CHAPTER 1

GENERAL

- SYMBOLS
- UNITS
- REVIEW OF A FEW PRINCIPLES
- PRINCIPLES OF PROPULSION
- VARIOUS TYPES OF ENGINES
- THEORY OF OPERATION OF A GAS TURBINE ENGINE
- GAS TURBINE ENGINE COMPONENTS
- PERFORMANCES AND CHARACTERISTICS
- FACTORS AFFECTING THE PERFORMANCES
- VARIOUS FUNCTIONS OF A TURBO ENGINE
- TURBO-SHAFT FREE TURBINE ENGINE
- TURBO-JET BY-PASS AND TWIN SPOOL
- TURBOMECA SURVEY
- ENGINE DRAWINGS

SYMBOLS

Cte	:	Constant
C	:	Consumption
CH	:	Fuel consumption (in kilograms per hour)
Cs	:	S.F.C. (Specific Fuel Consumption)
Ch or CV	:	Horse Power (French system)
d :	:	Distance
F	:	Force or Thrust
G	:	Air flow (in kilograms/second)
Hp	:	Hectopieze
K	:	Coefficient (a Constant)
K°	:	Kelvin Degree
Kw	:	Kilowatt
l	:	Litre
m	:	Mass
mb	:	Millibar
N	:	Rotation speed (in RPM)
da Nw	:	Deca Newton
Nw	:	Newton
P	:	Pressure
Px	:	x = ref. indicating station e. g. : P2 = Pressure at station 2
Ph	:	Oil Pressure
Pr	:	Residual thrust

Q	:	Flow in litres per hour
R or Rég	:	Regulator (control unit)
T	:	Absolute temperature (in degrees Kelvin)
t	:	Relative temperature (in degrees Centigrade)
Tx	:	x = ref. indicating station e. g. : T2 = temperature at station 2
th	:	oil temperature
t	:	Time in seconds
V	:	Velocity
V_i		Aircraft speed
Vo	:	Volume
W	:	Power
Z	:	Altitude
η (êta)	:	Efficiency
Δ (Delta)	:	Difference
Δ P	:	Pressure difference
Δ T	:	Temperature difference
Ω (Omega)	:	Ohm
α (Alpha)	:	Angle
β (Bêta)	:	Angle
γ (Gamma)	:	Acceleration
ω (Omega)	:	Angular velocity

UNITS

	C. G. S.	M. T. S.	M. K. p. S.	M. K. F. S. ou SI
Length	Centimètre cm	Mètre - m	Mètre - m	Mètre - m
Mass	Gramme - gr	Tonne - t	Kilogramme kgp	Kilogramme-mass kgf
Time	Seconde - s	Seconde - s	Seconde - s	Seconde - s
Force	Dyne - dy	Sthène - sn	Kilogramme kg	Newton - Nw
Work	Erg	Kilojoule kj	Kilogrammètre kg/m	Joule - J
Power	Erg/s	Kilowatt - kw	Kilogrammètre-seconde kg/m/s	Watt - W
Pressure	Barye - b	Pièze - Pz	Kilogram/cm2 kg/cm2	Pascal - P

CONVERSION FACTORS

Mass :	1 kgp	= 9,8I	kgf		
	1 kgf	= 0,I02	kgp		
Force :	1 kg	= 9,8I	Nw		
	1 Nw	= 0,I02	kg	=	10^5 dynes
	1 sn	= 102	kg		
Work :	1 kg/m	= 9,8I	Joules		
Power :	1 kg/m/s	= 9,8I	W		
	1 CV	= 0,736	kw	=	75 kg/m/s
	1 kw	= 102	kg/m/s	=	1,36 CV
Pressure :	1 kg/cm2	= 98,1	Pz		

1 Atmos : 1013 mb = 1,033 kg/cm2 = 760 mmHg = 101,3 Pz = 29,92 inch/Hg.

Conversion table for units of pressure

UNITS OF PRESSURE	Pa	mb	pz	mm H^2 O	g/cm2	mm Hg	p.s.i.	in.of.hg
Pascal Newton/m2	1	0,01	0,001	0,101972	0,010197	0,007500	0,000145	0,000295
Hectopascal mb	100	1	0,1	10,1972	1,01972	0,75006	0,014503	0,02953
Kilopascal [illegible]ze	1000	10	1	101,972	10,1972	7,5006	0,145037	0,2953
mm H2O kg/m2	9,80665	0,098066	0,0098066	1	0,1	0,073556	0,001422	0,002896
g/cm2	98,0665	0,980665	0,0980665	10	1	0,73556	0,014223	0,02896
mm Hg	133,322	1,33322	0,133322	13,5951	1,35951	1	0,01934	0,03937
Pound Per square inch	6.894,8	68,948	6,8948	703,08	70,308	51,71	1	2,036
inch of Hg	3.386,4	33,864	3,3864	345,3	34,53	25,4	0,4912	1

REVIEW OF SOME BASIC PRINCIPLES

PRINCIPLE OF ACTION AND REACTION

When a body A exerts a force F on a body A', the body A' exerts a force F' on the body A, equal and opposite to F.

It is said that the action is equal to the reaction.

FUNDAMENTAL LAW OF DYNAMICS

The force which creates the movement is proportional to the acceleration :

$$F = m\gamma$$

GRAVITY

When the force represents the weight of the body, the acceleration of the fall of the body is called the acceleration of gravity.

$$P = mg$$

$$g = 9{,}8I \text{ m/S/s at Paris}$$

QUANTITY OF MOVEMENT (MOMENTUM)

This is the product of the mass into the velocity.

$$Q = m \times V$$

FORCE-TORQUE

The moment of a force is the product of the force into its distance from the point of application.

$$M = Fd$$

The couple is the combination of two equal forces, parallel and in opposite directions.

The moment of the couple is equal to :

$$C = Fd$$

WORK This is the product of the force times the displacement :

POWER Work done by unit of time

$$W = \frac{T}{t} = \frac{Fl}{t}$$

When the displacement is angular : $W = C \times \omega$

$$C \text{ (couple)} = FL \qquad \omega = \frac{2\pi N}{60}$$

$$W = \frac{2\pi N \times F \times L}{60}$$

ENERGY

Potential

Energy stored in a body and which can be released as required.

$$T = Mgh$$

Kinetic

Energy of a displaced body.

$$E = \frac{1}{2} mv2$$

BERNOUILLI'S THEOREM

In a liquid flow, the sum of the energies is constant.

$$P = \frac{1}{2} \rho v2 = Cte$$

? = static pressure

$\frac{1}{2} \rho v2$ = dynamic pressure

ρ = Density

v = Velocity

The Bernouilli's theorem is only applicable at subsonic speeds. At the supersonic level, St Venant ' s law must be applied.

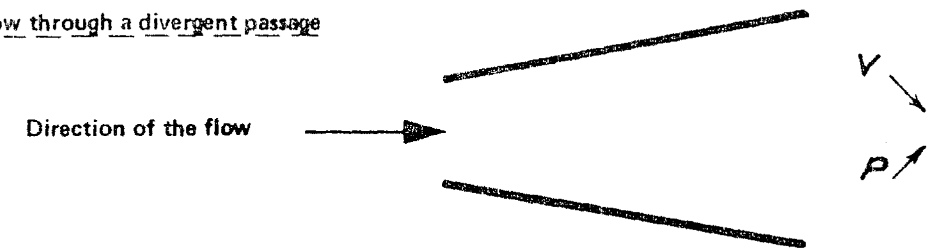
$$Cp \quad T + \frac{1}{2} \rho V2 = Cte$$

Cp = Specific heat at a constant pressure

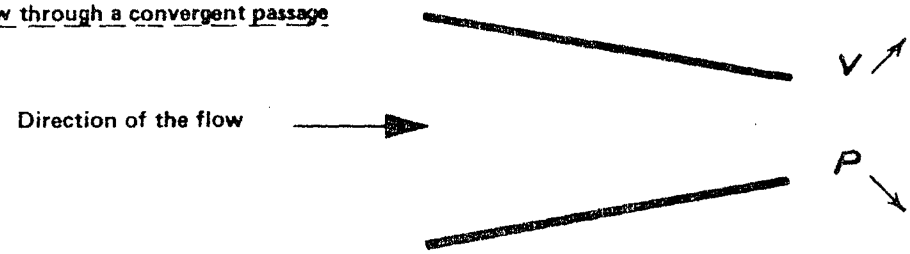
T = Absolute temperature

Application of Bernouilli's theorem

Flow through a divergent passage

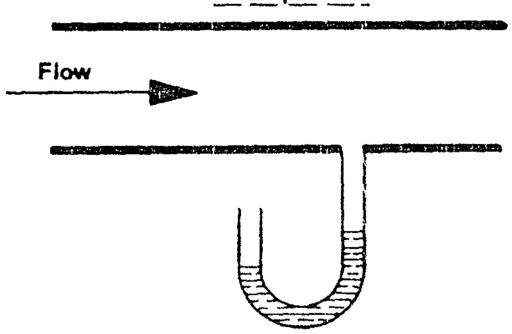


Flow through a convergent passage

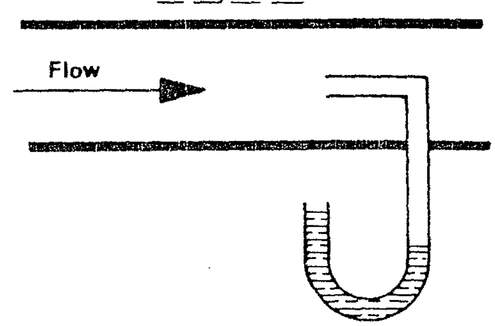


Measurement of pressure

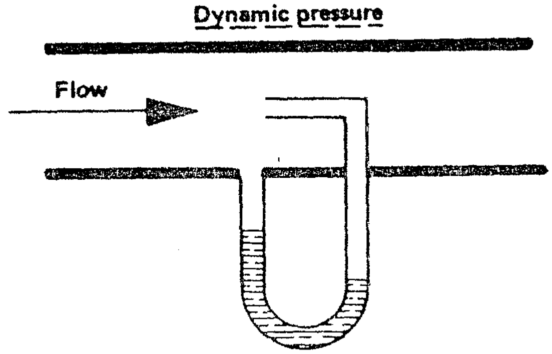
Static pressure



Total pressure



Dynamic pressure



$$P + \frac{1}{2}\rho v^2 = P_t$$

$$\frac{1}{2}\rho v^2 = P_t - P$$

REVIEW OF THERMODYNAMICS

Perfect gas equation

$$PV = RT$$

P : Pressure
V : Volume
T : Temperature

R : Constant
about 287 for air

Two of the above parameters are sufficient to determine the state of a gas.

Specific heat

At constant volume

$$Q = m\,Cv\,(T2 - T1)$$

Q : quantity of heat
Cv : specific heat
T2 - T1 : change in temperature

At constant pressure

$$Q = mCp\ (T2 - T1)$$

Cp : specific heat

Relationships

$$Cp > Cv$$

$$\frac{Cp}{Cv} \approx 1{,}4 \text{ for cold air}$$

First law of thermodynamics

$$W + JQ = 0$$

W = Work
Q = Heat
J = Mechanical equivalent of heat

J = 4.186 j = 425 kg/m

Transformation of state

- Adiabatic : without exchange of heat with the atmosphere = no heat transfer
- Isothermic : at constant temperature
- Isobar : at constant pressure

Example of a reversible adiabatic transformation

$$\frac{CP}{CV} = \gamma$$

$$P1\,V1 = P2V2$$
$$P1\,V1 = RT1$$
$$P2V2 = RT2$$

$$\frac{T2}{T1} = \left(\frac{P2}{p1}\right)^{\frac{\gamma - 1}{\gamma}}$$

FLUID MECHANICS

$$CpT + \frac{I}{2} \rho v2 = Cte$$

Cp : specific heat at constant pressure

Calculated impact temperature

$$Cp\ T1 = Cp\ To + \rho \frac{1}{2} v2$$

$$T1 = To + \frac{V2}{2\ Cp}$$

With the Mach number : $M = \dfrac{Vi}{\text{Speed of sound} = 20.1\sqrt{to}}$

$$T1 = To\ (1 + 0.2\ M^2)$$

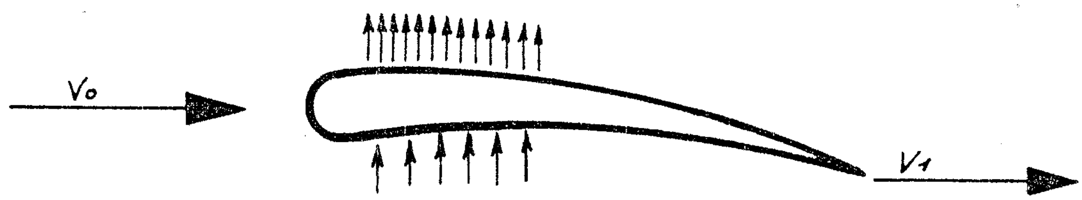
Total pressure calculation

$$\frac{T1}{To} = \frac{P1}{Po}^{\frac{\gamma - 1}{\gamma}}$$

$$\frac{P1}{Po} = \frac{T1}{To}^{\frac{1}{\gamma - 1}}$$

PRINCIPLES OF PROPULSION

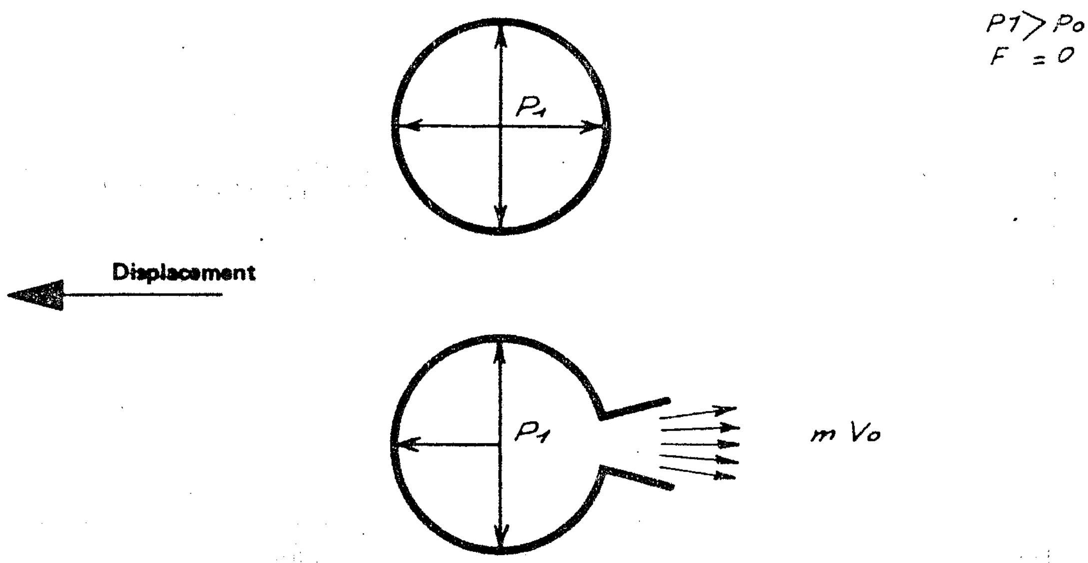
Propulsion by action



Low speed difference

High pressure difference

Propulsion by reaction



The forward force is the result of the internal pressure forces.

If we recall the fundamental law of dynamics :

$$F = m\gamma$$

In this case : $F = mv$

m = mass of ejected gas
v = speed of ejected gas

JET DEVICE

$$F = m\,(V_1 - V_o)$$

A mass of air "m" enters the engine with a velocity VO.

By some means (e.g. combustion) the engine gives an acceleration to this mass which is ejected towards the rear at a velocity V1.

Then a forward force is produced which is called the thrust.

$$F = m\gamma$$

$$F = m\,(V1 - Vo)$$

It can be seen then, that this propulsive force depends on the mass of air and the exit velocity of the gas.

It is not necessary to take into account the quantity of fuel which has to be injected to obtain acceleration when calculating the thrust.

VARIOUS TYPES OF ENGINES

The engines used in aeronautics are those which transform the potential energy contained in the fuel.

- either into kinetic energy (direct reaction)
- or into mechanical energy (indirect reaction).

Most of the engines use the air as a combustor and make it undergo a series of transformations which are generally divided into three phases : compression, combustion, expansion.

An engine is therefore divided into three main sections :

- A compression stage (static, rotative, or alternative).
- A combustion chamber
- An expansion stage (static, rotative, or alternative).

CLASSIFICATION OF ENGINES

Jet engines may be classified in two main categories :

- Those not using the ambient air.
- Those which do use it.

One can also consider :

- The direct reaction engines (kinetic energy).
- The indirect reaction engines (mechanical energy)

The above illustrated diagram shows some of the most frequently used engines.

NOTE

The rocket is the only jet engine which does not use the ambient air.

NOTE

The diagrams illustrate some gas turbines produced by TURBOMECA.

DIRECT REACTION DEVICES
(Producing kinetic energy)

Rocket

The engine is composed of : a tank assembly, a supply and injection system, a combustion chamber, an exhaust pipe ; There is a distinction between rockets using powder and those using liquid fuel.

Ram Jet

Like the rocket, this engine has no moving mechanical parts. The compression is carried out in the air intake channel, chiefly by means of a ram effect at high speed. The fuel is injected and burnt in the airstream. The exhaust gases are released through a jet propulsion nozzle.

Pulso Jet

It is a ram jet with air intake guide vanes which open and shut according to changes in the air pressure. These guide vanes can be operated or closed down as required.

Turbo Jet

The atmospheric air is sucked in, compressed and released into the combustion chamber by the compressor.

It is mixed with the fuel injected into the chamber, and burnt continually.

The gases coming out of the combustion stage are released towards the rear through a turbine and a nozzle.

Part of the energy is used by the turbine to drive the compressor.

By-pass Turbo Jet

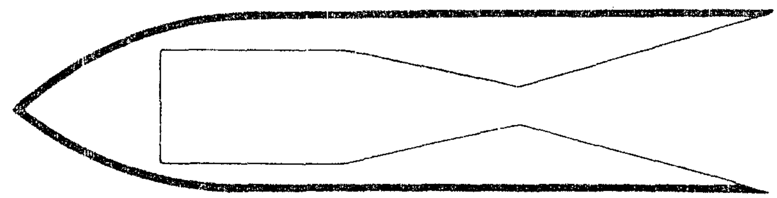
This is a turbo jet into which enters more air than required for the generator. The air is divided into two flows :

- a cold flow
- a hot flow for the gas generator

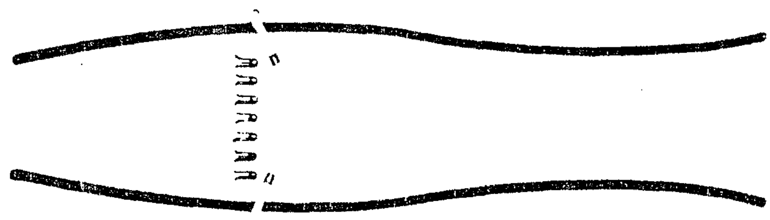
Increasing the air flow allows an increase in the efficiency of the propulsion.

KINETICAL ENERGY

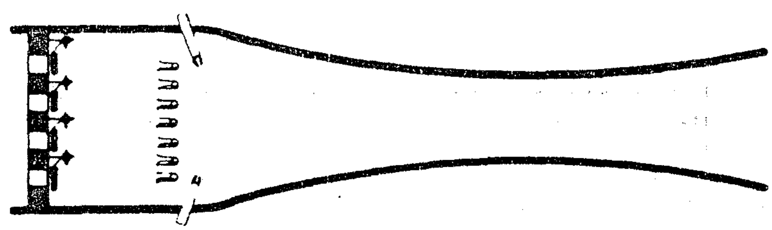
Rocket engine



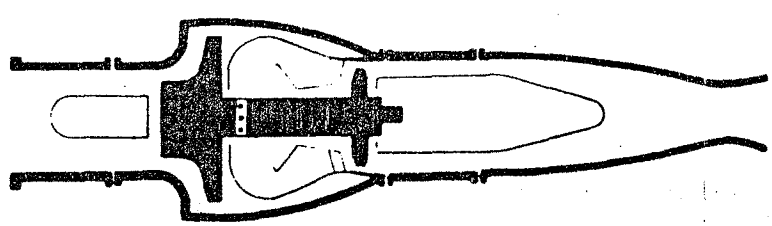
Ram jet engine



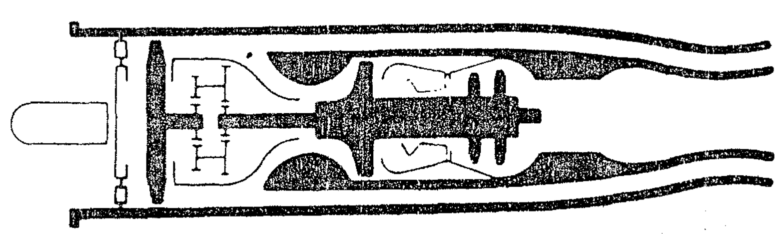
Pulso - jet engine



Turbo - jet engine



By - pass jet engine



INDIRECT REACTION DEVICES

(Producing mechanical energy)

Reciprocating engine Turbo-compound

A reciprocating engine driving a propeller. In the case of a turbo-compound there is one rotative compression stage (supercharger) and one expansion stage (turbine)

Turbo-propeller

A gas turbine driving a propeller. The turbines of the generator use as much of the energy from the burnt gases in order to drive the compressor and the propeller.

Turbo-shaft

A gas turbine for various applications. Driving a helicopter rotor, an electric current generator, a hydraulic pump, etc.

Free turbine

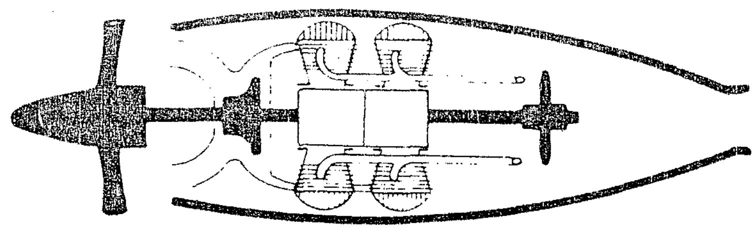
A classical gas generator (same principle as a turbo-jet engine) which delivers power in the form of kinetic energy to a free turbine. The free turbine converts this kinetic energy into mechanical energy through a driving-shaft to the receiving body. A free turbine can be used in the turbo-jet, turbo-propeller, or turbo-shaft plant.

