AVON 200 SERIES

ENGINE GAS FLOW

SEQUENCE HEADING CHART

1. INTRODUCTION.

(a) Summary of the Operating Cycle.

(b) Static and Total Measurements of Pressure and Temperature.

(c) Airflow in a Divergent Passage.

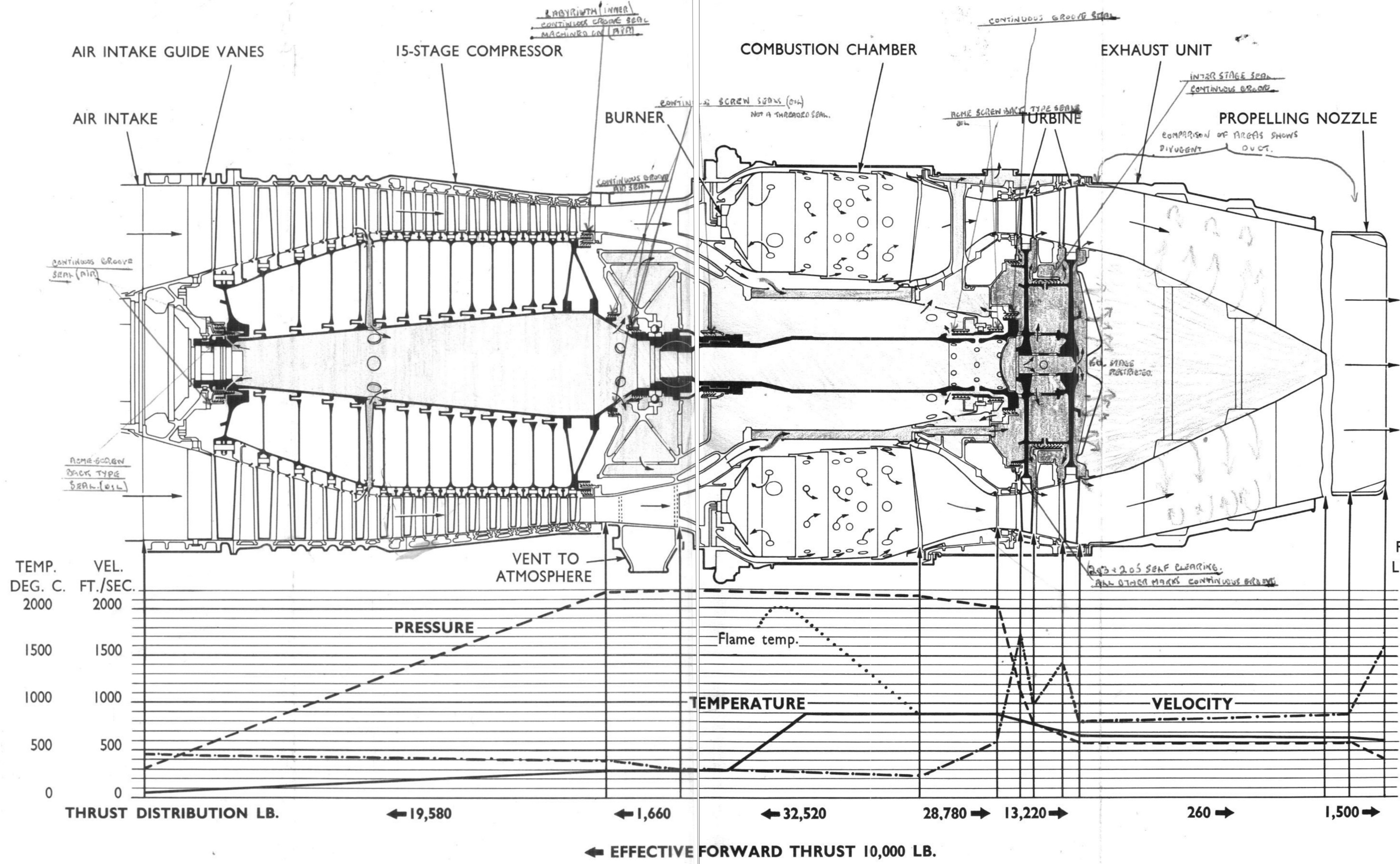
(d) Airflow in a Convergent Passage.

