combustion process can be prevented from rising by allowing for an unrestricted flow expansion along the combustion chamber.

The Turbine Assembly

In a way, this is the reverse of the compressor, for the turbine extracts and makes use of the head of energy and converts a proportion of it into mechanical power to drive the compressor. The amount of work done by exhaust gases in going through the turbines is measured by the drop in total temperature. The gas may be thought of as giving up some of its stock of internal energy when expanding through the turbine, so doing work on it and maintaining its own continuous flow.

The Jet

Finally, in the propelling nozzle, a further drop in pressure occurs as the expansion through the nozzle increases the velocity to its final value.

The above sequence is a broad and brief picture of flow conditions. If we go into greater detail, to examine what changes occur in these parts of the engine where the flow is being directed from passages of larger to smaller cross-section and vice versa, we shall find the velocity and pressure changes governed by:-

1 Expansion in which flow from larger to smaller passages produces an increase in velocity and fall in static pressure (with corresponding decrease in static temperature).

2 Diffusion.......

<u>2 Diffusion</u> in which flow from smaller to larger passages produces a decrease in velocity and increase in static pressure (with corresponding static temperature increase).

If these changes occur without any change in the total heat they are called adiabatic or isentropic, and the flow proceeds without any loss due to friction.

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 seven 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 to the intermediate casing, and from here it now enters the eight 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.

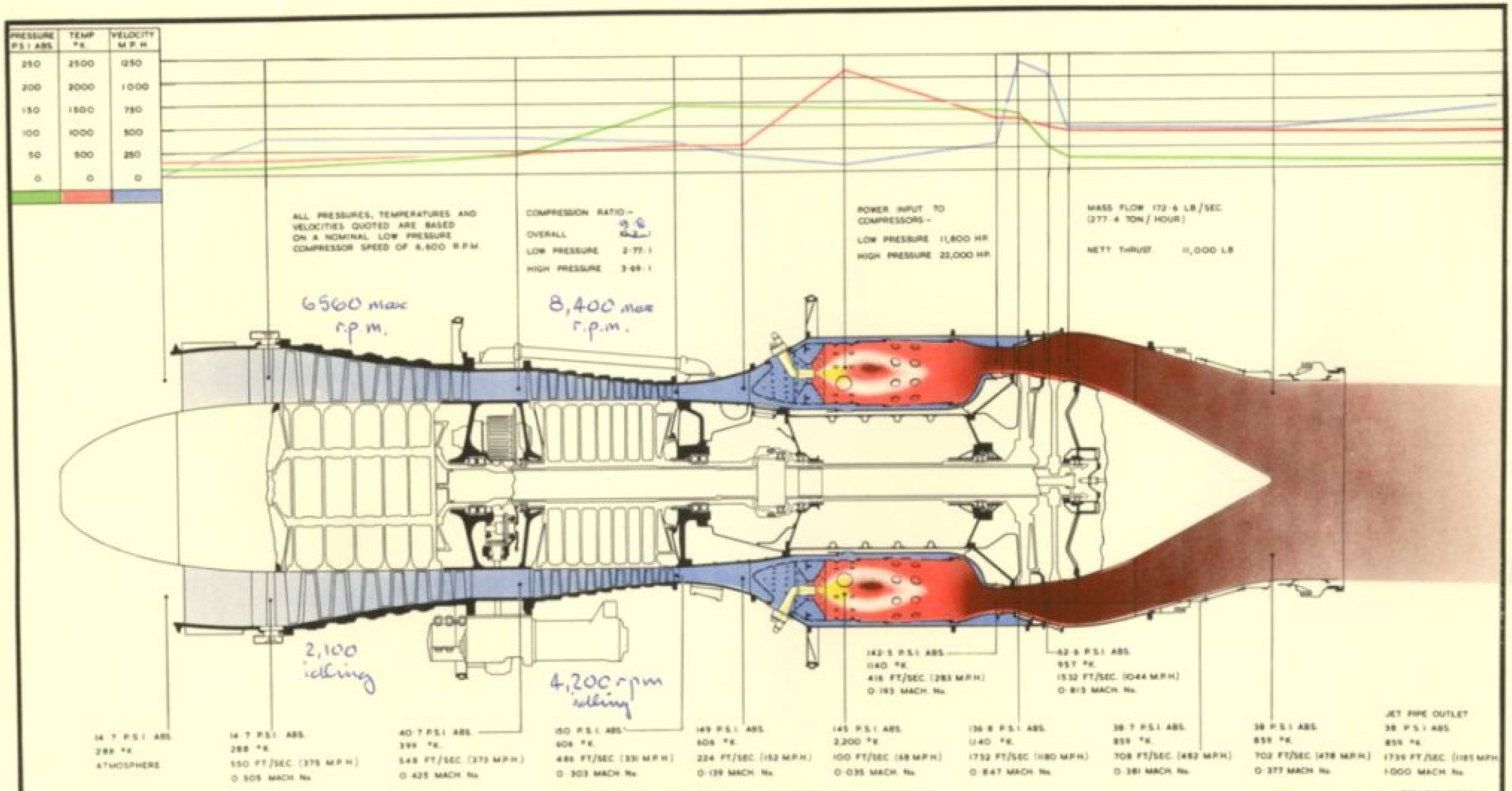
On entering the compressor delivery casing the air is diffused, so that its velocity is reduced before entering the combustion chambers.

As a result of combustion, in the flame tubes, expansion takes place at constant pressure, so that the velocity of the gas moving towards the turbine 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.



RESTRICTED.

GAS FLOW DIAGRAM
OLYMPUS TURBOJET MK. 10101 E.C.U.

TP. 2736