Turbo air generator

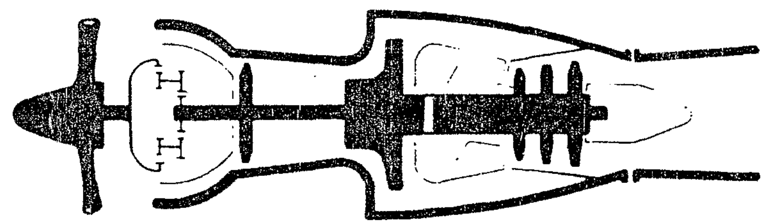
This can be considered as a special case in our classification since it delivers neither mechanical energy on to a shaft, nor kinetic energy from burnt gases which could be used for propulsion. The compressor is oversized, so that the compressed air should be used at a relatively high temperature immediately after it oomes out of the compressor. Such an assembly is used for the jet propulsion of helicopter rotor (Djin), as a starting unit, as a heating device, etc ...

MECHANICAL ENERGY

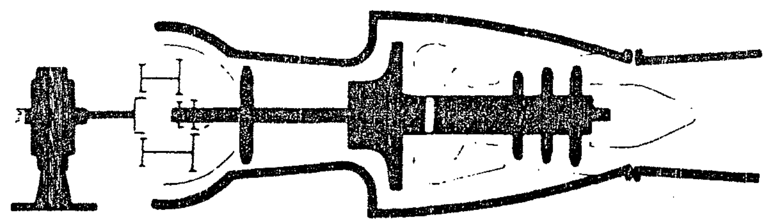
Reciprocating engine



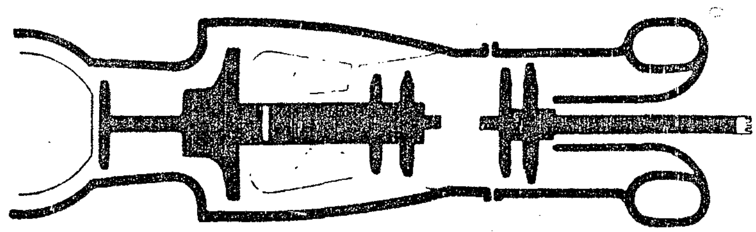
Turbo - propeller



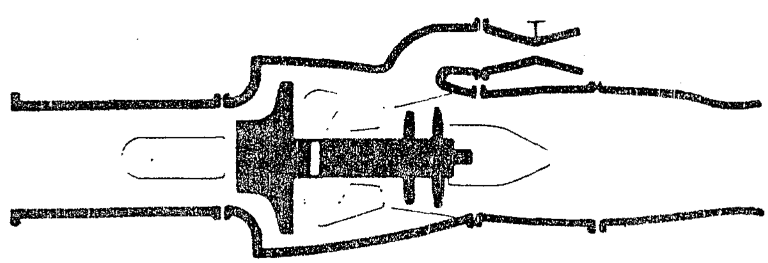
Turbo - shaft



Free turbine



Turbo - air generator



GAS TURBINE ENGINE

THEORY OF OPERATION

PHASES OF OPERATION

Whatever the type of propulsion, the following phases of operation are always present :

- Compression
- Combustion
- Expansion

GAS TURBINE ENGINE MAIN COMPONENTS

A gas turbine contains the following sections :

- Air intake - Compressor	) compression
- Combustion chamber	) combustion
- Turbine - Jet pipe	) expansion

PRINCIPLE OF OPERATION (see diagram page 23)

The air is taken in at a certain speed through the air intake. In flight, because of the air speed, it undergoes an initial conversion.

It is then compressed in the compressor and released into the combustion chamber.

In the combustion chamber, it is divided into two flows.
- A primary air flow (mixed with the fuel and burnt under constant pressure)
- A secondary air flow (for cooling).

The burnt gases then undergo a first expansion in the turbine, yielding to the latter a fraction of their energy required to drive the compressor, the accessories, and, on occasion, the receiving body (in a turbo-shaft) then a second expansion in the exhaust pipe.

P = Pressure

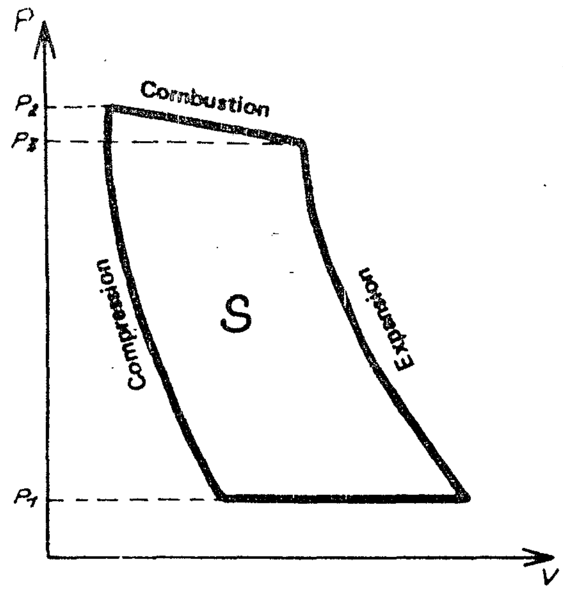
T = Temperature

V = Velocity

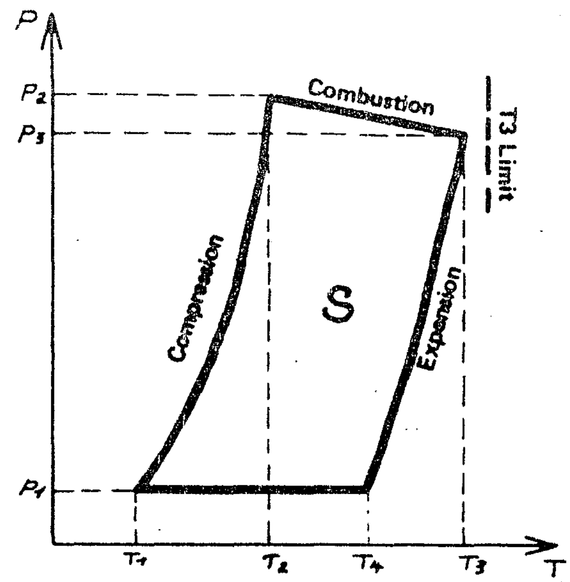
________ = Primary air

------- = Secondary air

ENGINE DIAGRAMS (THEORETICAL)



Pressure - Volume



Pressure - Temperature

Compression

Adiabatic : $\frac{T1}{To} = \left(\frac{P2}{Po}\right)^{\frac{\gamma - 1}{\gamma}}$

Required power mcp (T2 - T1)

Combustion

Isobar P2 $>$ P3
T2 $\rightarrow$ T3

Expansion

Adiatic $\frac{T3}{T4}$ $\left(\frac{P3}{P4}\right)^{\frac{\gamma - 1}{\gamma}}$

CONCLUSIONS

To increase the surface, i. e. the useful work, one must :
- increase the compression ratio P2/P1
- increase the temperature at the entry of the turbine T3.

POWERS AND EFFICIENCIES

Thermodynamic power (WT)

This is the power that oould be got from the fuel if the machine was perfect :

$$WT = Wc \times Nt$$

Wc = power supplied by the burnable fuel
Nt = theoretical efficiency of the cycle

Thermic power (W th)

This is the power transmitted to the mass of gas during its passage through the machine :

$$W\ th = \frac{1}{2} M (V_1^2 - V_o^2)$$

Propulsive power (Wp)

This is the power used in flight :

$$Wp = T \times Vo$$

T = thrust = m (V1 - Vo)
Vo = Air speed

$$Wp = M (V1 - Vo) Vo$$

Dissipated power (Wd)

This is the difference between the thermic power and the propulsive power :

$$Wd = W\ th - Wp \qquad W_j = \frac{1}{2} m v^2$$

Jet power (Wj)

This is the energy of the mass of gas as it leaves the turbo-shaft :

$$W\ th = Wd = Wj$$

Thermodynamic efficiency (ηT)

This is the ratio between the the thermodynamic powe: WT and the energy supplied by the combustible fuel :

$$\eta T = \frac{WT}{Wc} = \frac{\gamma - 1}{1}$$

Should the compression ratio be called γ, it can be seen that the higher γ is, the greater is the efficiency.

Thermic efficiency (η th)

This is the ratio between the thermic power and the calorific power of the combustible fuel :

$$\eta\ th = \frac{W\ th}{Wc}$$

It is of the order of 25 to 30 %.

Internal efficiency (ηi)

This is the ratio between the thermic power and the thermodynamic power :

$$\eta i = \frac{W\ th}{WT}$$

It is about 80 %.

Efficiency of propulsion (ηp)

This is the ratio between the propelling power and the thermic power.

$$\eta p = \frac{Wp}{Wth} = \frac{M\ (V1 - Vo)\ Vo}{\frac{1}{2}\ M\ (V1^2 - Vo^2)} = \frac{2\ Vo}{V1 + Vo}$$

It is about of 60%

Overall efficiency

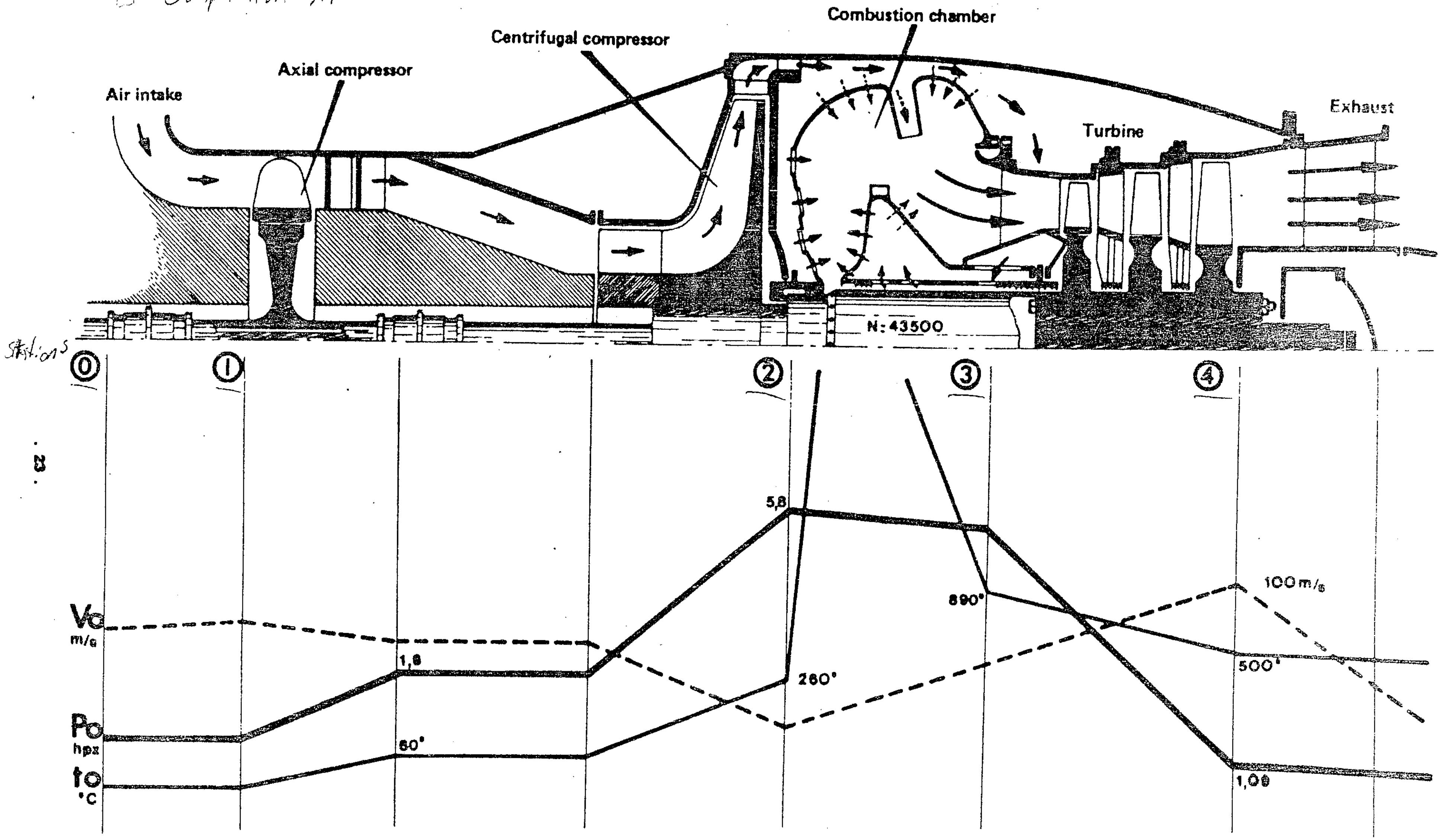
This is the ratio between the energy created by the machine and the energy released by the fuel. It is equal to the product of the thermodynamic, internal and propulsive efficiencies ; or alternatively, to the product of the thermic and product of the thermic and propulsive efficiencies.

$$\eta g = \eta th \times \eta p$$

It is about of 20%

NOTE - The schematic diagram on page 23 shows the flow of gases into a TURBOMECA turbo-shaft. The values are given only for guidance.

★ Overall F/A mixture ≈ 45 parts air to 1 part fuel
★ Combustion F/A " = 15 to 1



ENGINE GAS FLOW DIAGRAM

AIR INTAKE

This is a duct designed to take in the air, and guide it in the best conditions possible to the entry of the compressor.

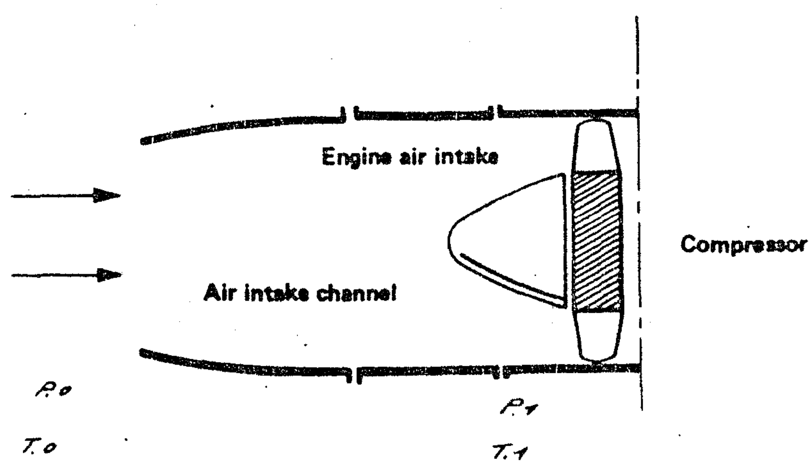
It is shaped so that the air resistance should be as small as possible, and the air flow even in all aspects of flight.

Air duct can have :
- a convergent passage
- a divergent passage
- a variable passage

The compression ratio in the air entry is $\frac{P1}{Po}$, if one calls :

- The pressure at entry Po.
- The pressure at the entry of the compressor P1.

This compression ratio, like the air mass flow, varies with the air speed.



C OMPRESSOR

The combustion (and in particular, the achievement of a high level of efficiency in combustion) requires the supply of a certain flow of air under pressure. The role of the compressor is to provide this air supply.

A compressor is composed of :

- Rotor blades which move a certain mass of air and start the process of compression.
- Stator blades which convert the velocity into pressure.

The following parameters characterize a compressor :

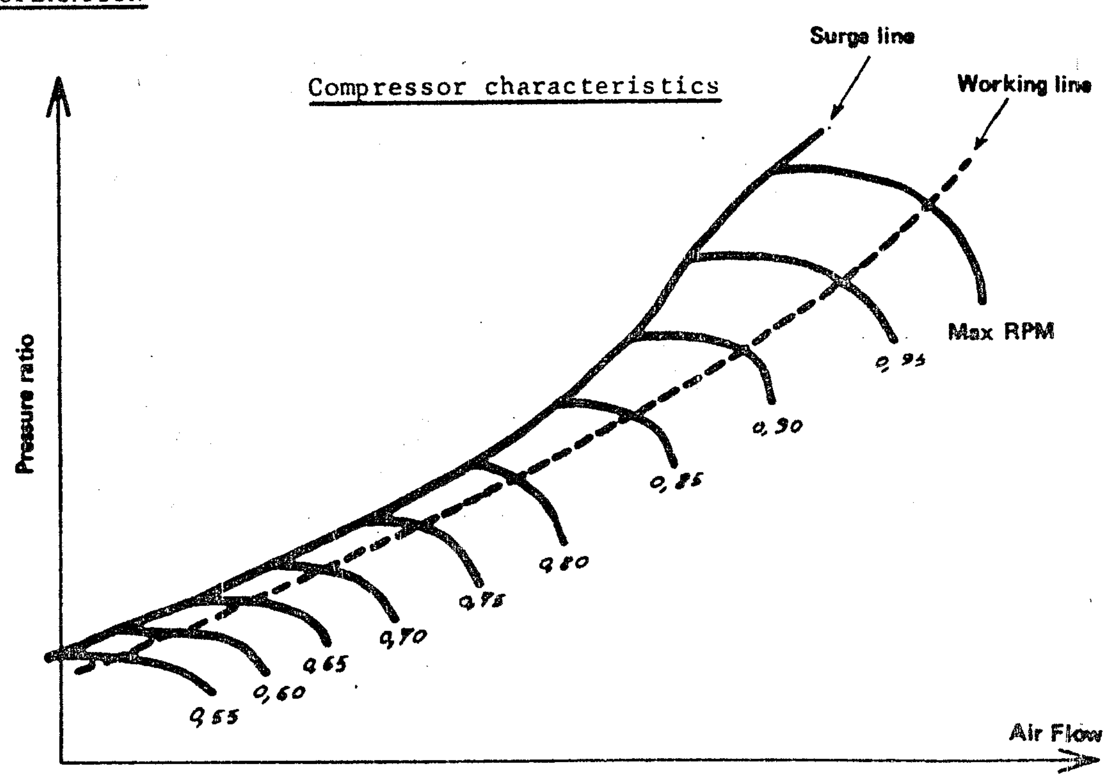
- The compression ratio : $\frac{P2}{P1} = \frac{\text{Pressure at outlet}}{\text{Pressure at inlet}}$

- The air flow G in kg/sec.

- The efficiency $\rho = \frac{\text{Total change of energy}}{\text{Energy supplied by turbine-shaft}}$

It is about 0.8

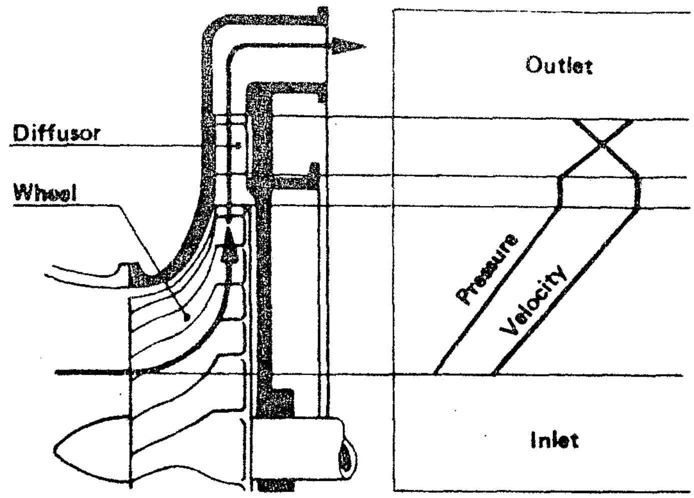
CURVE OF OPERATION



CENTRIFUGAL COMPRESSOR

Basically it is composed of :

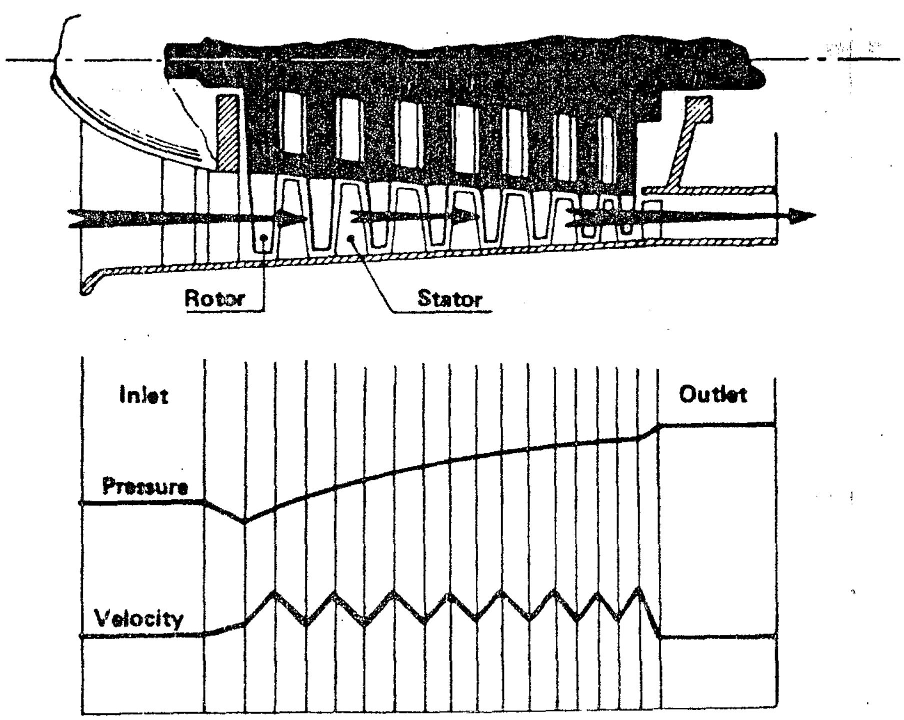
- Rotor blades with guide vanes
- A stator or diffusor.