2. DETAILED STUDY OF AIRFLOW.

(a) Compressor	-	ROTOR AND STATOR BLADES.
(b) Combustion	-	FLAME TUBE AND FUEL BURNER.
(c) Turbines	-	TURBINE BLADES AND NOZZLE GUIDE VANES.
(d) Exhaust	-	EXHAUST UNIT AND JET PIPE.

19.2.60.

AERO ENGINE SCHOOL
COURSE NOTE
No. TAv.94
Printed in England



AIR FLOW DIAGRAM - AVON

5th stage press air front centre & rear.

15th stage press cooling turbine discs.

1.8.57

AVON 200 SERIES

ENGINE GAS FLOW

1. INTRODUCTION.

(a) SUMMARY OF THE OPERATING CYCLE.

The gas turbine is a form of heat engine which converts the chemical energy of fuel oil into mechanical work. The working fluid which is air passes through three major components, the compressor, combustion chamber and the turbine.

In passing through the compressor, work is done on the air and thus the outlet pressure of the air (P_2), is several times greater than the inlet pressure of the air (P_1). The ratio of these pressures (P_2/P_1) is called the compression ratio.

The compressed air is then delivered to the combustion chamber, where finely atomised fuel is injected into the airstream and combustion of the fuel takes place at a constant pressure. Thus the temperature of the gas stream is increased and heat energy is added to the gas stream.

On leaving the combustion chambers, the gas stream flows through the turbine assembly. In passing through the turbines the gas stream does work on turbine blades which is transferred to the turbine shaft through the discs. The turbine shaft then drives the compressor and the engine driven auxiliaries.

After passing through the turbines, the gas stream flows into the parallel section jet pipe. A propulsion nozzle is attached to the end of the pipe where the residual energy in the gas stream is converted into a high speed jet for propulsive purposes.

Above is only a brief summary of the events in the operating cycle, a more detailed analysis will now follow. To do this, a little basic knowledge of airflow through ducts is required.

(b) STATIC AND TOTAL MEASUREMENTS OF PRESSURE AND TEMPERATURE.

Two different measurements of pressure can be obtained from a moving airstream:-

> The static pressure (p) which can be obtained by positioning a tapping in the wall of the duct.
>
> The total pressure (P) which can be obtained by positioning a pitot tube in the airstream.

The difference between the two values is due to the fact that the pitot tube measures the static pressure plus the dynamic pressure of the airstream.

i.e. Total pressure = Static pressure + Dynamic pressure.

The dynamic pressure is a function of the speed of the airstream, therefore, it can be seen that, if the total and static pressures are known, the speed of the airstream may be determined.

/continued.

There are also two different measurements of the temperature for a moving airstream, total temperature (T) and static temperature (t).

i.e. Total temperature = Static temperature + Dynamic temperature

The next step is to see how these values of pressure and temperature change when the airstream passes through ducts of changing cross sectional area.

(c) AIRFLOW IN A DIVERGENT PASSAGE.

The speed of the airstream reduces as it passes into the increased cross-sectioned area of the duct. As energy is neither added nor subtracted from the airstream and there are no functional losses, the values of total pressure and temperature are unchanged across the section. However, the kinetic energy reduction of the airstream, gives an increase in the values of static pressure and temperature.

(d) AIRFLOW IN A CONVERGENT PASSAGE.

As probably would be expected a reverse set of conditions applies when the airstream passes through a decreasing cross-sectional area. The speed of the airstream increases and with the gain in kinetic energy a resulting decrease in the values of static pressure and temperature. Once again the values of total pressure and temperature across the section remain constant.

2. DETAILED STUDY OF AIRFLOW.

(a) COMPRESSOR,

The compressor consists of fifteen sets of rotor blades mounted on a common shaft, which is revolved at high speed between an equal number of stator blades retained in the compressor casings. A stage of the compressor consists of a set of rotor blades and a set of stator blades, the compressor is therefore a fifteen stage unit.

Prior to entering the compressor, the air passes through the intake ducting and the engine air intake casing. Positioned in the air intake casing are variable angle inlet guide vanes which automatically direct the air into the compressor, at an angle appropriate to its speed.

As the air passes through the rotor blades, work is done on the air, with the result that the total and static values of pressure and temperature are increased. The kinetic energy of the airstream is also increased in passing through the rotating blades. On leaving the rotor blades, the air passes through the stator blade passages where it is re-directed at the correct angle on to the next set of rotating blades.

A diffusion process takes place as the air flows through the divergent stator blade passages, thus the static values of pressure and temperature are increased as the kinetic energy is reduced. The values of total pressure and temperature are constant across the stator blades as there is no energy transfer.