AXIAL COMPRESSOR

It is composed of several stages, each stage containing.:

- Moving blades (rotor)
- Fixed blades (stator)

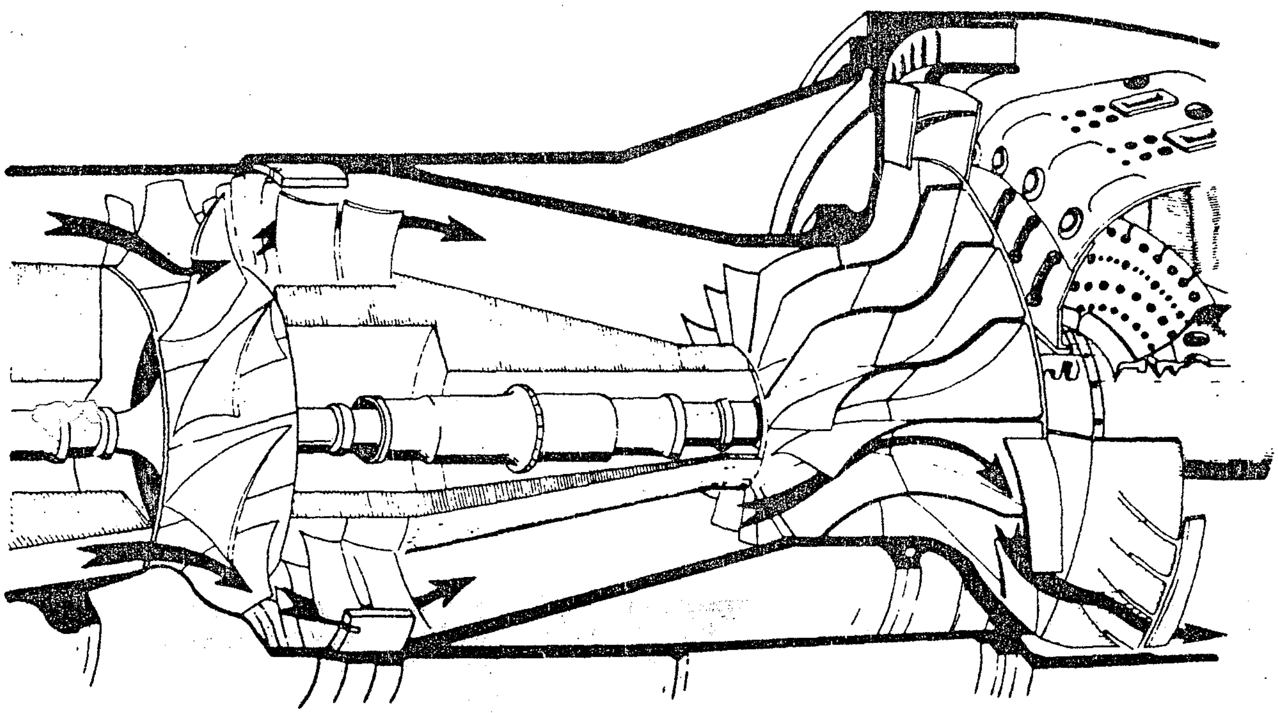


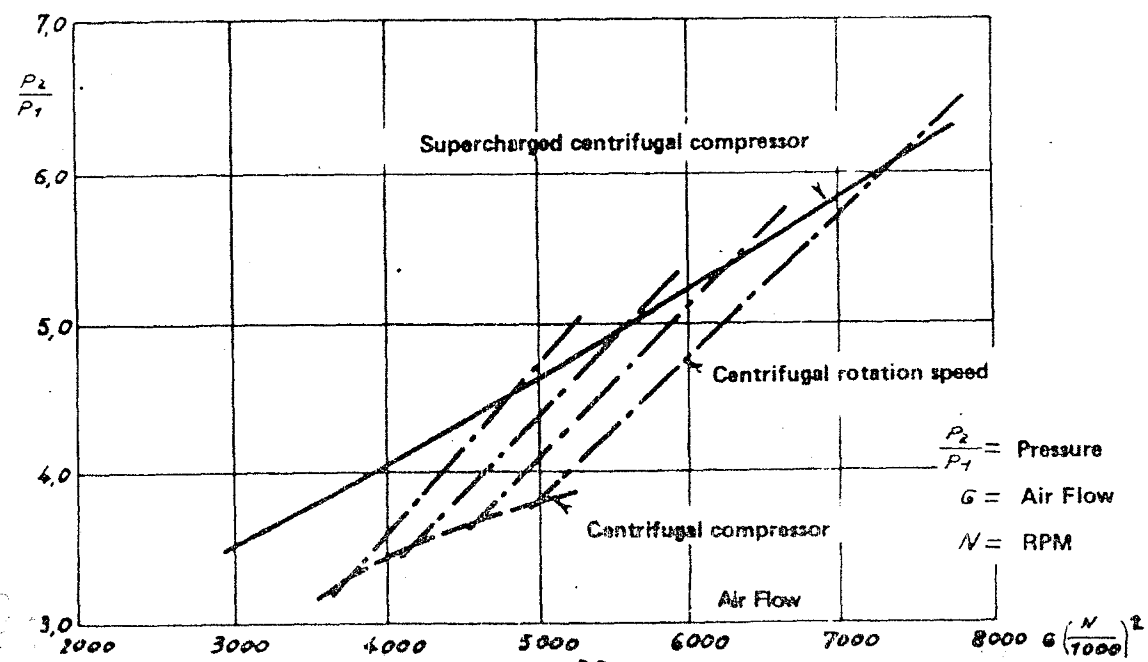
AXIAL + CENTRIFUGAL COMPRESSOR

In some Turbomeca engines, there are two stages of compressors : an axial compressor with 1 or 2 stages, and a centrifugal compressor.

This kind of axial compressor gives an extra supply of air into the centrifugal compressor, in order to increase the compression ratio.

In this way, a compression ratio of about 4 with a single centrifugal compressor can be increased to about 6 with an axial stage supplying extra air, and about 8 with two axial stages.



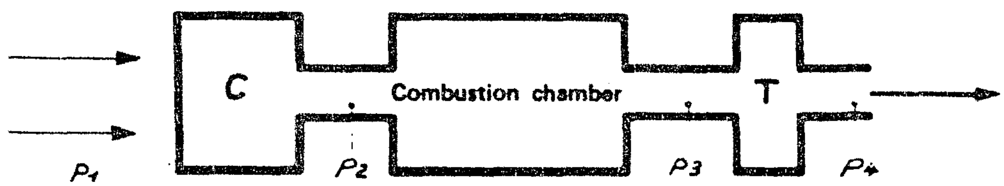


SURGING

This phenomenon results from instable operating of the engine.

Study of the phenomenon

The limits of the compressor's work-rate are set by the combustion chamber, the turbine, and the tail pipe (downstream circuit).



If, for reasons which we shall look into, the pressure of this downstream circuit P3 becomes superior to the pressure P2 at the discharge of the compressor, the compressor air flow stops, and the expansion takes place towards the compressor as well as towards the turbine. Being no longer supplied with air, the downstream pressure P3 falls, the compressor starts working again until once again the downstream pressure overtakes the pressure at discharge and so on. This cyclical phenomenon occurs at a rate of about 120 cycles per second. It is clear that this phenomenon disturbs the working of the engine and could have serious effects.

Causes of surging

Surging then occurs everytime P3 becomes greater than P2. It can therefore be due to an excessive fall of P2 (upstream circuit) or to an excessive increase of P3 (downstream circuit).

A distinction can be made between surging coming from the downstream circuit and the surging coming from the upstream circuit.

- Upstream circuit : A disturbance in the air flow will cause an aerodynamic stall on the compressor blades, and as a result, a fall in P2 bringing on surging. Any deterioration or defect in the air intake and the compressor could therefore result in surging. An identical phenomenon may also occur when the speed of sound is achieved at any point of the compressor.

- Downstream circuit : When the pressure in the downstream circuit becomes too great, or rises too suddenly, surging may occur. The main causes to name are : too sudden a change in the rate, defect or deterioration in the combustion chamber, the turbine, or the exhaust system.

Consequences of surging

- Increase of the temperature at the turbine entry, which could lead to deterioration of the turbine blades.

- Heavy vibrations which could lead to deteriorations of the rotating assembly and the bearings.

- Abnormal and violent noises.

- Smoke and flames.

Recommended procedures and remedies

In a turbo-jet, generally the fuel flow should be reduced and the plane put into a dive, when surging occurs.

In a turbo-propeller, the load put on the generator by the receiving body should be reduced (reduce propeller RPM)

After surging, the engine should be inspected.

Some devices are avaible to prevent surging, such as : discharge valve, air intake guide vanes, acceleration control...

COMBUSTION CHAMBER

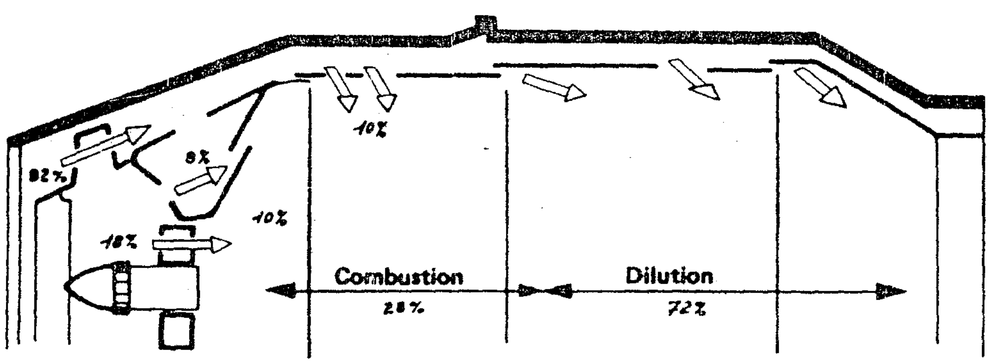
The role of the combustion chamber consists in burning a mixture of fuel and air in given conditions and releasing the resulting combustion gases towards the turbine.

The ratio air/fuel for a perfect combustion is about 1/15. However one cannot achieve this ideal ratio, because the resultant temperature would be much too high for the turbine blades. The combustion chamber therefore has a ratio of about 1/50, but only 1/15 is used for combustion and the remainder for cooling the burnt gases. The efficiency of combustion is about 95 %. The chamber has other requirements, for example, it must keep the flame stable, be able to work within wide limits of air flow and power rating, be able to re-start in flight if needed, work at altitude, etc...

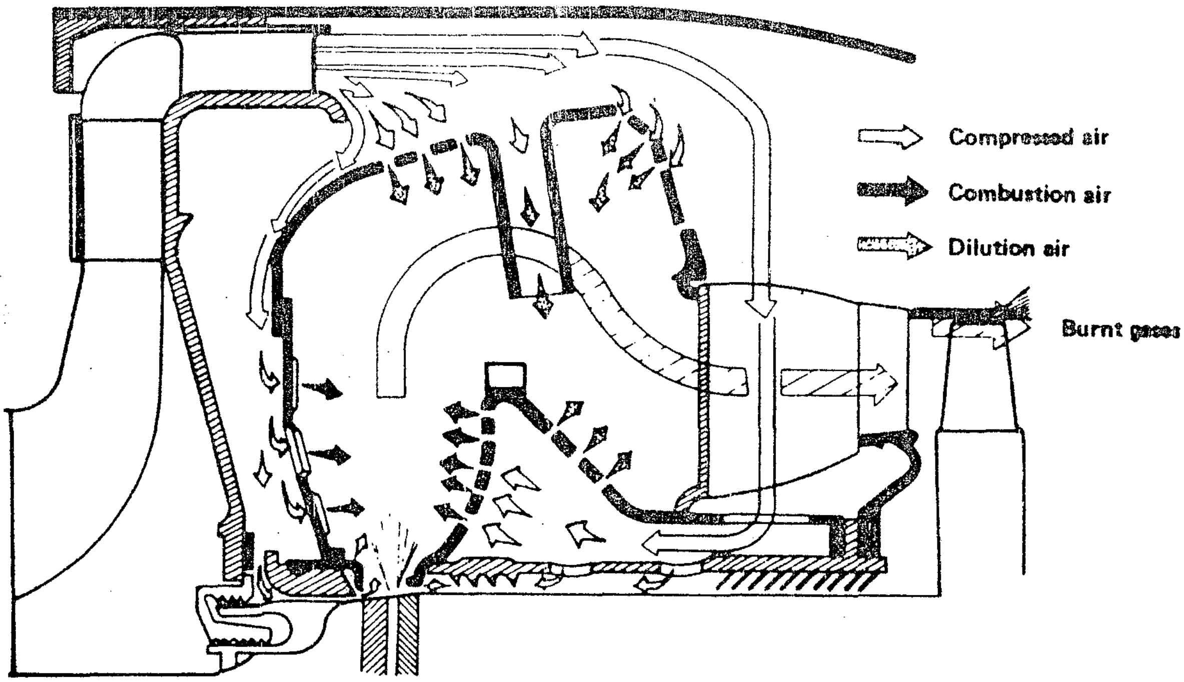
Various types of chambers

Chambers are classified in two categories :

- Multiple chambers
- Annular chambers.



FLOW IN A MULTITYPE COMBUSTION CHAMBER



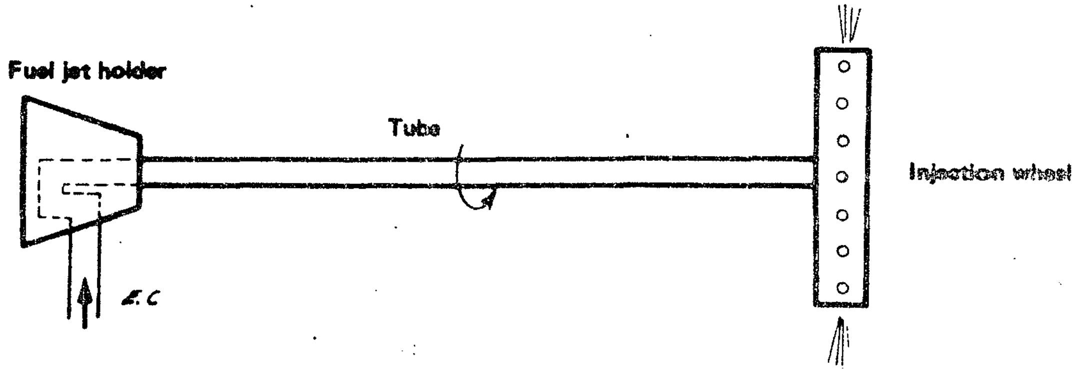
FLOW IN A TURBOMECA TYPE COMBUSTION

Fuel injection

There are various types of fuel injection :

- Injection by atomisation (direct or indirect) by means of gas-jets.
- Injection with pre-vaporisation.
- Centrifugal injection as applied by Turbomeca. This kind of injection presents the following advantages :
  - * No need for a high pressure fuel system.
  - * Quality of atomisation practically independant of the fuel flow.
  - * Less risks of clogging being given that the diameter of the jets is greater than the diameter of a classical burner.

The sealing between the fuel tube turning at high speed, and the static fuel supply sets, however, a delicate problem.



TURBINE

The purpose of the turbine is to convert the energy of the burnt gases (kinetical energy) after combustion, into mechanical energy allowing to drive the compressor, the accessories and finally the receiving body.

In a turbo-jet, the turbine uses a part of the energy to drive the compressor and the accessories, whilst in a turbo-shaft, the turbine uses as much energy as possible to drive the receiving body also.

The turbine assembly contains a fixed section (nozzle) and a moving section (wheel). The combination of a nozzle and a wheel constitutes a stage.

A turbine efficiency is ranging about 92 %. In a turbo-shaft, about 2/3 of the power developed is used to drive the compressor.

Principle of operation

The gases coming from the combustion stage flow first across the fixed blades of the nozzle. The convergent passage increases the gas velocity and diverts them into a rotating path coincidental with that of the wheel.

The gases then flow across the blades of the turbine and by impulse and reaction, cause it to rotate.

The applied torque depends on the gas flow and the variation of energy in the wheel.

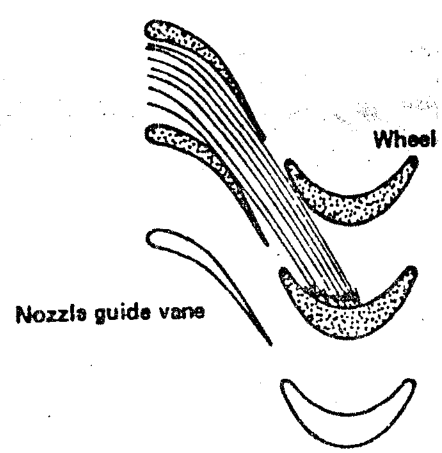
The pitch of the turbine blades, like the pitch of fixed blades, varies from the root to the tip in order to equalise the work done by the mass of gas.

Various types of turbines.

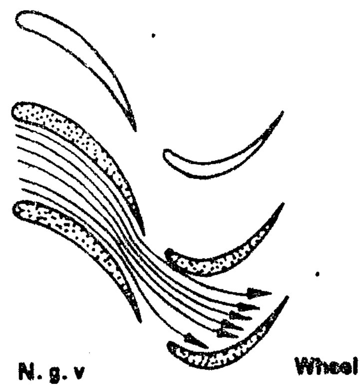
Turbines are classified into three types :

- Those based on impulse
- Those based on reaction
- Those based on combination of impulse and reaction

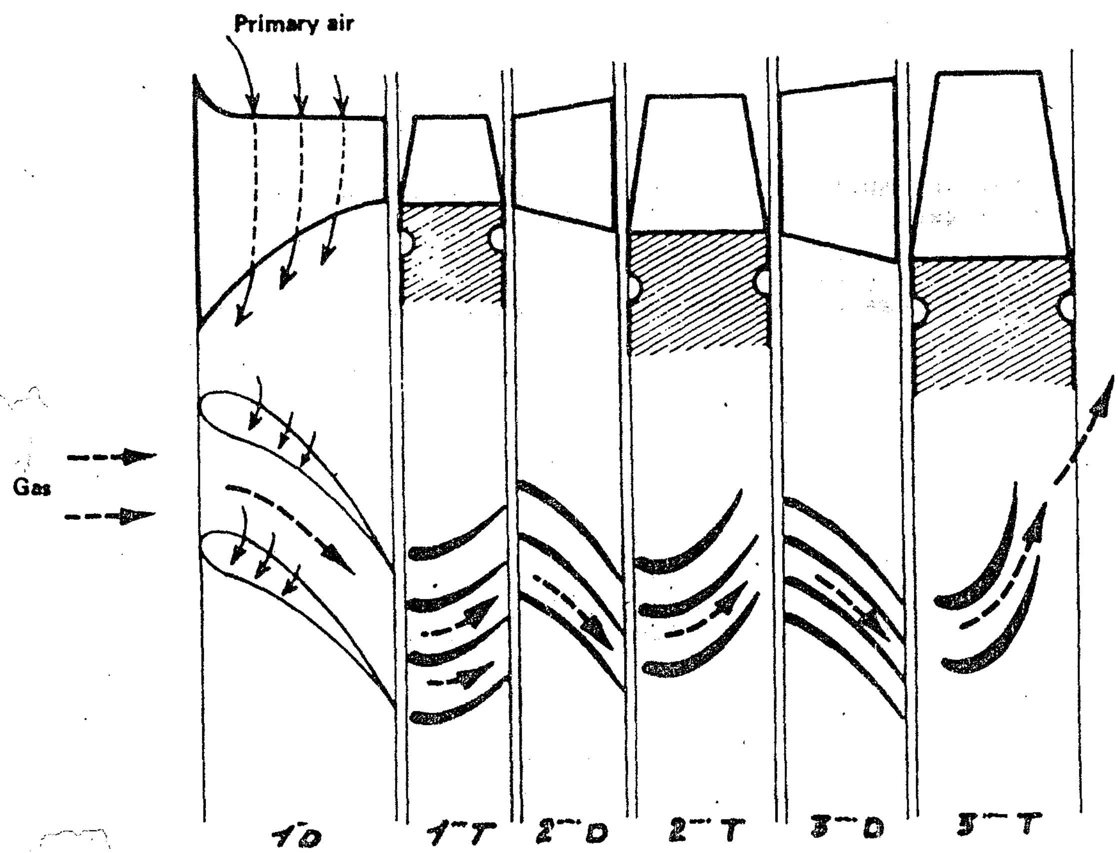
Impulse turbine - (Turbine driven only by impulse of gas)



<u>Réaction turbine</u> (Turbine driven by the reaction resulting from the flow)



<u>Example of a Turbomeca 3-stage turbine</u>



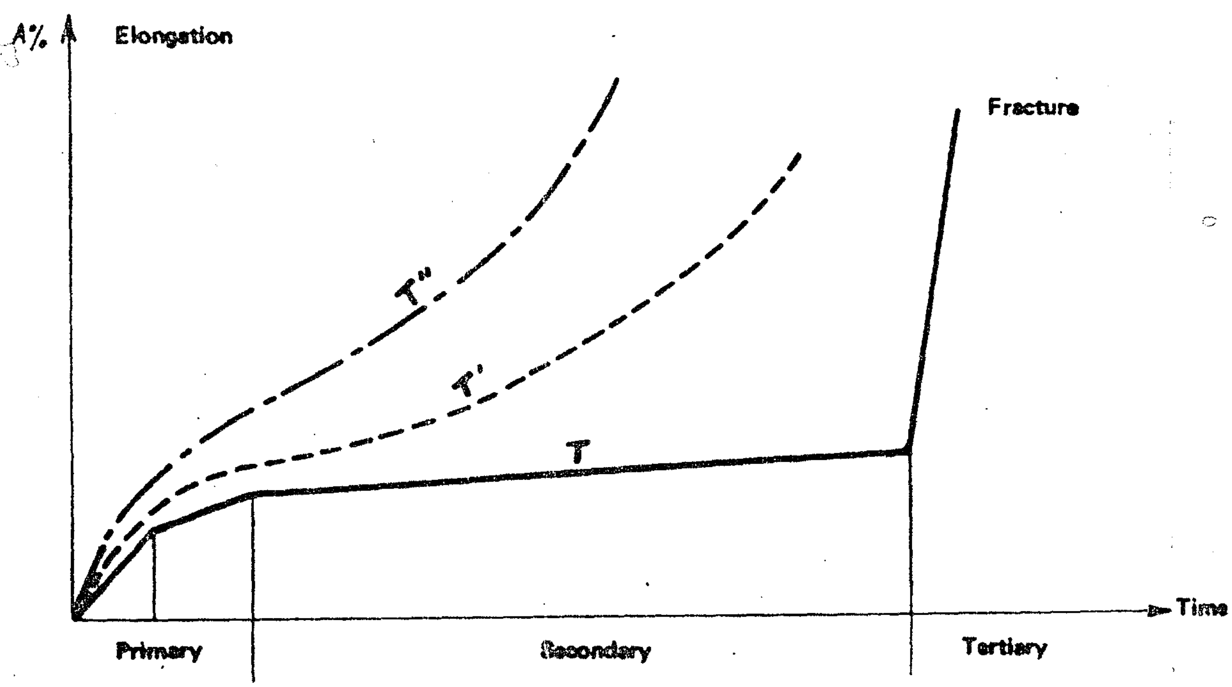
Strain on the turbine blades

The turbine blades carry heavy mechanical loads (centrifugal force) at very high temperatures (T3).

It is thus vital to limit these strains in order to avoid deterioration of the blades.

In fact, if the efforts which the blades have to sustain are too high, the molecules of the metal could slip and produce an elongation of the blades. This phenomenon is called "creep", and it is important to know the turbine blades'resistance to creep, in order to guarantee their operation within well defined limits.

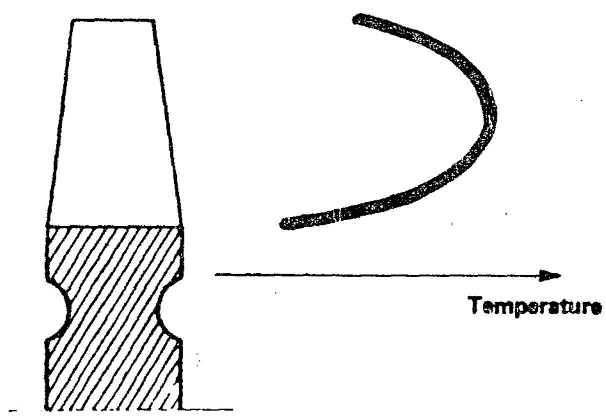
This resistance to creep is determined by measuring the elongation of a specimen bar of metal placed under strain for some time. Thus we get a curve of creep which therefore represents the resistance characteristics of the metal.



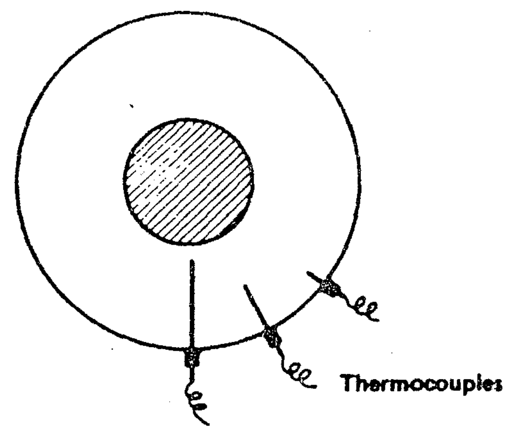
Creeping curve

T= Temperature T" > T' > T

To avoid creeping, it is important to limit the temperature, but one should also make sure that this temperature is correctly spread over the turbine wheel. The ideal spread over a blade would be to have the highest temperature at the middle section and the lowest temperature at the root and at the tip end of the blades. As this ideal spread cannot be obtained, one has to find the best means for protecting the roots of the blades.

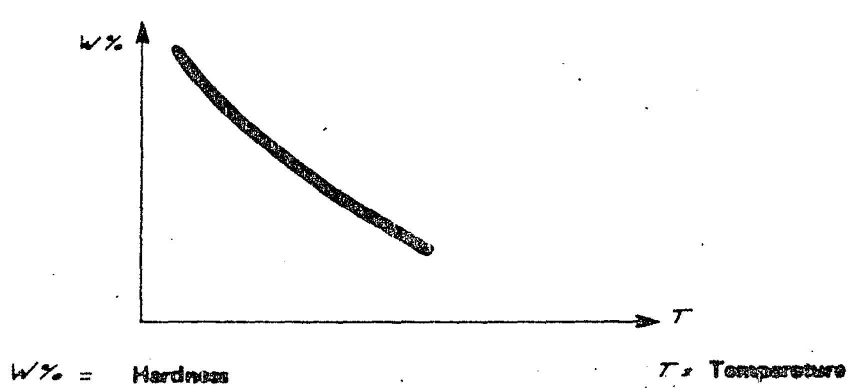


Blade t° distribution



T° distribution check

There is a relationship between the temperature and the metal's hardness which allows a check of good condition of the turbines by measuring the hardness.



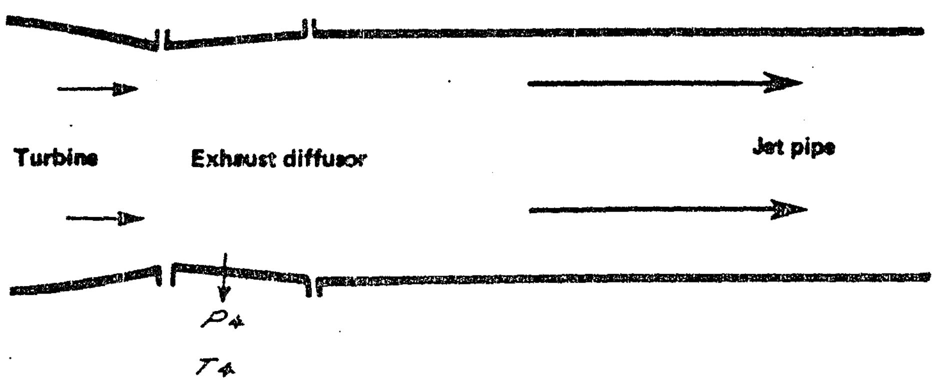
EXHAUST SYSTEM

Its purpose is to expand the gases in order to obtain the maximum thrust (turbo-jet).

This expansion takes place in the tail pipe which has a convergent passage.

In a turbo-shaft, the expansion takes place mainly in the turbine, and since an increase in thrust is not desired, the pipe forms a divergent passage.

Some engines are fitted with variable-passage tail pipes, so that the expansion should be controlled (particularly for afterburning).



PERFORMANCES AND CHARACTERISTICS

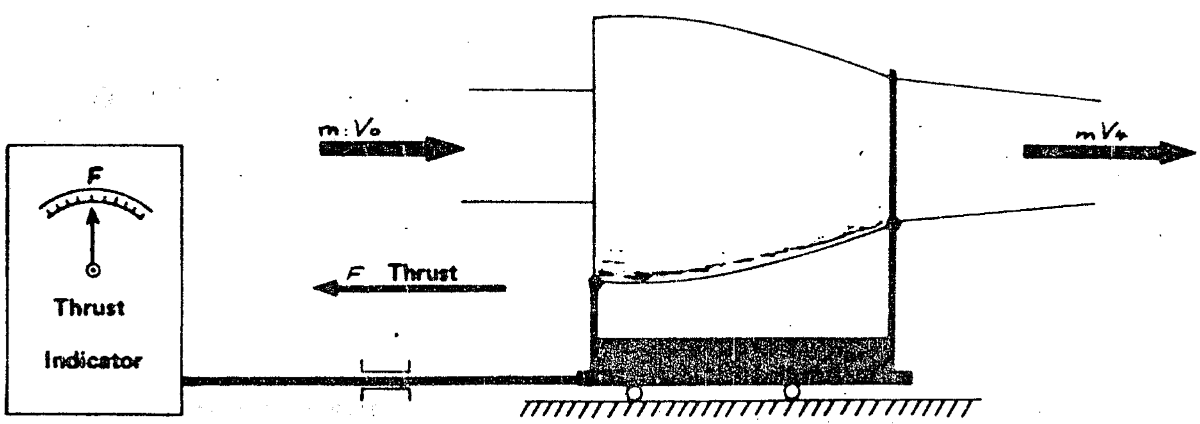
THRUST OF A TURBO-JET

Thrust F or T

The thrust may be calculated by means of the formula :

$$F = m\ (V4 - Vo)$$

It may also be measured on a test-bench
the thrust is expressed in kilograms or in Newtons.



Thrust distribution

It is quite difficult to define exactly the points on which the thrust is felt. However, an order of importance can be given :

- 60 % forward from the reaction force of the compressor
- 30 % forward from the force coming from the combustion chamber
- IO % forward on to the shaft
- 55 % towards the rear from the reaction force in the turbine.

The actual thrust is a force equal to :

$$(60 + 30 + IO) - 55 = 45\ \%$$

THRUST OF A TURBO-PROP.

The total thrust is equal to the propeller thrust plus the residual thrust from the generator.

Propeller thrust = M (vl - vo)
- When M = great mass of air, vl - vo small change in velocity

Residual thrust = m (Vl - Vo)
- When m = small mass of air, Vl - vo = great change in velocity

Total thrust = M (vl - vo) + m (Vl - Vo)

The thrust may also be measured on the test

POWER

Let us recall the formula for power : W = Cw
C = Torque = force x distance = F x L
ω = angular velocity $\frac{2\pi N}{60}$

$$W = \frac{2\pi N \times F \times L}{60}$$

Measure of power

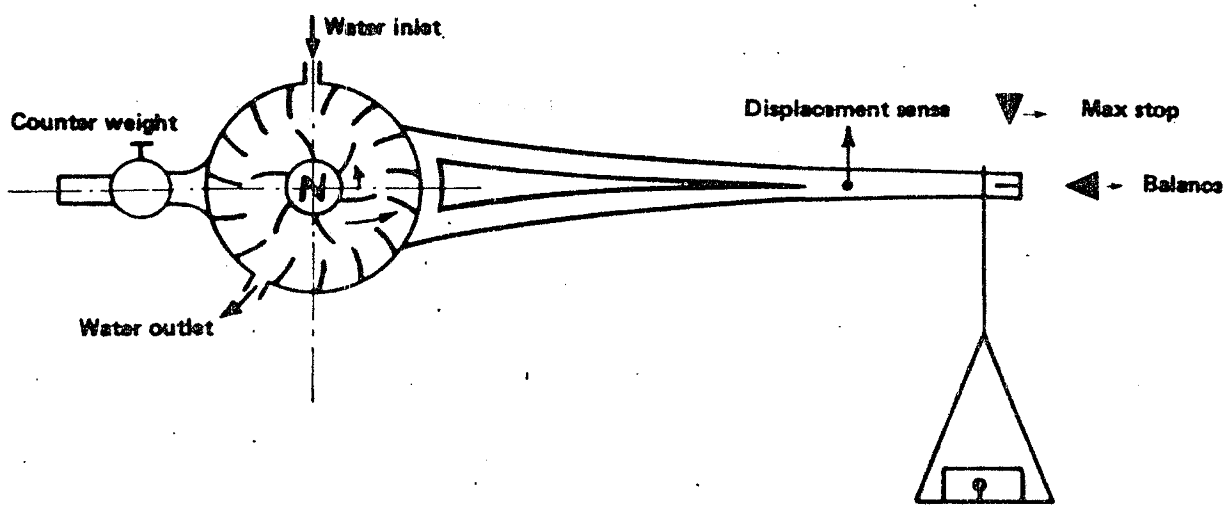
A torque is applied to the output shaft of the engine and knowing the value of this couple and the rotating speed, (RPM), one can calculate the power. To do this, a test-bench of water brake type is used.

Equivalent power

The sum of the shaft power plus the equivalent of the power of the residual thrust is called the equivalent power.

Units of power :

kg/m/sec.	75 kg/m/sec. = 1CV = 0.736 kw
horse power (CV)	1 kw = I.36 CV
kilowatt (kw)	



FUEL CONSUMPTION (CH)

CH = fuel consumption in kg per hour
CH = Q x d
Q = Fuel flow in litres per hour
d = Fuel density

. A flowmeter is used to measure the fuel flow (or number of litres nb) during a certain period t in seconds.

$$CH = \frac{nb \times d \times 3.600}{t}$$

SPECIFIC CONSUMPTION (Cs)

This is the quantity of fuel required to produce a unit of power (or thrust) during a certain unit of time.

In other terms : $Cs = \frac{CH}{W \text{ or } F}$

In the case of a turbo-jet, Cs is expressed in kg/kg/hour.
In the case of a turbo-shaft : in kg/kw/hour (or gr/kw/hour)

AIR-FUEL RATIO

$$R = \frac{CH}{G} = \frac{\text{real fuel flow in gr/sec.}}{\text{real compressor air flow in gr/sec}}$$

COMPRESSION RATIO

$$\frac{P2}{P1} = \frac{\text{Pressure at outlet of the compressor}}{\text{Pressure at inlet of the compressor}}$$

POWER-WEIGHT RATIO

$$\frac{P}{W} = \frac{\text{Engine weight}}{\text{Power}}$$

ROTATION SPEED (N)

The rotation speed of the compressor-turbine assembly is expressed in revolutions per minute (RPM). N can be indicated as a percentage of the maximum speed.

TURBINE INLET TEMPERATURE (T3)

This is the temperature before the first stage of the turbine nozzle. This temperature serves as a standard which must be limited and controlled.

TURBINE OUTLET TEMPERATURE (T4)

This temperature is measured since it is not possible to measure T3 directly.

ENGINE RATINGS.

- Take-off : rating equivalent to maximum thrust or power.
- Max. continuous : max. rating without time limit.
- Cruise : rating equivalent to the aircraft cruising conditions.
- Intermediaries : according to the aircraft.
- Flight idling : minimum rating in flight. Generally used for descent.
- Ground idling : rating when waiting on runway.
- Start-up.

FACTORS AFFECTING PERFORMANCES

EFFECTS OF AIRCRAFT SPEED (Vi)

- on the efficiency of propulsion

The diagram hereunder shows the ranges of utilisation of the turbo-prop., turbo-jet (by-pass and single).

- on the thrust

The thrust depends on the air mass and its change in velocity. It appears that as air speed increases, thrust is reduced. This reduction is however compensated by the ram effect causing an increase in the air flow after reaching a certain speed.

- on the fuel consumption of a turbo-jet

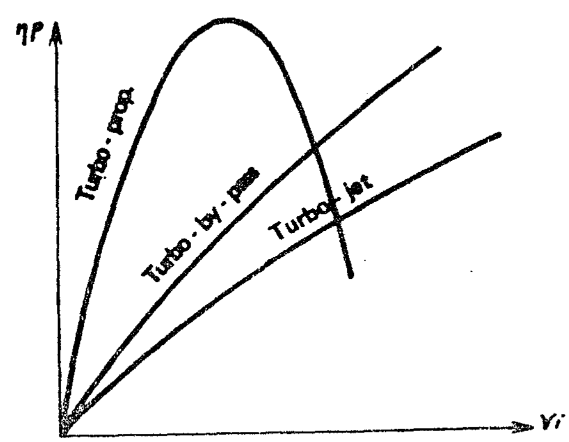
As the air flow increases with the air speed, the fuel flow is also increased. The fuel consumption thus increases with speed, as well as the specific consumption.

- on the power of a turbo-prop.

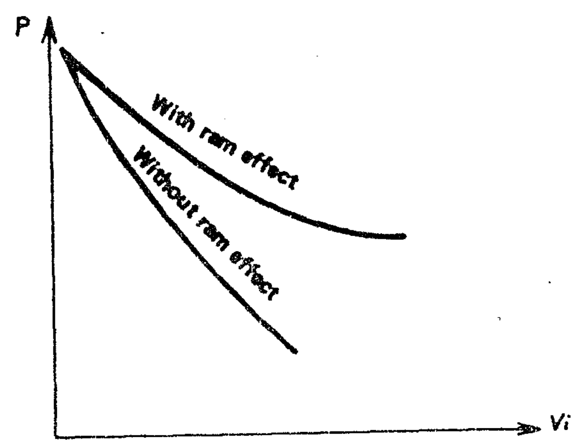
The increase in airspeed (Vi) causes an increase in pressure and temperature at entry, as well as in the air flow. The rise in temperature tends to reduce the power, but the effect of the pressure is stronger. Power thus increases with airspeed. (Vi)

- on the consumption of a turbo-prop.

The fuel consumption increases with airspeed (Vi), but at a low rate. The specific consumption therefore falls with airspeed (Vi). (Remember that a fall in specific consumption means a better specific consumption).



Propulsive efficiency - Aircraft speed



Thrust - Aircraft speed

EFFECTS OF ALTITUDE (Z)

Remember that, as altitude increases, the atmospheric pressure falls, as also the temperature and the density of air.

- on thrust

- The drop in pressure causes a fall in thrust.
- The drop in temperature tends to cause an increase in thrust.
- However, the effect of the pressure is stronger than the effect of the temperature, and thus it may be said that as altitude increases, the air density falls, the air mass decreases, and as a result, the thrust drops.

- on the consumption of a turbo-jet

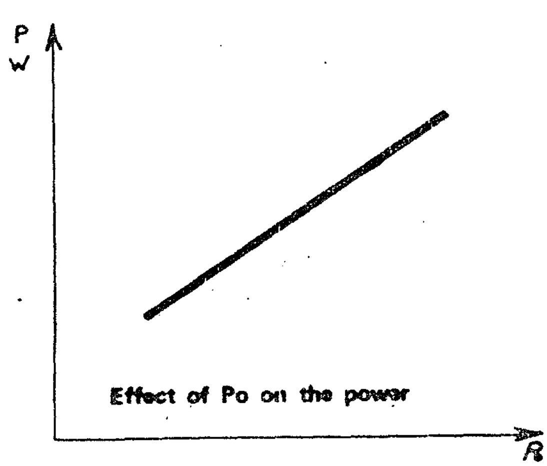
Being given that the air flow falls as altitude increases, there is an automatic reduction of the fuel flow (fuel control unit keeping the standard parameter within the prescribed limits). The fuel consumption thus falls as altitude increases, as well as the specific consumption (the specific consumption improves by reason of the effect of the fall in temperature).

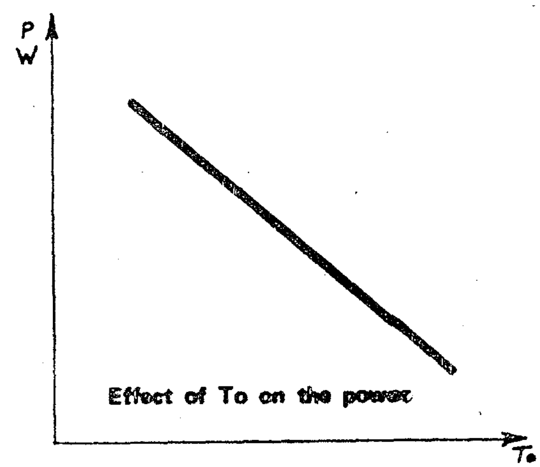
- on the power of a turbo-prop.

The power drops for the same reasons as the thrust.

- on the fuel consumption of a turbo-prop.

In the same way, the fuel consumption falls as altitude increases. With consumption falling more quickly than power, the specific consumption improves with increased altitude. There is however a limit for each type of turbo-prop.



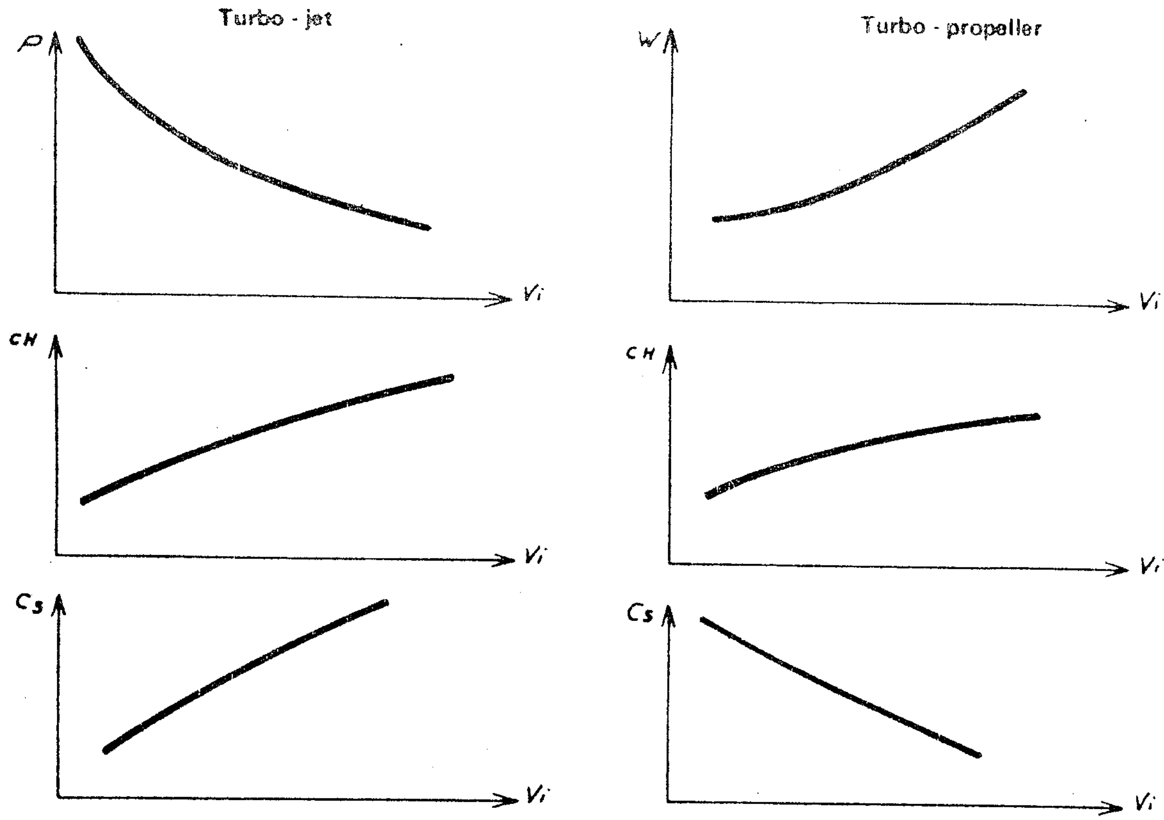


EFFECT OF ALTITUDE

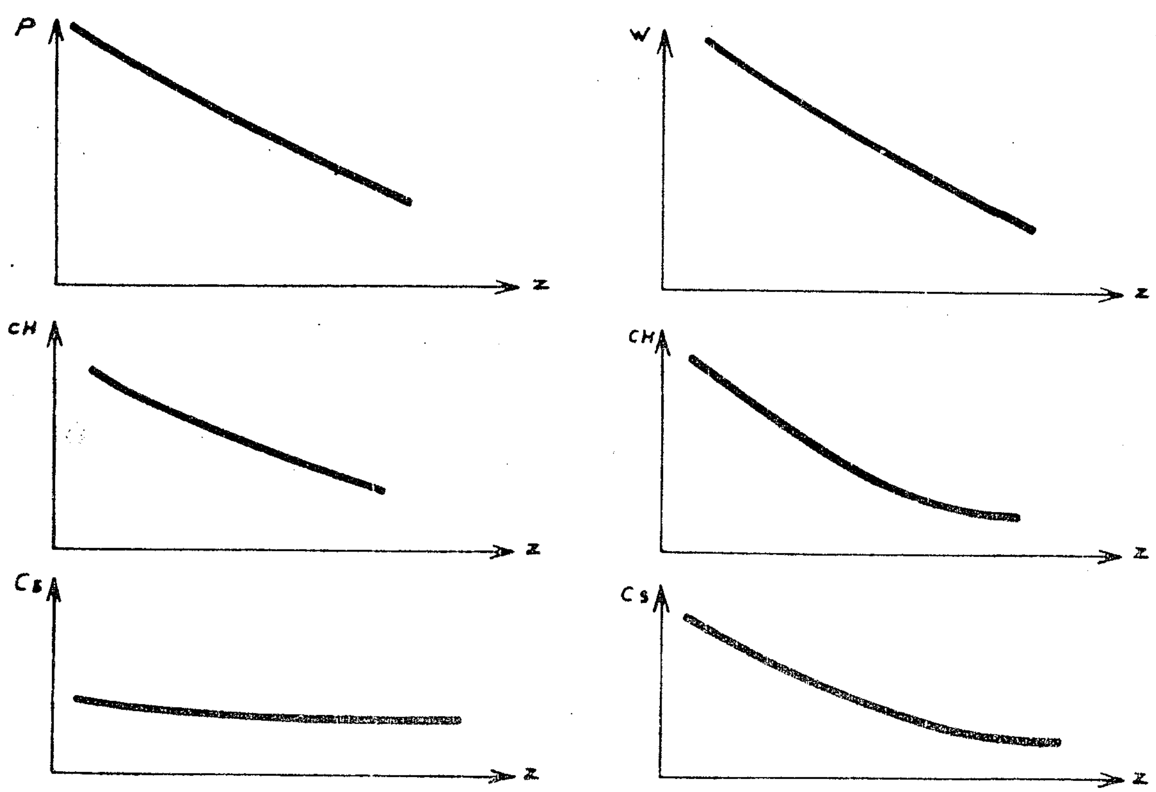
Z ↗ Po ↘ To ↘
↓ ↓
W ↘ W ↗

But the effect of Po is stronger therefore Z ↗, W ↘

EFFECT OF AIRCRAFT SPEED



EFFECT OF ALTITUDE



CORRECTION OF PERFORMANCES AND CHARACTERISTICS

To allow a comparison between the characteristics of engines tested in various atmospheric conditions, one must re-adjust the results noted during the tests, so that they should be expressed as under standard atmospheric condition.