The above processes are repeated in successive stages of the compressor, each stage imparting a small pressure and temperature rise to the airstream. At maximum speed the compressor outlet pressure is approximately eight times the inlet pressure, therefore, the annulus area of the compressor is gradually reduced to accommodate the increasing air density. The last stage of stator blades act as outlet guide vanes and direct the airstream in a smooth axial flow into the compressor outlet section.

 /continued.

(b) COMBUSTION.

Radial spars in the compressor outlet casing divide the annular area into eight segmental shaped divergent ducts. An air scoop to provide front end location for the flame tube is centrally positioned in each duct.

The air inlet to the scoop is elliptically shaped to blend in with the section of the duct. The amount of air which passes through the scoop is determined by a circular metering orifice inside the scoop, downstream of the air inlet. The air is then supplied to a ring of swirl vanes in the front end of the flame tube, located around the centrally positioned fuel burner. Emerging from the swirl vanes, the general pattern of the airflow is in the form of a hollow cone, producing a central region of low pressure.

Most of the air from the compressor passes around the outside of the air scoop and is delivered into the combustion chamber annulus area, surrounding the flame tubes. In passing around the scoop, a small amount of air is tapped through twelve holes positioned in the scoop outer wall. This air is then delivered on to the front face of the flame tube flare for cooling purposes. On emerging from the flare, the flow blends in with that from the swirl vanes.

The air delivered to the outside of the flame tubes is mainly used for gas temperature dilution and flame tube cooling purposes and is progressively fed into the flame tube through corrugated strips and holes.

However, some of the air which enters the first set of holes, flows inwards and forwards towards the low pressure region created by the swirler and flare. Thus a low velocity re-circulating vortex is created in the primary zone of the flame tube.

Fuel from the burner is continuously sprayed into the centre of the air rotation where the returning hot gases raise the freshly injected fuel droplets to the combustion temperature. The pattern of the airflow in the region is responsible for anchoring and stabilizing the heart-shaped flame.

The combustion of the fuel completes the addition of energy to the gas stream, some of which will be converted into shaft horse power by the turbines to drive the compressor and auxiliaries, the residue providing jet thrust.

(c) TURBINES.

The flow of gas from the flame tubes enters the nozzle box where discharge nozzles convert the flow into an annular form and direct it into the convergent passages between the high pressure nozzle guide vanes. The guide vanes impart a high angular velocity to the gas with a consequent reduction of static pressure and temperature.

The high velocity gas stream is then directed on to the turbine blades, producing an 'impact' force on the turbine blades to rotate the wheel, this occurs in the first section of the turbine blade passages.

The gas then flows through the convergent second section of the turbine blade passage, which produces an acceleration of the gas stream through the passage. This acceleration of the gas produces a 'reaction' force on the turbine blades to rotate the wheel.

/continued.

Thus the turbine blades extract energy from the gas stream which is reflected by a reduction in the total pressure and temperature. In passing through the intermediate and low pressure stages of the turbine assembly, there is a repetition of the events in the high pressure stage.

The annulus area of the assembly is gradually increased from front to rear to accommodate the increasing expansion of the gas.

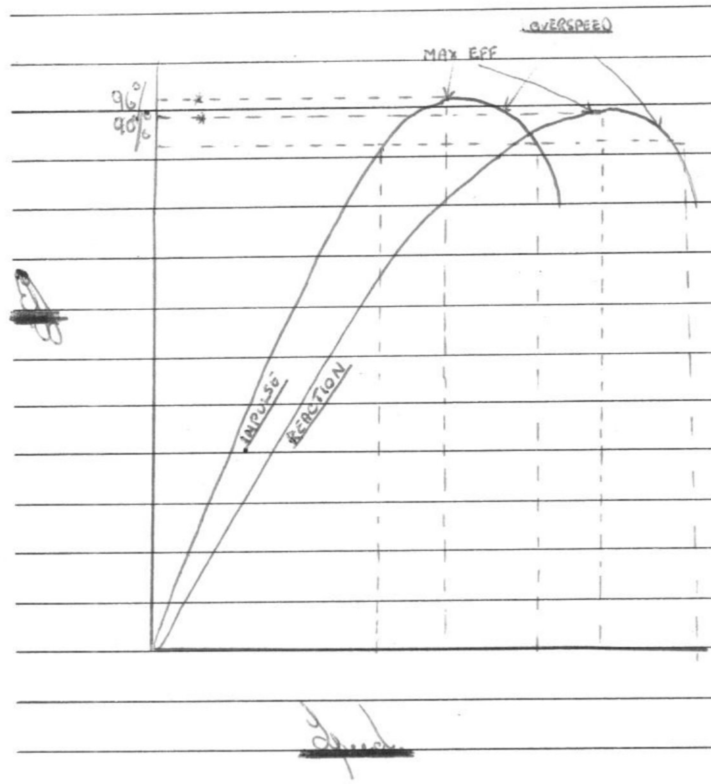
(d) EXHAUST.