Remember that, by standard atmospheric condition, we mean :

Pressure Po : 1013 mb or 760 mmHg
Temperature to : 15°C or 273° + 15° = 288° K

The correction of the engine characteristics is done with the help of the following formulae :

Rotation speed

$$N = N1 \sqrt{\frac{288}{To}}$$

N = corrected speed
N1 = speed noted
To = absolute temperature at the time of the test.

Thrust

$$F = F1 \times \frac{IOI3}{Po}$$

Po : pressure at the time of the test.

Power

$$W = W1 \times \frac{IOI3}{Po} \times \sqrt{\frac{288}{To}}$$

Consumption

$$CH : CHL \ \frac{IOI3}{Po} \times \sqrt{\frac{288}{To}}$$

Temperature

$$T = T1 \times \frac{288}{To}$$

VARIOUS FUNCTIONS OF A GAS TURBINE ENGINE

COOLING

Cooling must guarantee the thermic balance of the engine.
Cooling of the components and accessories can be carried out.

- either by air circulation
- or by lubricating oil
- or by circulation of a liquid

LUBRICATION

One must make sure that the bearings supporting the generator shaft, the gear-train driving the accessories, and the reduction gear-box are correctly cooled and lubricated.

The lubricating oil must contain certain properties which ensure clean lubrication. There are two main types of oil : mineral and synthetic ones.

The lubricating circuit is generally of dry sump type. Lubrication is carried out by atomisation through the component to be lubricated. The system usually consists of the following elements : a tank, a group of pumps (generally of gear type), safety valves, a filtering assembly, a cooler, some accessories intended to check pressure and temperature.

FUEL SUPPLY AND FUEL FLOW CONTROL

This involves supplying and metering fuel in all conditions of operation..

The fuel used is generally kerosen TRO-TR4.

A typical system contains : a pump assembly, a regulator, filters, safety devices, a fuel injection system.

STARTING

The following three functions have to be fulfilled in starting :

- Cranking the rotating assembly. Most often done by an electric motor.
- Supply injection system with pressurised fuel. Carried out either by the main pump, or by an auxiliary pump.
- Ignition of the air-fuel mixture. Generally achieved by igniter-plugs. The required high tension current is supplied either by a high tension unit or by a high energy unit.

The starting cycle is generally automatic. An electric control-box carries out the sequence of automatic operations.

VENTILATION (MOTORING)

Sometimes it is necessary to procede to the rotation of the rotating assembly without using fuel injection and ignition. This is usually called "motoring". Mototing could be used for the following reasons:

- To release unburnt fuel accumulated in a combustion chamber (e. g. as a result of a previous failure at start-up).
- To cool the residual temperature.
- Tests, inspection...

RELIGHT IN FLIGHT

The procedure for re-ignition in flight is usually identical to that of starting on the ground. However in the case of a turbo-jet or a turbo-prop., the windmilling of the rotating assembly caused by the air flow, makes the starting function redundant. The starter can thus be cancelled by some device (e. g. ground-flight switch).

ENGINE INSTRUMENTATION

The following indications are generally used to check the operation of the engine :

- rotation speed of the rotating assembly
- turbine temperature (generally T4 at the turbine outlet)
- fuel flow
- pressure of lubricating oil
- various pressures and temperatures
- temperature of lubrication oil
- warning lights.

WATER-METHANOL INJECTION

The purpose of this injection is to increase the power in certain conditions of operation.

The method consists in injecting a mixture of water-methanol into the compressor entry.

The injection has the following effects : fall in temperature as a result of vaporisation, increase of the compression rate, and increase of the flow. One may thus either increase the fuel flow, or use the combustion of the methanol. Either way, a resultant increase of power is thus obtained (e. g. it could be used for take-off with at high To).

There are also other methods of water injection. For example : water injection into the combustion chamber, water injection in the turbines.

AFTERBURNING (REHEAT) = P.C. (Post-combustion)

This is a method for increasing thrust in a turbo-jet. It consists in carrying out a second combustion in the jet pipe in order to increase the exhaust velocity of the gases. This second combustion is quite possible being given that the burnt gases at the turbine exit are for the most part "fresh" air. Besides, a very high temperature may be allowed into the jet pipe in consideration that there are no moving mechanical parts.

The increase in thrust obtained depends on the exhaust velocity. Now, the exhaust velocity increases proportionally to the square root of the temperature $V = \sqrt{T}$. The increase in thrust can reach 50 %, but the P.C. is obviously a heavy burden

The use of reheat also must not disturb the working of the gas generator ; reheat must be carried out at a constant pressure, and this involves a controlled adjustment of the jet pipe section. Similarly, using the P.C. requires a device to control the flow of injected fuel.

Finally note that P.C. is especially useful in the case of a by-pass turbo-jet.

FUEL HEATING

The method consists in transferring the calorific energy of lubricating oil or of the gases into the fuel.

This fuel heating, by raising the fuel temperature, would

- improve its flow
- improve the atomisation in the chamber
- avoid icing of the water contained in the fuel
- and finally to restore to the engine's cycle a quantity of energy which would otherwise be lost.

DE-ICING

One must distinguish between :

- the anti-icing devices which seek to prevent the formation of ice.
- the de-icing devices which seek to remove ice.

The main component to be protected is the air entry duct. It can be protected by hot air (taken from the compressor exit) or by electric circuit.

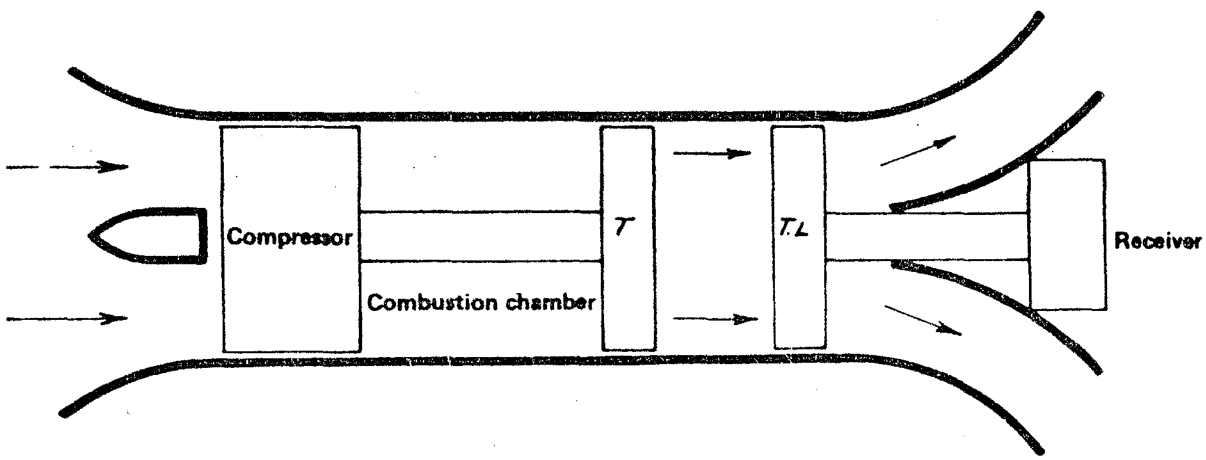
FIRE PROTECTION

The power-plant is generally fitted with a fire detection system - thermic detector and warning light - and a fire extinguishing system (extinguishing bottles and atomising manifold).

FREE TURBINE TURBO-SHAFT

GENERAL

There are two rotating assemblies. The first is a gas generator, the operation of which is quite similar to that of a jet engine. The second (free turbine) drives the power shaft . Both assemblies are rotating at different speeds. The gas generator works practically independently of the free turbine and its functionning depends on the fuel flow as in a jet-engine. The operation of the free turbine depends upon the balance between the energy received from the generator and the one taken by the receiving body.

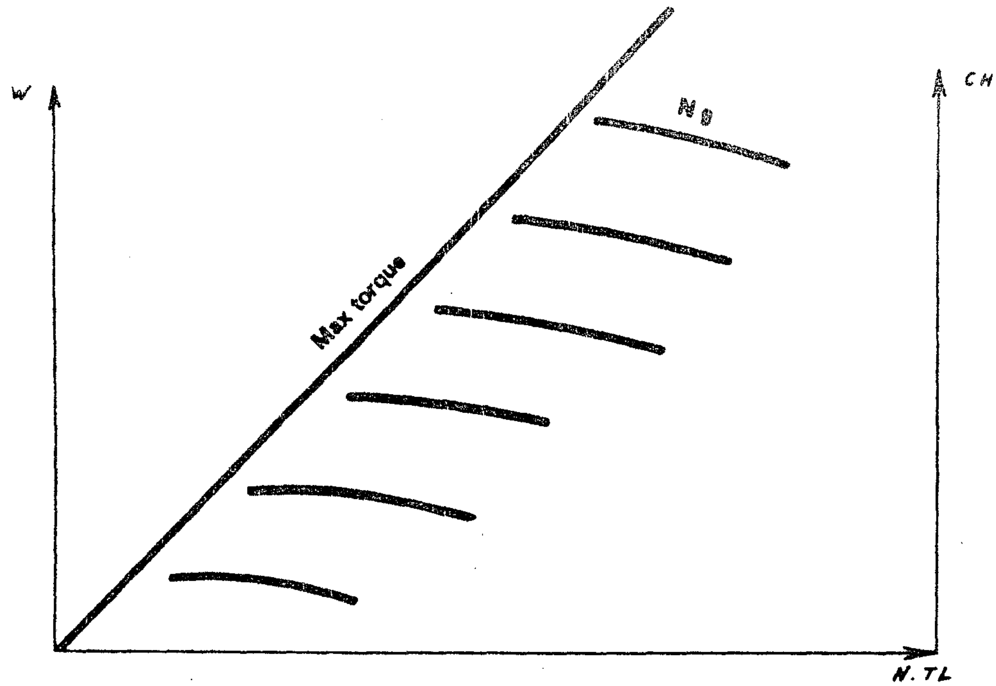


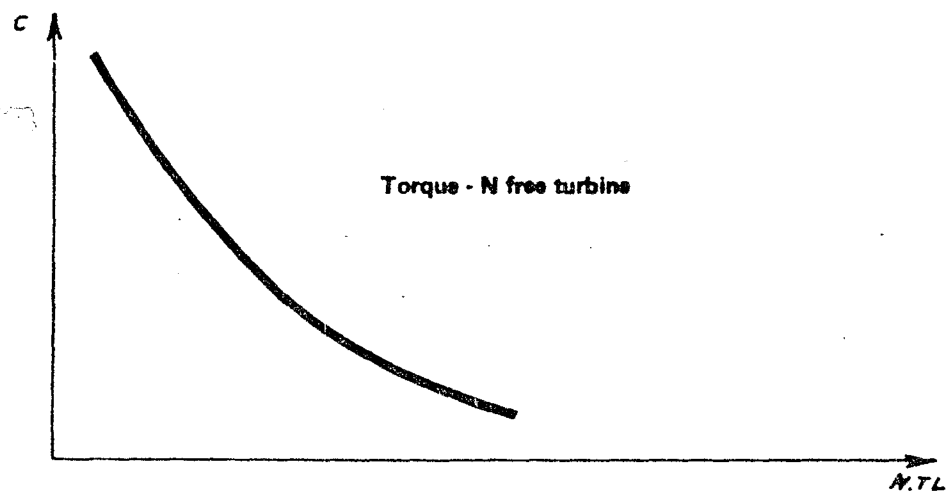
CHARACTERISTICS

These are generally represented by the graph which shows, on the x-axis, the reduced speed of the free turbine, and on the y-axis the reduced power. On this graph, are plotted the curves corresponding to a reduced speed of the generator. As the generator is considered to work independently of the free turbine's rotation speed, the fuel consumption is also independant of it and the iso-speed curves of the generator are iso-consumption curves too.

Within a large range of free turbine rotation speed, the power varies just a little, i.e. the efficiency of the free turbine is not greatly influenced by its rotation speed. The best conditions for achieving maximum power are present when the rotation speed of the free turbine is as low as that of the gas generator.

The torque on the transmission shaft varies inversely with the free turbine's rotation speed. It reaches its maximum when the free turbine speed is zero.





ADVANTAGES OF FREE TURBINE ENGINE

- Better accommodation, since the generator works independently.
- Easy starting.
- Possibility of accumulation of a high energy.
- No need to have a clutch on helicopter.

BY-PASS TURBO-JET

PROPULSIVE POWER

This is the power used in flight, i.e. the work done in the unit of time of thrust.

$$Pp = TV$$

T = thrust = m (w - v)
V = aircraft speed

$$Pp = m\ (w - v)\ V$$

PROPULSIVE EFFICIENCY

$$p = \frac{Pp}{Pd} = \frac{\text{Propulsive power}}{\text{Dynamic power}}$$

$$p = \frac{m\ (w - v)\ V}{\frac{1}{2}\ m\ (w^2 - v^2)}$$

$$p = \frac{2\ V}{w + v}$$

INCREASE IN EFFICIENCY

If, in the equation immediately above, we substitute for w its value in the thrust equation above,

$$T = m(w - v) \qquad\qquad w = \frac{T}{m} + V$$

We obtain the propulsive efficiency in sympathy with T

$$np = \frac{2V}{\frac{T}{m} + v + v} = \frac{2}{\frac{T}{m\,v} + 2}$$

Thus it appears that the smaller that $\frac{T}{mv}$ is, the greater is np.

In other words, given a constant thrust, the greater that "m" is greater the efficiency is. And, if V is relatively low "m" must be important to allow an acceptable efficiency.

One solution consists in increasing the air flow without increasing the fuel flow in order to obtain a slower exhaust velocity W, this is not quite satisfactory because it reduces the thermic efficiency of the engine (drop in T3). Thus, to increase "m" and reduce "w" without reducing T3, a solution remains : to separate the air flow into two channels.

BY-PASS TURBO-JET

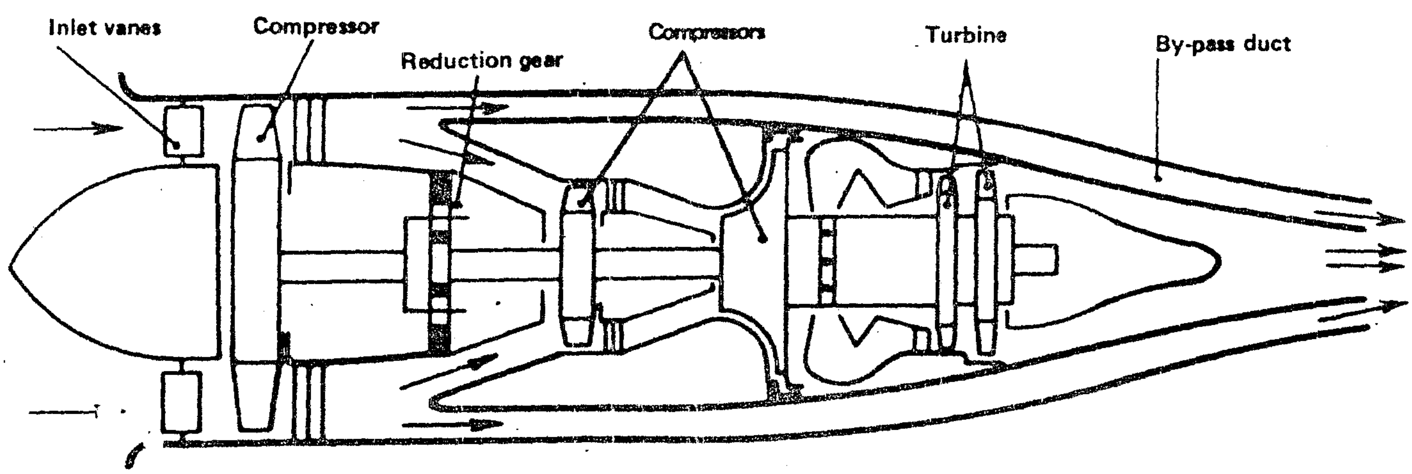
Flow ml, at a high pressure is used by the gas generator with a fuel flow such as T3 be at a max in order to obtain high thermic efficiency.

Flow m2, at a low pressure, by-passes the gas generator and mixes with flow ml either in the jet pipe or in the atmosphere, which allows to reduce W.

Thus a compromise is achieved between the turbo-jet and the turbo-prop. In the by-pass turbo-jet, the values of "m" and "w" come between the values of the single turbo-jet and of the turbo-prop. That is why the range of utilisation of the by-pass turbo-jet comes between that of the turbo-prop. which is limited by the fall of efficiency at high speed (from about 700 km/h = 437.5 or 440 miles/hour), and that of the turbo-jet the propulsive efficiency of which only becomes variable at high speeds.

A comparison between a by-pass turbo-jet and a single turbo-jet shows that :

- The thrust of the by-pass is less
- Its diameter is larger
- Its weight is less
- Its Cs is better
- The efficiency is improved
- The radius of action is increased
- It is less noisy
- The use of P.C. is less burdensome



SCHEMATIC DIAGRAM OF A BY-PASS JET ENGINE

(AUBISQUE TYPE)

TWIN SPOOL TURBO-JET

A twin spool turbo-jet essentially consists in two "rotating assemblies" mechanically independant.

- A compressor body BP, BP turbine.
- A compressor body HP, HP turbine.

The driving shaft of the BP coupling is co-axially set inside the HP shaft.

The disposition of the various functional components as follows :

- BP compressor
- HP compressor
- combustion chamber
- HP turbine
- BP turbine

Though the solution of the twin is used in a single flow turbo-jet, it is much more suited to the by-pass turbo-jet.

In the case of the twin spool by-pass turbo-jet, the BP compressor ensures a flow which is separrated into two flows :

- A by-pass flow circulating round the generator.
- A generator flow running through the "HP compressor, combustion chamber, turbine" system.

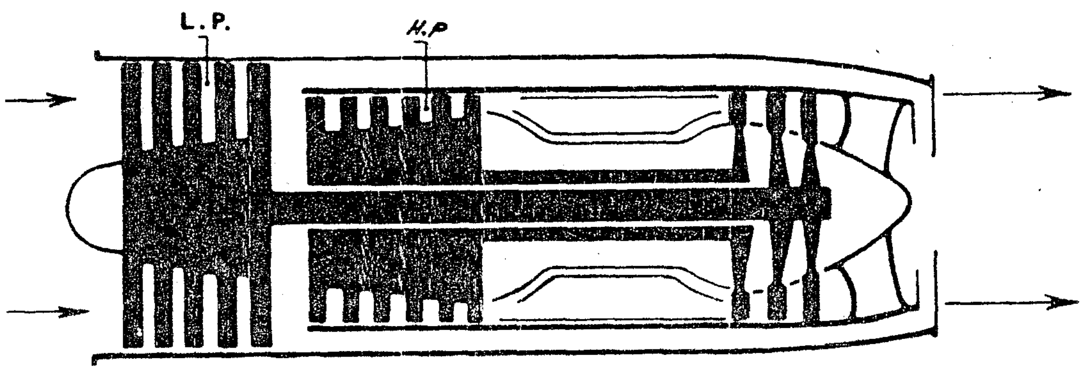
The thermodynamical operation is nearly the same as that of a single flow turbo-jet.

Therefore, the following points may be noted :

- The rotating speeds of both rotors are fairly proportional.
- Each compressor has its own graph on which the adaptation lines can be drawn.
- The graphs show the lower risk of surging in altitude, but a greater risk of surging theBP compressor at low rotation speeds.
- It is possible to obtain compression rates identical to those of a single body with less oompressor stages.

- The driving of a BP compressor is carried out at the required rotation speed without using a reduction-gear.
- The first turbine (HP turbine) being rotated faster than the second one (BP turbine), the safety range towards creeping is greater. One therefore admits higher expansion rates and reduction of stage number (or also increase the efficiency).

For all the above mentioned reasons, a reduction in weight and length can be achieved. Further, the power needed for starting is clearly lower (driving of the HP shaft). On the contrary, the technology is much more complicated.



SCHEMATIC DIAGRAM OF A BY-PASS JET ENGINE

(ROLLS ROYCE TYPE)

TURBOMECA

SURVEY OF THE COMPANY

Founded in I938 by Mr. SZYDLOWSKI.

1968 : three plants BORDES (Headquarters), TARNOS, MEZIERE.

- Covered area : 82 000 square metres.
- Number of employees : about 3 000.
- Number of machine-tools : about I IOO.
- Monthly production : about 100 engines.
- Turnover I966 : I52 million Francs, including 86 for exports to different countries.

- Number of engines produced : MARBORE : 5 000, ARTOUSTE : 2 000
  ASTAZOU : 400, TURMO : I50, BASTAN : 300,
  etc... (these figures are approximate).

- Life of some engines : MARBORE : 500 to 750 hours, ARTOUSTE:: I 000 hours,
  ASTAZOU : I 000 to I 500, BASTAN : I 250 hours,
  TURMO : 750 hours, ASTAGAZ : 6 000 hours.

- Foreign licence-holders :
  Continental : U.S.A.

  ENMA : Spain
  Yugo-Slavia : State
  India : State
  Israël

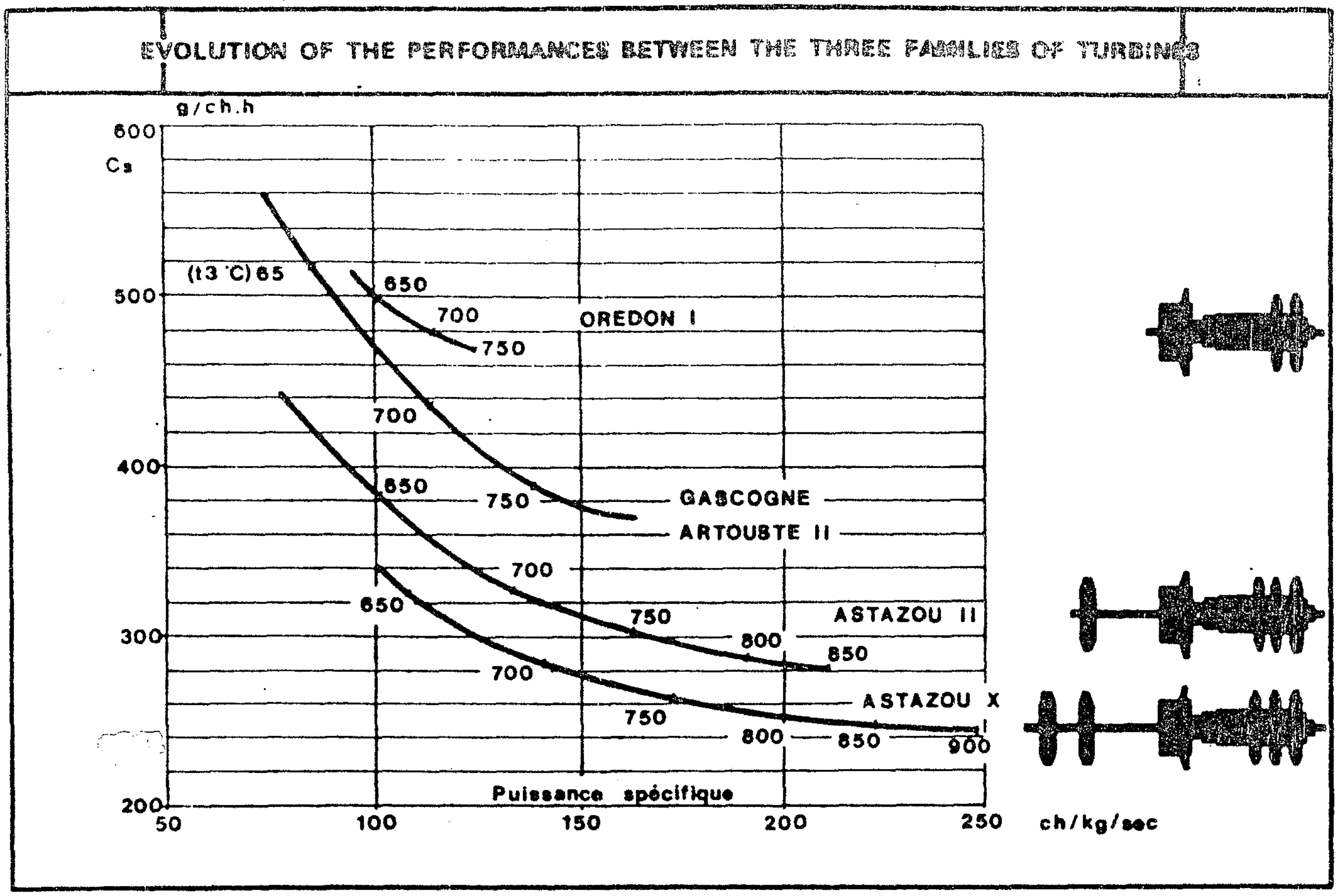
TURBOMECA ENGINES

BASIC COMPONENTS

- Centrifugal compressor.
- Annular combustion chamber with fuel injection wheel.
- Turbine.

VARIOUS GENERATIONS

- First generation : a one-stage centrifugal compressor (Marbore, Artouste 111).
- Second generation : an axial stage followed by a centrifugal stage (Artouste 111, Astazou 11, Aubisque, Bastan, Turmo.)
- Third generation : Two axial stages followed by a centrifugal stage (Astazou X11, Astazou X1V ...)



SURVEY OF TURBOMECA PRODUCTION

ENGINE NAMES

Turbo-jet	: name of a mountain in the Pyrénées.
By-pass turbo turbo-jet	: name of a saddle in the Pyrénées.
Turbo-jet RR	: name of a river.
Turbo-shaft	: name of a lake.
Turbo-propeller	: name of a valley.
Air generator turbo	: name of a wind.

Example of naming.: ASTAZOU XIV C01 .

ASTAZOU	: Name
XIV	: Type
C	: Variant (According to utilisation)
01	: Version

FIRST MODELS

PIMENE : Turbo-jet - carried out in 1947 - thrust : 80 kg
OREDON 1 : Turbo-shaft - carried out in 1948 - power 160 kg
ASPIN : By-pass turbo-jet - carried out in 1949, thrust : 360 kg
PALAS : Turbo-jet - carried out in 1950 - thrust : 160 kg
GOURDON : Turbo-jet - carried out in 1953 - thrust : 380 kg
GABIZO : Turbo-jet - carried out in 1955 - thrust : 1,100 kg

ENGINES IN PRODUCTION

TURBO-JETS

NAME	TYPE	YEAR	N	T	Cs	P2/P1	G	T3	P
MARBORE II	TR	I951	22 600	400	I,I5	3,9	8	770°	I46
MARBORE VI	TR	I959	2I 500	480	I,II	3,8	9,6	770°	I65
AUBISQUE	TR. d. F	I964	32 500	700	0,6	6,92		850°	243
ADOUR	TR. d.F. RR	I968		2000	0,68	9,6	4I,7		365
LARZAC	TR.d.F. SNECMA	I970	HP : 22 700	I025	0,605	9	26	I000°	I90

TURBO-SHAFTS

NAME	TYPE	YEAR	N	W	Cs	P2/P1	G	T3	P
ARTOUSTE IIC	TM	I958	34 000	406	400	3,4	3,25	750°	I43
ARTOUSTE III	TM	I959	33 500	550	340	5,3	4,5	675°	I82
ASTAZOU IIA	TM	I960	43 500	530	290	5,9	2,5	860°	I22
TURMO III C3	TM-TL	I959	33 500	I 500	260	5,85	6,I	900°	220
TURMO III C4	TM-TL	I967	33 500	I 300	279	5,8	4,5	870°	225
OREDON III	TM	I967	59 000	380	259	7,5			93
ASTAZOU XIV	TM	I968	43 000	800	230	8	3,3	900°	
ASTAZOU IIIN	TM	I969	43 500	600	260	6	2,6	900°	I40

TURBO-PROPELLERS

NAME	TYPE	YEAR	N	W	Cs	P2/P1	G	t3	P
BASTAN VI	TP	I962	33 500	I 000	270	5,8	4,5	870°	2I2
TURMO IIID3	TP.TL	I960	33 500	I 067	300	5,8	6,I	850°	364
ASTAZOU II	TP	I960	43 000	550	280	5,97	2,56	860°	I23
ASTAZOU XII	TP	I964	43 000	700	254	7,8	2,9	900°	I56
ASTAZOU XIV	TP	I967	43 000	800	240	8	3	900°	I88
ASTAZOU XX	TP			I 000					

TURBO AIR GENERATOR

PALOUSTE IV		I954	34 III	1 140 gr/s	120 kg/h	3,8	3,3	725°	83

INDUSTRIAL ENGINES

BASTANGAZ	Turbo-Génér.	I968	33 500	550 kw		5,6	4,5		300
ASTAGAZ	Turbo-Gener.								
TURMO III C	Turbo-Rail								
TURMO III N	Turbo-Navi Pl.								
TURMO									

MANUFACTURING PROCESS

The production of a turbine calls for a very wide range of production processes. In the production of TURBOMECA engines, the diversity of the models means that one cannot afford to use special machines peculiar to each type of component. However, since the parts of the various engines are similar, it is feasible to apply one production process to several types of components.

We shall limit ourselves in naming some manufacturing processes :

- The casting of light alloy for the manufacturing of casings and some components (air intake casing, gear box casing, control unit, etc ...)

- Automatic drilling machines.

- Gear-cutting.

- Electric erosion. Method of cutting metal with electric charges. These charges are obtained by sparks taking place between two electrodes ; one is the component being machined, the other one the tool electrode : (turbine, nozzle guide vane, turbine wheel...) .

- Hydro-spin. Manufacturing process by cold-buckling of hollow metallic components, the generator of which is concentrically turning round an axis : (turbine casing, turbine rings, jet pipes, etc...).

- Welding and brazing process (argon welding, high temperature brazing, vacuum welding, electron-beam welding).

- Mass cutting of the turbine blades is carried out by means of a machine-tool designed by TURBOMECA.

- The casting process of the turbine blades (Nimocast)

- The whole range of the the thermic treatments.

- Tests, checks and metallurgical inspection.

CHAPTER 2

ARTOUSTE III GENERAL

- INTRODUCTION
- ENGINE MAIN COMPONENTS
- THERMODYNAMIC OPERATION
- GENERAL DESCRIPTION OF THE POWER PLANT
- GENERAL OPERATION
- PERFORMANCES AND CHARACTERISTICS
- EXTERNAL VIEWS OF THE POWER PLANT

Turbomecca
Artouste III
General
Manual

INTRODUCTION

The ARTOUSTE III is a turbo-shaft engine essentially designed to be installed on single-engine helicopters. At present it is mounted on ALOUETTE III helicopters produced by SUD-AVIATION, but it can be used for other purposes than in Aeronautics.

It is an engine of the second generation of TURBOMECA's productions, developed from the ARTOUSTE II which is mounted on the SUD-AVIATION's ALOUETTE II helicopter. It mainly differs from the ARTOUSTE II in an additional compressor stage and turbine stage which grant better performances to it.

It is designed according to the principles confirmed by the previous TURBOMECA's productions and it essentially consists of :

- a reduction gear
- an air intake
- an axial compressor
- a centrifugal compressor
- an annular combustion chamber with centrifugal fuel injection
- three stages of turbine
- an exhaust system.

It develops a shaft power of 550 CV with a fuel consumption of 180 kg per hour.

ENGINE MAIN COMPONENTS

The ARTOUSTE III is a turbo-shaft of fixed type turbine operating at a constant rotation speed.

It mainly consists of :

- a "front" section
- a gas generator
- equipment and accessories.

The front section includes :

- a reduction gear
- an accessory drive system
- an output shaft.

The gas generator includes the following components :

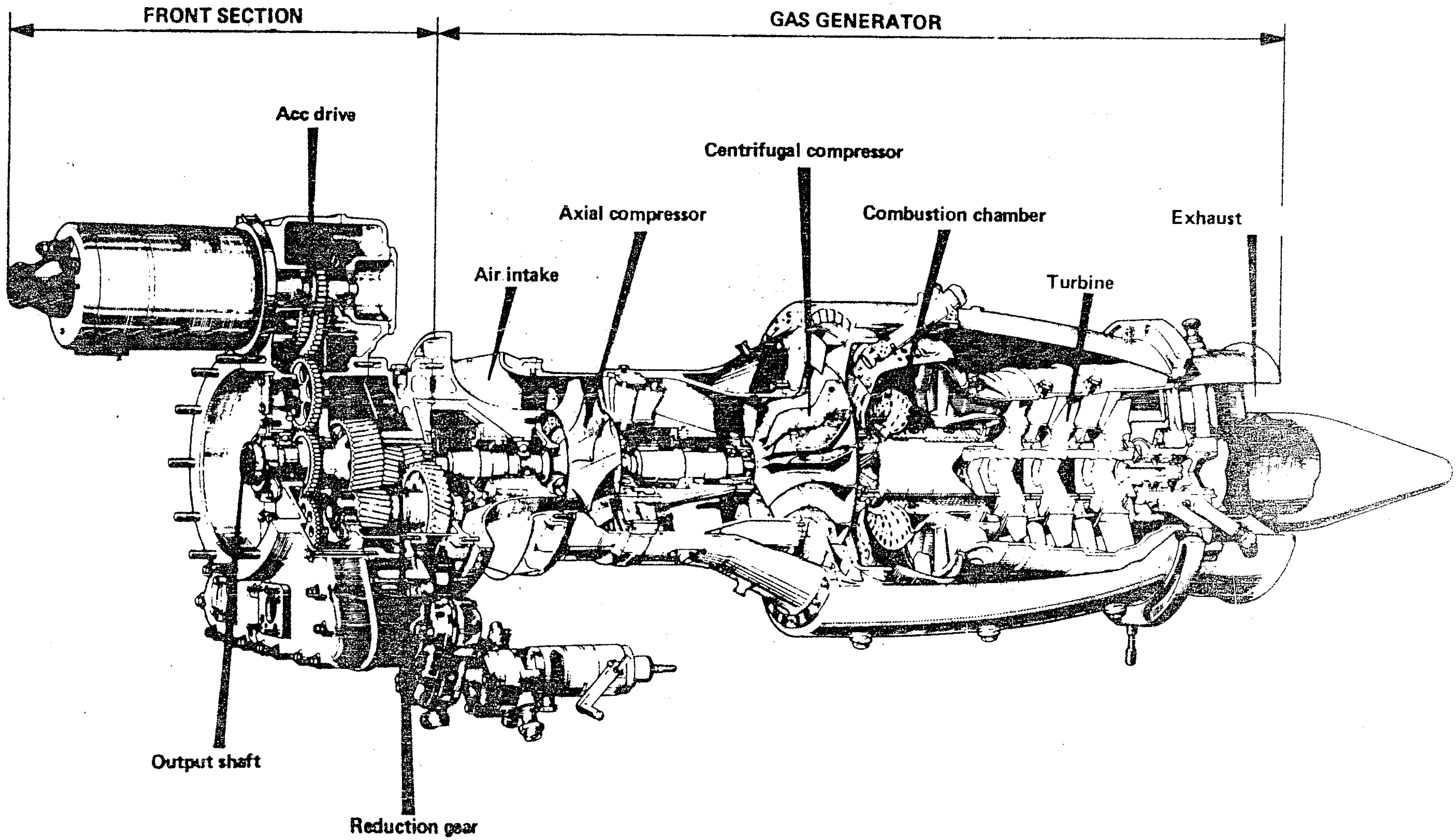
- an air intake
- an axial compressor
- a centrifugal compressor
- an annular combustion chamber
- a three-stage turbine
- an exhaust system.

Equipment and accessories

It is provided with all equipment and accessories allowing its use as a turbo-shaft power plant.

The nominal power delivered is 550 ch for a fuel consumption of 180 kg per hour and a weight of 182 kg.

The diagram attached shows the main components of this engine.



ARTOUSTE III PERSPECTIVE CUT–AWAY

THERMODYNAMIC OPERATION

The engine produces the shaft power by transforming the energy contained in the air and in the fuel.

The thermodynamic operation leading to this production of power is carried out in the following way :

- The ambient air enters the engine through the two side cowlings and the annular air intake.

- A first compression of this air is ensured by the axial compressor as follows :

  - increase in air velocity and pressure in the axial compressor rotor,

  - flow through the vanes of the stator which have a divergent passage section and transformation of velocity into pressure.

- The air subjected to this first compression is then directed towards the centrifugal compressor through an annular duct.

- A second compression is then ensured by the centrifugal compressor in the following way :

  - increase in velocity and pressure in the centrifugal rotor,

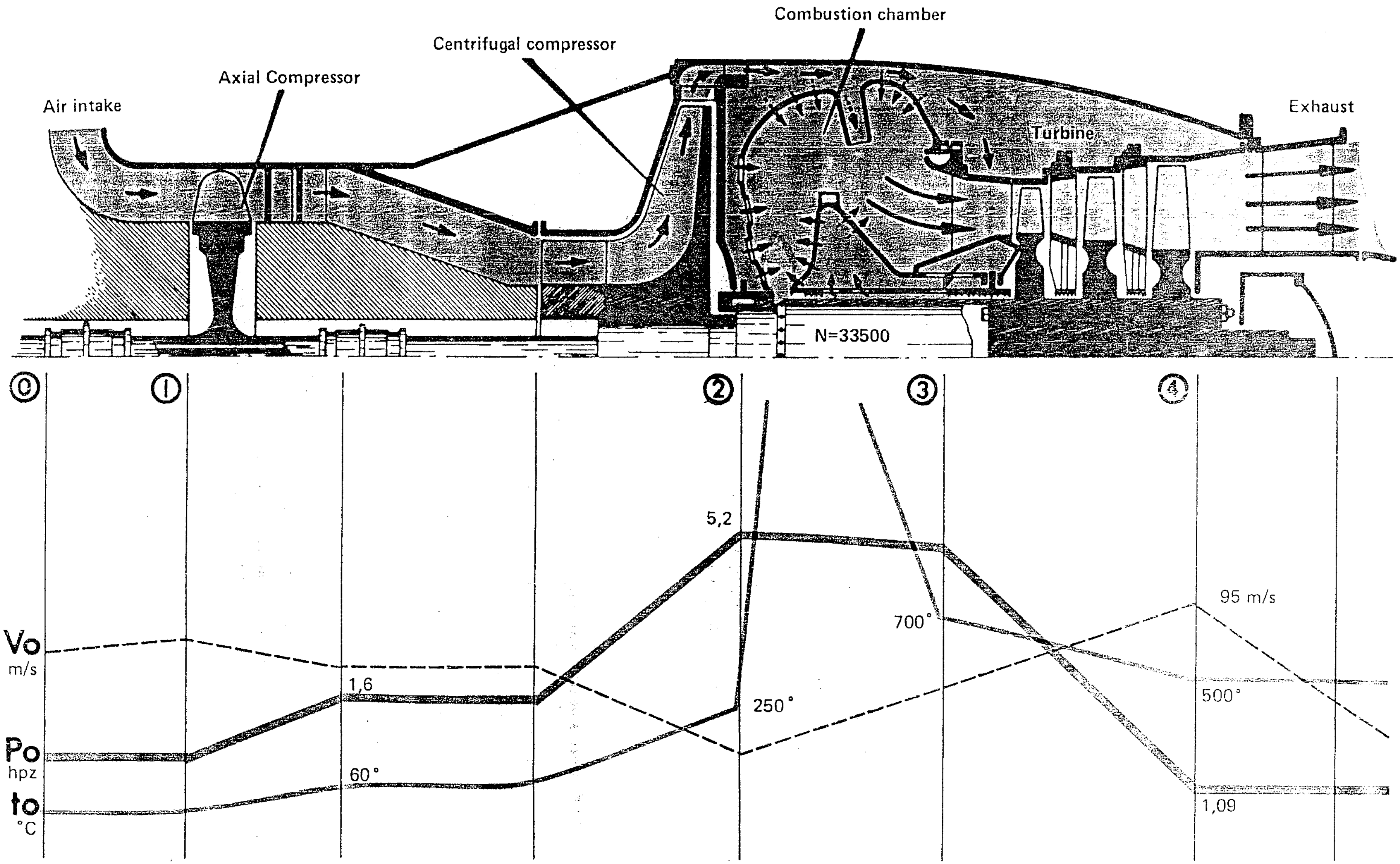
  - flow through the vanes of the two stators (or diffusers) which turn the velocity into pressure and guide the air towards the combustion chamber.

- The air under pressure enters the combustion chamber where it is divided in two flows :

  - a primary air flow mixed with the fuel atomized by the injection wheel ; this flow is itself divided in two paths : one path flowing through the slots of the front swirl plate, the other path through the first stage turbine nozzle guide vanes and the rear swirl plate,

  - a secondary air flow which passes through the tubes and the holes of the mixing unit and cools the burnt gases.

- The burnt gases from combustion then flow through the turbines and are expelled through the exhaust system. The turbines transform the kinetic energy of the gases into mechanical energy to drive the compressors, the accessories and the output shaft.



ENGINE GAS FLOW DIAGRAM

GENERAL DESCRIPTION OF THE POWER PLANT

ENGINE

The ARTOUSTE III is a turbo-shaft of fixed turbine constant rotation speed type.

It consists of the following components :

- a reduction gear
- an accessory drive
- an annular air intake
- an axial compressor
- a centrifugal compressor
- an annular combustion chamber
- a three-stage turbine
- an exhaust system.

LUBRICATION

The engine lubrication is ensured by an oil system mainly including :

- an oil tank (aircraft manufacturer's supply)
- a cooler (aircraft manufacturer's supply)
- a gear type oil pump unit
- a filter
- pipes and ducts
- indicating systems.

The oil of this circuit is also used as an hydraulic fluid for the speed governor.

The engine is capable of operation either with mineral oil or with synthetic oil.

FUEL SYSTEM

The fuel supply, flow control and injection are carried out by means of a system including :

- a mechanical fuel pump driven by the engine
- an idling device
- an isochronous speed governor
- an electric fuel cock
- a centrifugal fuel injection device.

The fuel injection and ignition at starting are carried out by an independent circuit including :

- a micro-pump
- a 4-way union
- two torch-igniters
- a dual ignition coil of high tension type.

AIR SYSTEM

The air is used to operate the following systems :

- torch-igniter ventilation
- supply to starter cut-out switch (P2 version)
- P2 air tapping at aircraft manufacturer's disposal
- Po air supply.

ENGINE CONTROL

The control of the engine is entirely automatic, it does not involve any manual control lever.

Nevertheless, the functions of engine starting, acceleration and stopping are carried out by means of a control lever and a switch.

The three-position switch allows the selection of starting, stopping and ventilation of the engine.

The control lever (called fuel flow valve control) allows engine acceleration and deceleration.

ENGINE INSTRUMENTATION

The engine indicating is carried out by means of the following systems :

- gas temperature indication
- engine rotation speed indication
- lubricating oil pressure indication
- oil temperature indication.

Moreover, various warning lights allow certain phases of operation to be indicated.

FUEL FLOW CONTROL

The engine fuel flow control is carried out so as to keep a sole constant rotation speed in every operating condition.

It essentially involves a speed governor which meters the fuel injected into the engine.