On leaving the L.P. turbine the gas stream passes through the exhaust unit which consists of an inner cone supported by four streamlined struts in an outer tapered tubular casing. The inner cone prevents the exhaust gases from re-circulating back on to the rear face of the L.P. turbine disc. The streamlined struts help to straighten out the gas stream by removing any residual whirl which may be left in the gas stream, after leaving the L.P. turbine.

From the exhaust unit the gas stream enters the parallel-sided jet pipe, the length of which will vary with different installations.

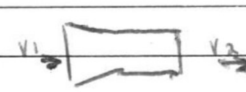
Finally the gas stream is accelerated back to atmosphere through the convergent propulsion nozzle attached to the end of the jet pipe.

ADDITIONAL NOTES



Thrust due to acceleration of air.

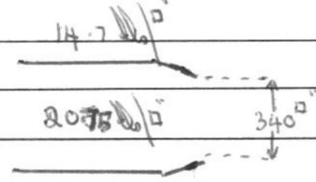
$T = W \times \frac{(V^2 - V^1)}{G}$



Static

W = weight of air	= 119 lbs/sec.	= $\frac{119(1670 - 0)}{32.2}$	
V^2 = final velocity	= 1670 ft/sec.		
V^1 = initial velocity	= 0 ft/sec.	= **7946** lbs thrust.	
G = gravity	= 32.2 ft/sec/sec.		

Thrust across final nozzle.



~~20.75~~ 20.75 − 14.7 × 340.
= 6.05 × 340
= **2057** lbs thrust.

7945 lbs thrust
2057 " "
10.002 lbs thrust.

ADDITIONAL NOTES

Development

MK No.	TYPE	THRUST	A/C.	REMARKS
201	R.A.14.	9,500 lbs.	VALIANT.	ELEC STARTER. NOT IN USE. } 1st 200s.
202.	R.A.24	11,250 lbs	SCIMITAR.	AIR STARTER.
203.	R.A. 28	10,000 lbs	HUNTER 6.	I.P.N. STARTER.
204.	R.A. 28	10,000 lbs	VALIANT	ELEC STARTER.
205.	R.A. 28	10,000 lbs	VALIANT	ELEC STARTER. (204 WITH WATER METHANYL INJECTION)
206.	R.A.24	11,250 lbs.	CANBERRA P.R.9	IPN STARTER.
GOLD STAR ENG. 207	R.A. 28	10,150 lbs	HUNTER MK 9 & MK 10.	IPN STARTER.
208.	R.A.24.	11,250 lbs	SEA VIXEN.	AIR STARTER.
209.	R.A.24.	11,000 lbs DRY 14,000 lbs WET.	LIGHTNING.	IPN STARTER.
210	RA24	11,250 lbs	LIGHTNING	IPN STARTER (MODIFIED REHEAT)

203 IDLING 2,500 APP IDLING 4,500 MAX 7850.
204 IDLING 3,000 APP IDLING 4,500 MAX 8000
205 " " " " " " "

% INDICATORS. 1% = 80 r.p.m. MAX being 8,000 r.p.m.

Removal of Corrosion on Magnesium Castings.

(1) Remove corrosion with rotary file or scraper (do not use a wire brush)

(2) Clean off with water and clean rag.

(3) Apply a solution of 10% Selenious Acid and water. (until casting turns brown)

(4) Wipe down with water and clean rag.

(5) Apply one coat of magnesium primer.

(6) Apply one coat of air drying black enamel.

Pressure Coding.

P.0. = Atmospheric.
P.1. = Intake Pressure.
P.2. = Compressor Delivery. (15th stage).
P.3. = Turbine Entry.
P.4. = Jet pipe.

Compressor stage pressures denoted by p.1. to p.15.