The speed governor driven by the engine and hydraulically assisted is of integral type and it is called isochronous speed governor.

DRAINAGE

The turbo-shaft is provided with the following air tapping and draining points :

- jet-holder drain (at present blanked)
- micro-pump drain
- starting fuel valve drain
- combustion chamber drain
- jet pipe drain (aircraft manufacturer)
- rear bearing air vent
- idling device Po supply
- oil tank air vent (aircraft manufacturer).

AIRCRAFT SERVICES

The power plant is provided with three mounting pads allowing it to be installed on the aircraft ; two brackets located on each side of the engine front part and a rear bracket.

A hoisting point is located nearly in the line of the centre of gravity.

The accessory drive housing is provided with gears at the aircraft manufacturer's disposal ; alternator drive, hydraulic pump drive, spare drive.

A compressed air tapping point at compressor outlet is at the aircraft manufacturer's disposal.

The protection against fire of the power plant is provided by the aircraft manufacturer.

STARTING

The engine cranking is ensured by a starter-generator mounted on the accessory drive plate.

The fuel ignition in the chamber is ensured through two torch-igniters supplied with fuel under pressure by a micro-pump and in high voltage current by a dual ignition coil.

The sequences of engine starting and stopping are automatically carried out by means of an "automatic control box".

The ventilation function is obtainable by cranking the engine only.

ELECTRIC SYSTEM

The engine electric system is operated with direct current.

It includes :

- the engine indicating system
- the starting and stopping control system.

All the wirings are connected to the automatic control box which ensures the junction with the aircraft manufacturer's equipment.

ENGINE MAINTENANCE

All the accessories are located inside the engine cross-section and have a good accessibility.

Removal and installation of the power plant require only a few operations and can be quickly performed.

Practices on the engine itself are at present restricted to rear bearing removal and installation and output shaft removal and installation.

The recommended frequency of inspection is of 100 hours (accurate frequency stated by the aircraft manufacturer).

The operating time between general overhaul is at the moment...... hours. All the accessories have the same operating time between overhaul as the engine.

All the engine components have a high reliability.

The time required for maintenance by flying hour is about :-----

GENERAL OPERATION

INTRODUCTION

The energy delivered by the engine is essentially represented by the power developed on the shaft.

Its operating point is mainly characterized by :

- the rotation speed
- the torque
- the gas temperature.

PRINCIPLE

The power variations are initiated by the "receiver" and the engine is designed so as to adapt itself automatically to these variations.

The principle consists in a permanent adaptation of the engine torque to the resisting torque. This adaptation is performed by controlling the engine torque in function of a rotation speed detection.

Thus a constant rotation speed of the engine is obtained in every operating condition.

The torque is therefore variable with the operating conditions but it is clearly obvious that a max. limitation is required. Nevertheless it is considered that the torque will remain within acceptable limits for the receiver operating envelope.

In the same way, the engine gas temperature will remain within the permissible limits for the receiver operating envelope.

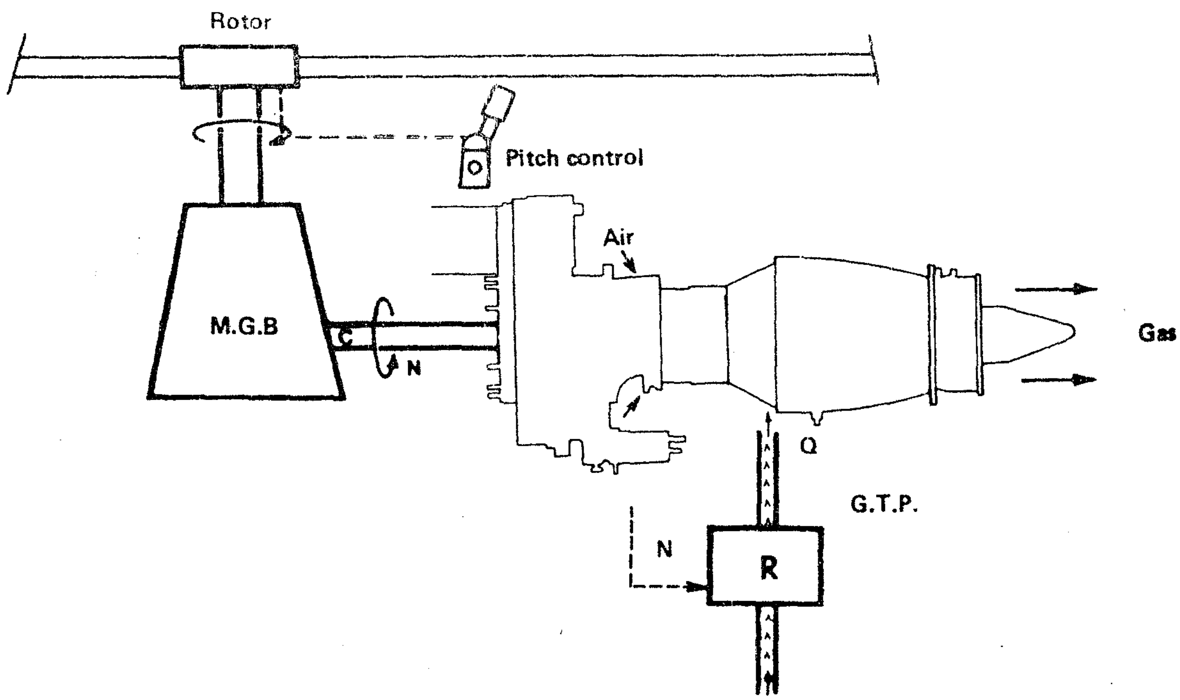
The fuel flow control then consists in keeping constant the nominal rotation speed in all operating conditions.

ROTATION SPEED CONTROL

A speed governor of "integral" type, mechanically driven by the engine and hydraulically assisted, detects the rotation speed and meters the fuel according to this detection.

Thus it ensures the balance between the energy taken by the receiver and the energy delivered by the engine ; and this maintains constant the rotation speed (rotation speed variations in transient condition being only of low magnitude).

The indication of operation is made by watching the rotation speed and the gas temperature.



Receiver

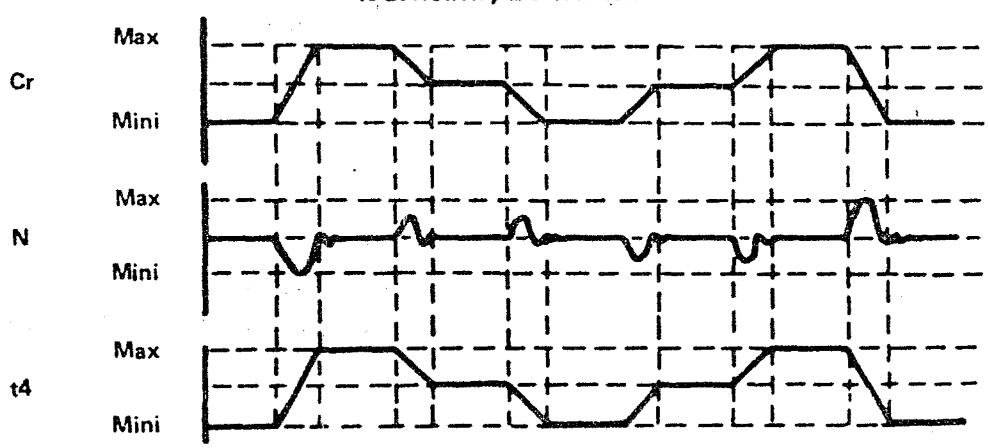
Resisting torque : f(pitch and flight)

Generator

Engine torque : f (Q/G , c)

Fuel flow control – Engine torque adapted to resisting torque

N detection , Q correction



GENERAL OPERATION (Helicopter operation)

PERFORMANCES AND CHARACTERISTICS

MAIN PERFORMANCES

- Power on the shaft .... 405 kw (550 ch)
- Residual thrust .... 43.4 daN (44.2 kg)
- Specific consumption .... 0.469 kg/kw/h (0.345 kg/ch)

Note   The power of 550 ch is kept up to an atmospheric temperature of 45° or an altitude of 4,000 standard meters.

ENGINE MAIN CHARACTERISTICS

- Air flow .... 4.5 kg/s
- Compression ratio 5.2
- Compressor efficiency 0.759
- Air fuel ratio 1/45
- Turbine efficiency 0.862
- Exhaust gas velocity .... 95.2 m/s
- Turbine inlet temperature .... 700° C
- Rotation speed .... 33,500 RPM
- Output shaft rotation speed ..... 5,773 RPM

ENGINE REFERENCE STATIONS

0 .... Upstream atmosphere

1 .... Air intake

2 .... Compressor outlet

3 .... Turbine inlet

4 .... Turbine outlet

REVIEW OF A FEW SYMBOLS

N .... Rotation speed

P .... Pressure

T .... Absolute temperature in "Kelvin" degrees

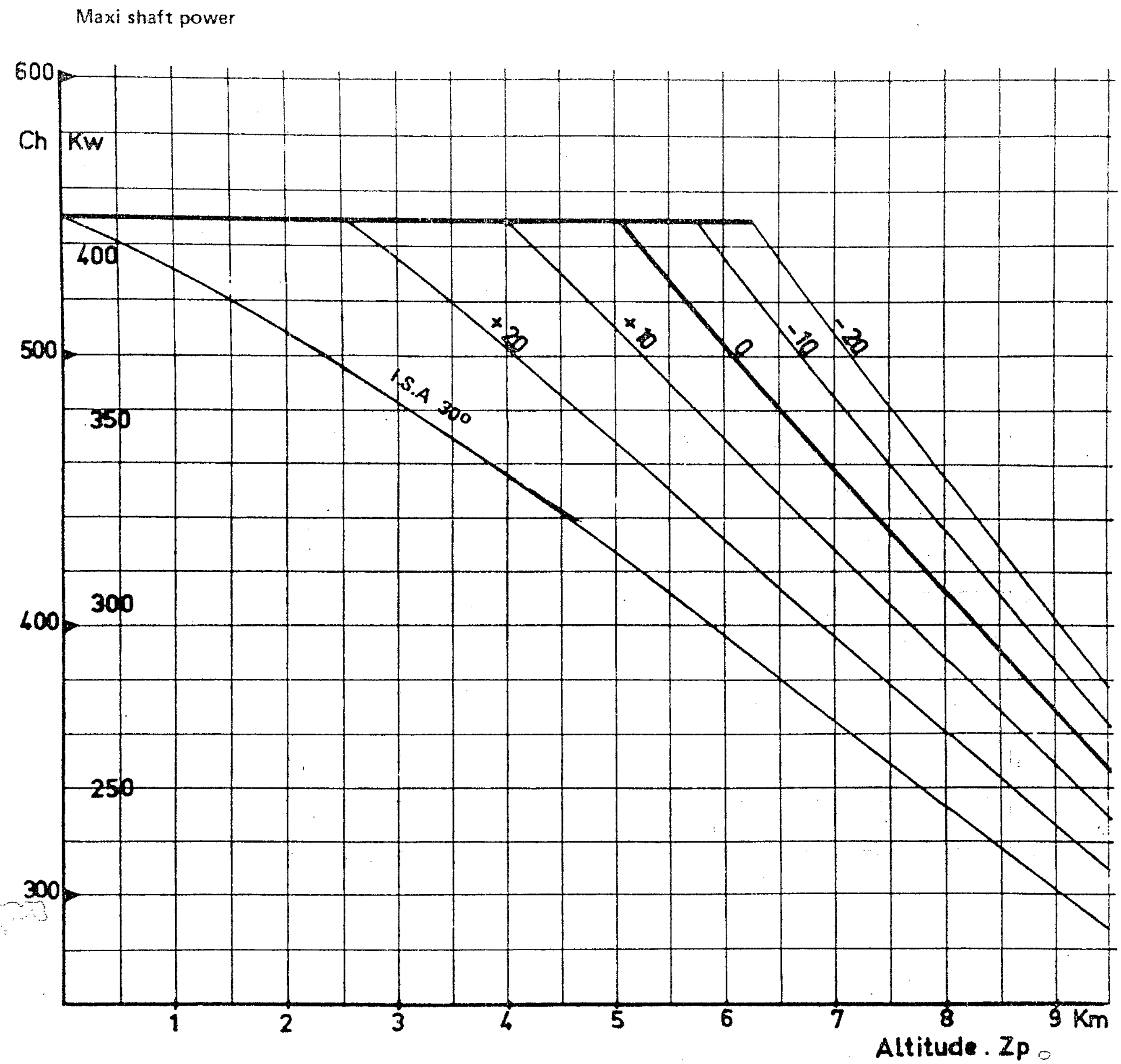
t .... Relative temperature in "centigrade" degrees

CH .... Fuel consumption per hour

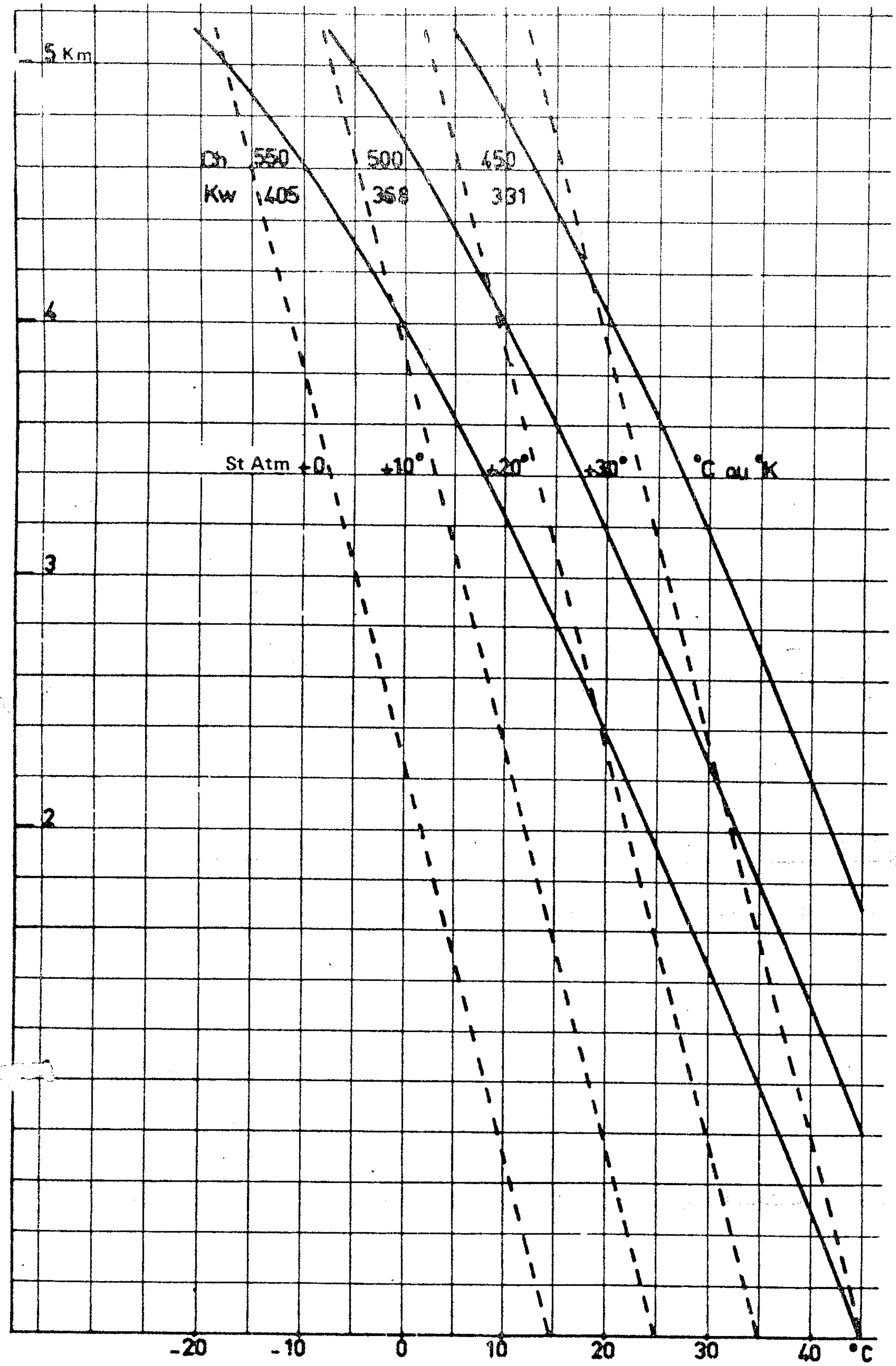
Cs .... Fuel specific consumption

W .... Power

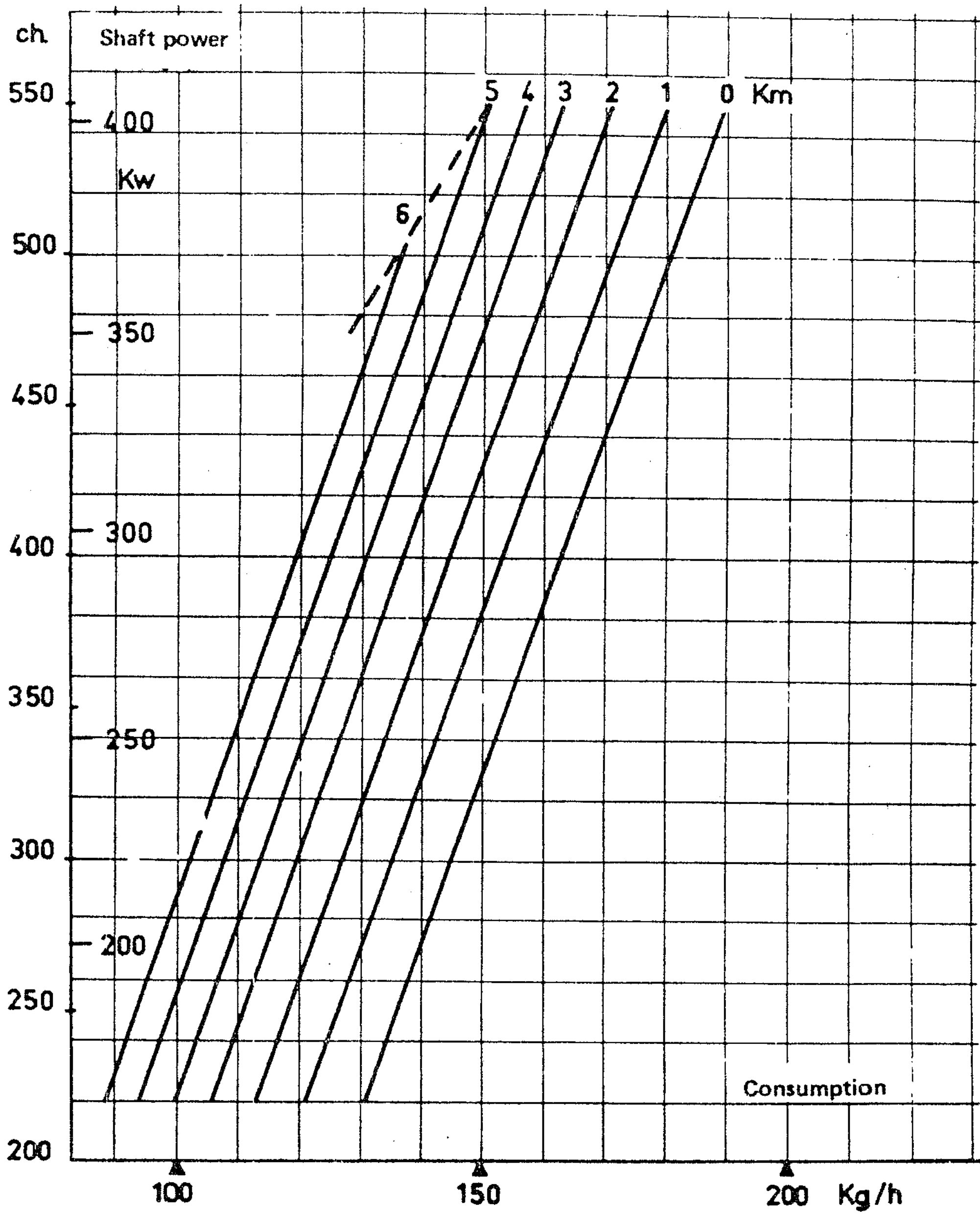
Note   The above values are given for information only and must not be regarded as official data.



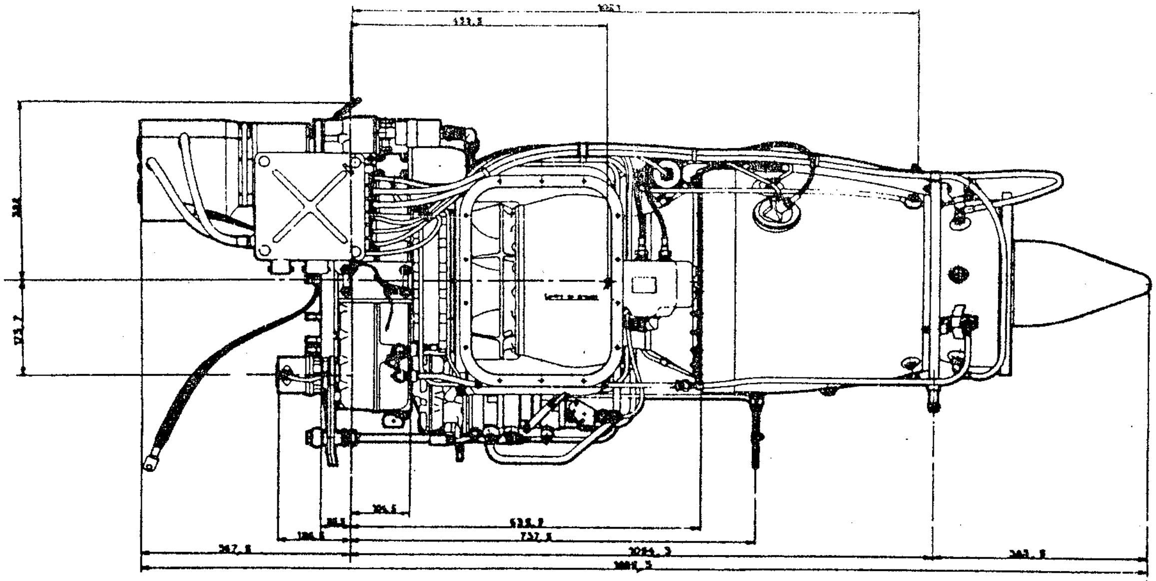
SHAFT MAXIMUN POWER IN FUNCTION OF ALTITUDE AND TEMPERATURE



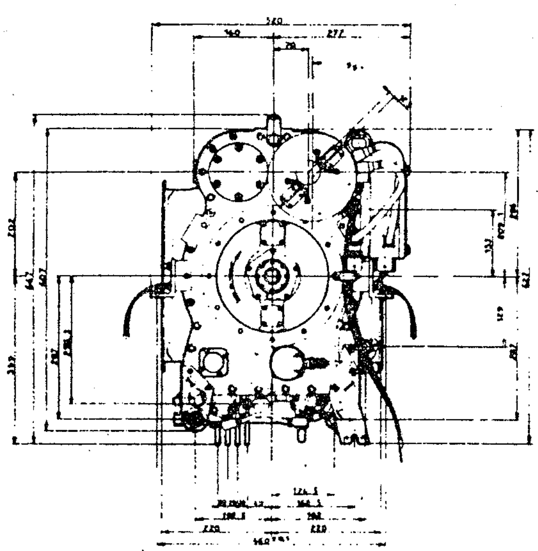
SHAFT POWER IN FUNCTION OF EXTERNAL CONDITIONS



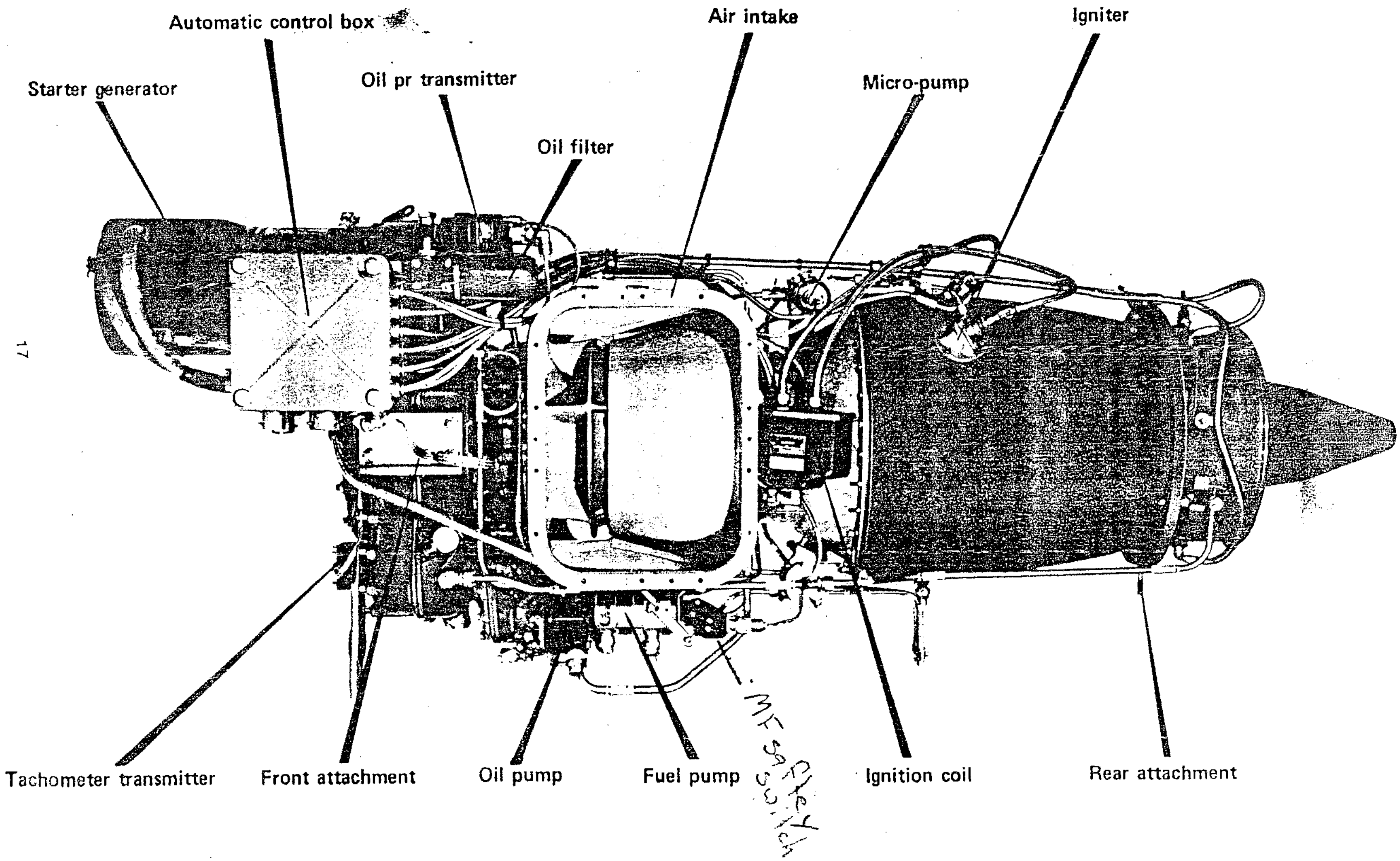
SHAFT POWER AND CONSUMPTION IN FUNCTION OF I.S.A



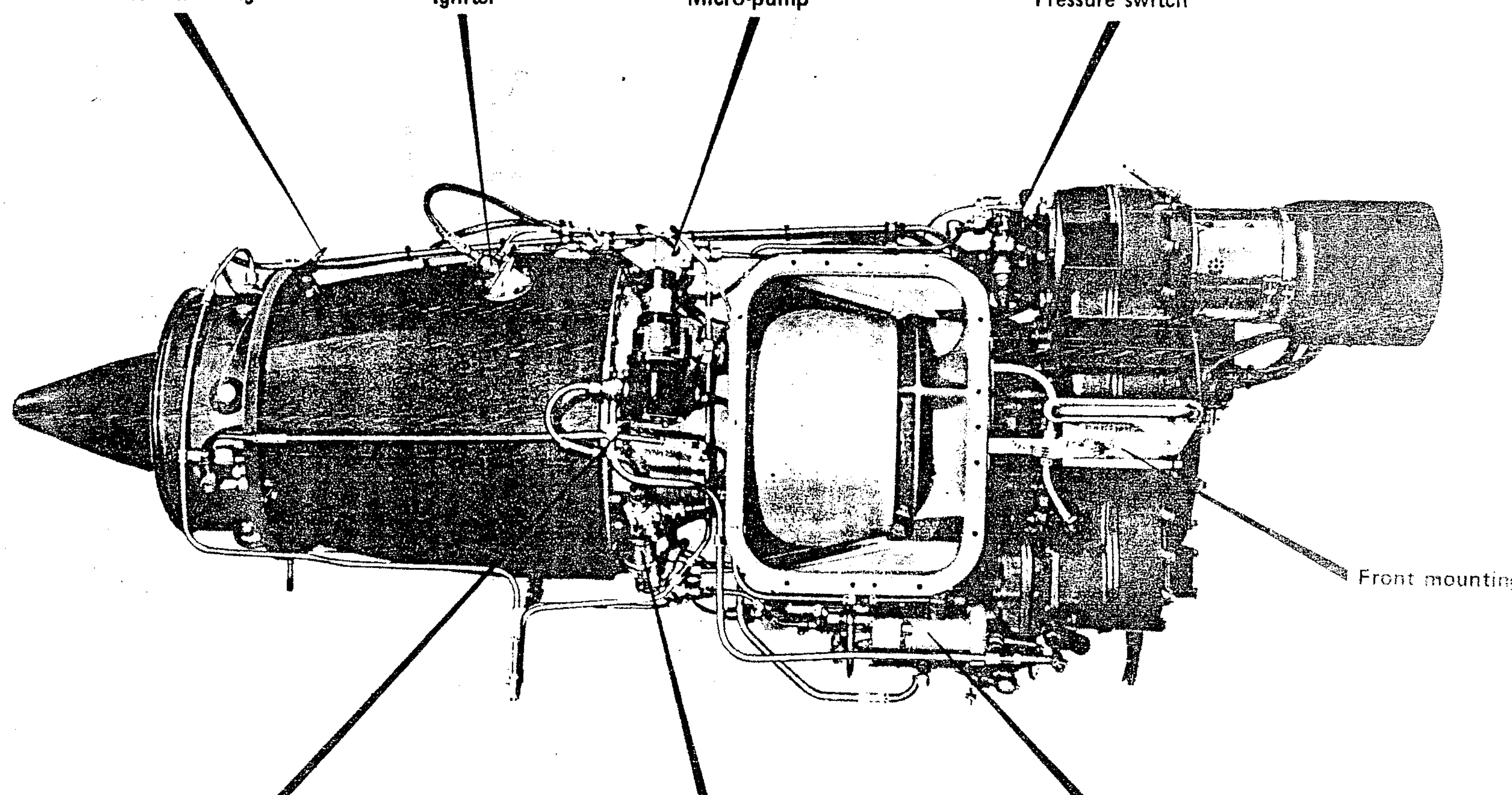
DIMENSIONS – LEFT VIEW



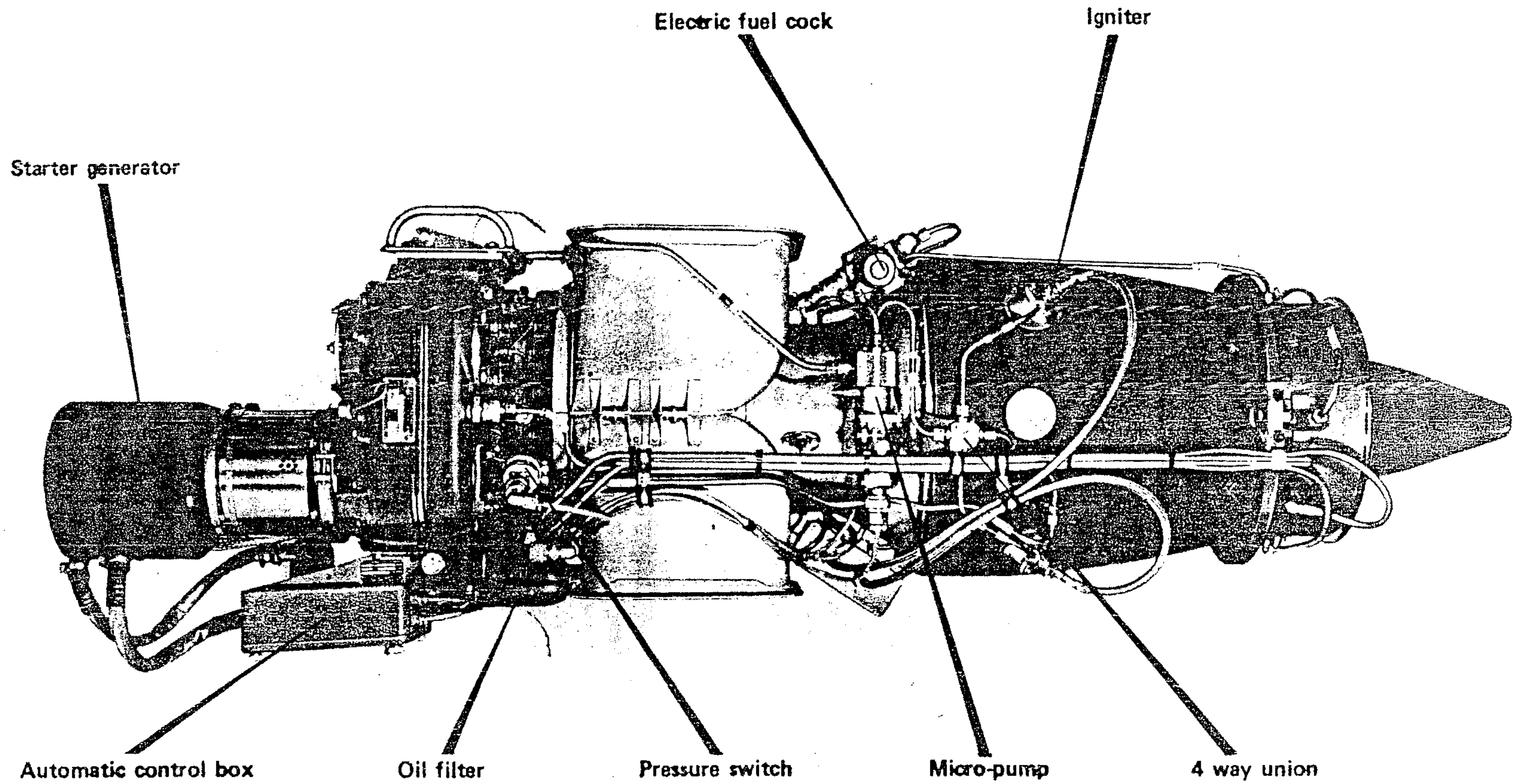
DIMENSIONS – FRONT VIEW



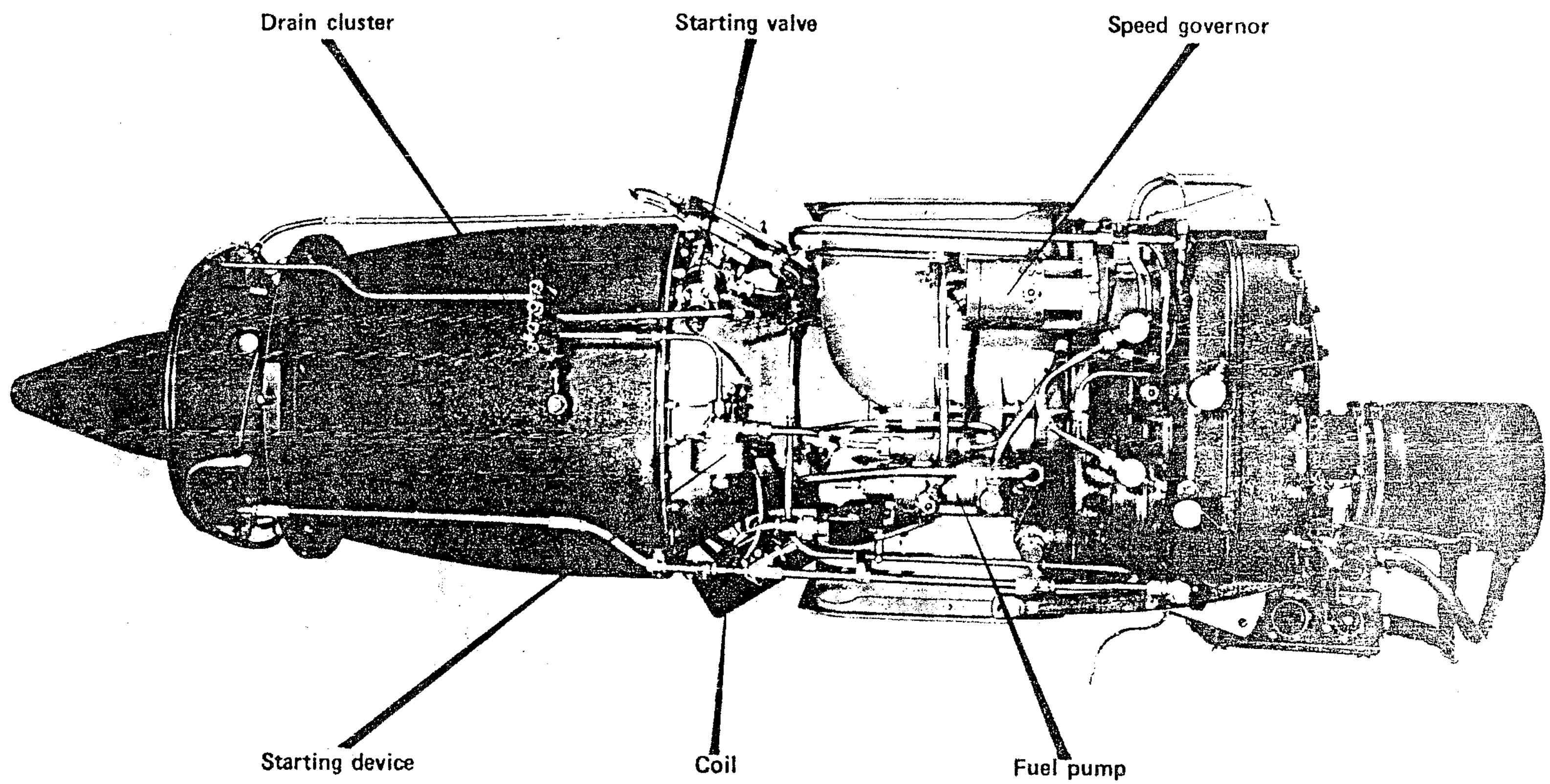
ENGINE VIEW FROM THE LEFT



ENGINE VIEW FROM THE RIGHT



ENGINE VIEW FROM THE TOP



ENGINE VIEW FROM THE BOTTOM

NOTES

CHAPTER 3

ENGINE DESCRIPTION

- INTRODUCTION
- ENGINE FRONT SECTION
- AIR INTAKE
- AXIAL COMPRESSOR
- CENTRIFUGAL COMPRESSOR
- COMBUSTION CHAMBER
- TURBINE AND EXHAUST SYSTEM
- FUEL INTERNAL SYSTEM
- MAINTENANCE

INTRODUCTION

GENERAL

This chapter is devoted to the technical study of the bare engine main components.

It is laid down in the following way :

- Engine front section
- Air intake
- Axial compressor
- Centrifugal compressor
- Combustion chamber
- Turbine
- Exhaust system
- Internal fuel system
- Maintenance.

Only the points being the object of special practices in field maintenance will be dealt with in full details.

During a training course, the various maintenance operations are covered in practical work.

GENERAL CONSTITUTION

The ARTOUSTE III is a turbo-shaft of fixed turbine type with drive shaft at the front.

It essentially consists of :

A front section including :

- a reduction gear
- an accessory drive
- an output shaft.

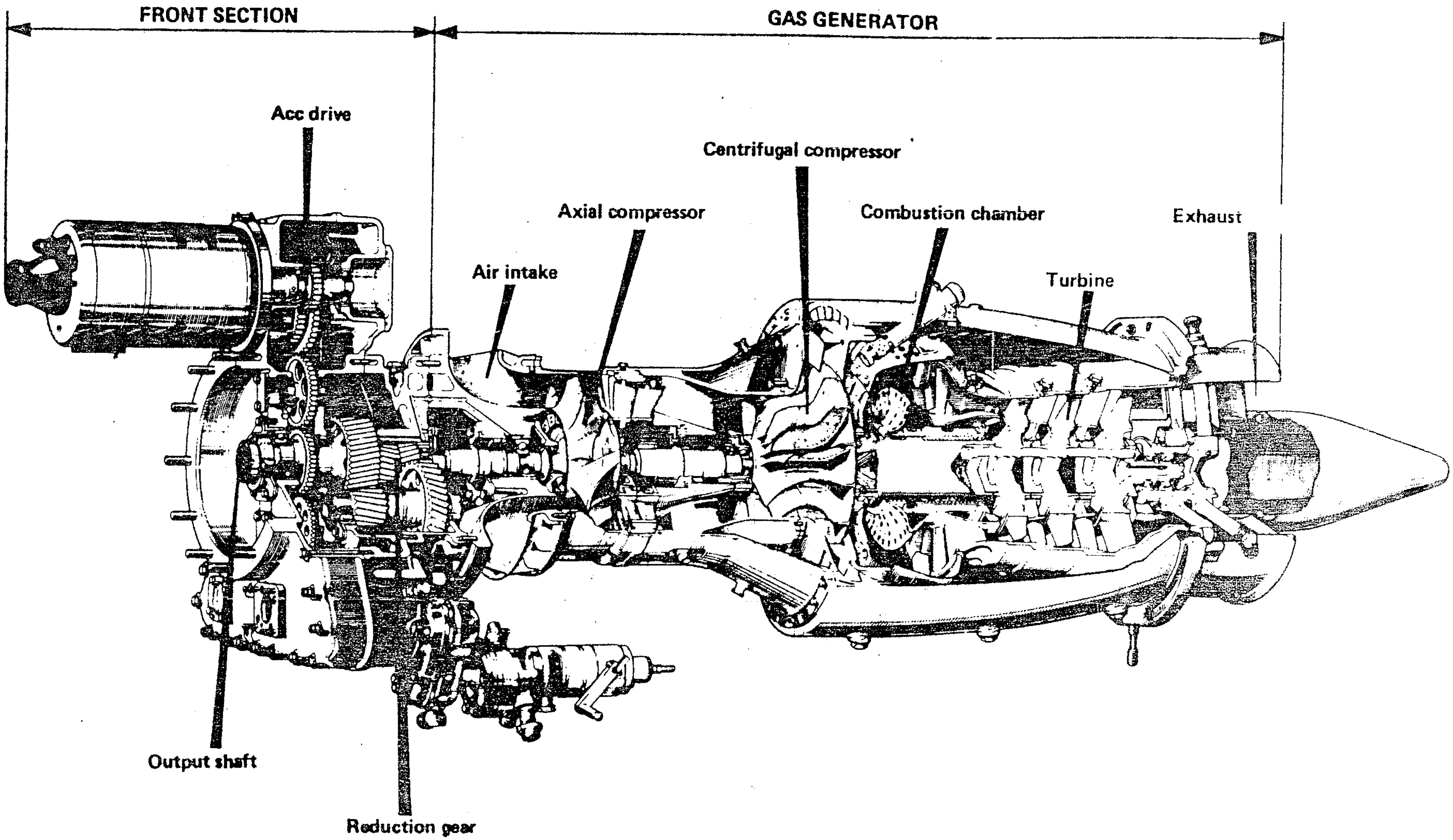
A gas generator including :

- an air intake
- an axial compressor
- a centrifugal compressor
- an annular combustion chamber
- a three-stage turbine
- an exhaust system.

The generator shaft rotates in counter clockwise direction when facing the engine from the rear, at a nominal rotation speed of 33,500 RPM.

The reduction ratio is 1/5.8025, which gives a rotation speed of the output shaft of 5,773 RPM.

The nominal power on the shaft is 550 ch.



ARTOUSTE III PERSPECTIVE CUT–AWAY

ENGINE FRONT SECTION

INTRODUCTION

The front section of the engine is composed of :

- the reduction gear
- the output shaft
- the accessory drive.

REDUCTION GEAR

It ensures the reduction of the rotation speed in a ratio of 1/5.8025. Thus the output shaft rotation speed is 5,773 RPM for 33,500 RPM at the gas generator.

It mainly includes :

- a dual driving pinion
- two intermediate pinions
- a crown wheel integral with the output shaft
- a casing which forms the housing of the reduction gear.

OUTPUT SHAFT

The output shaft is integral with the crown wheel of the reduction gear.

It consists in a hollow shaft provided with grooves which constitutes the drive.

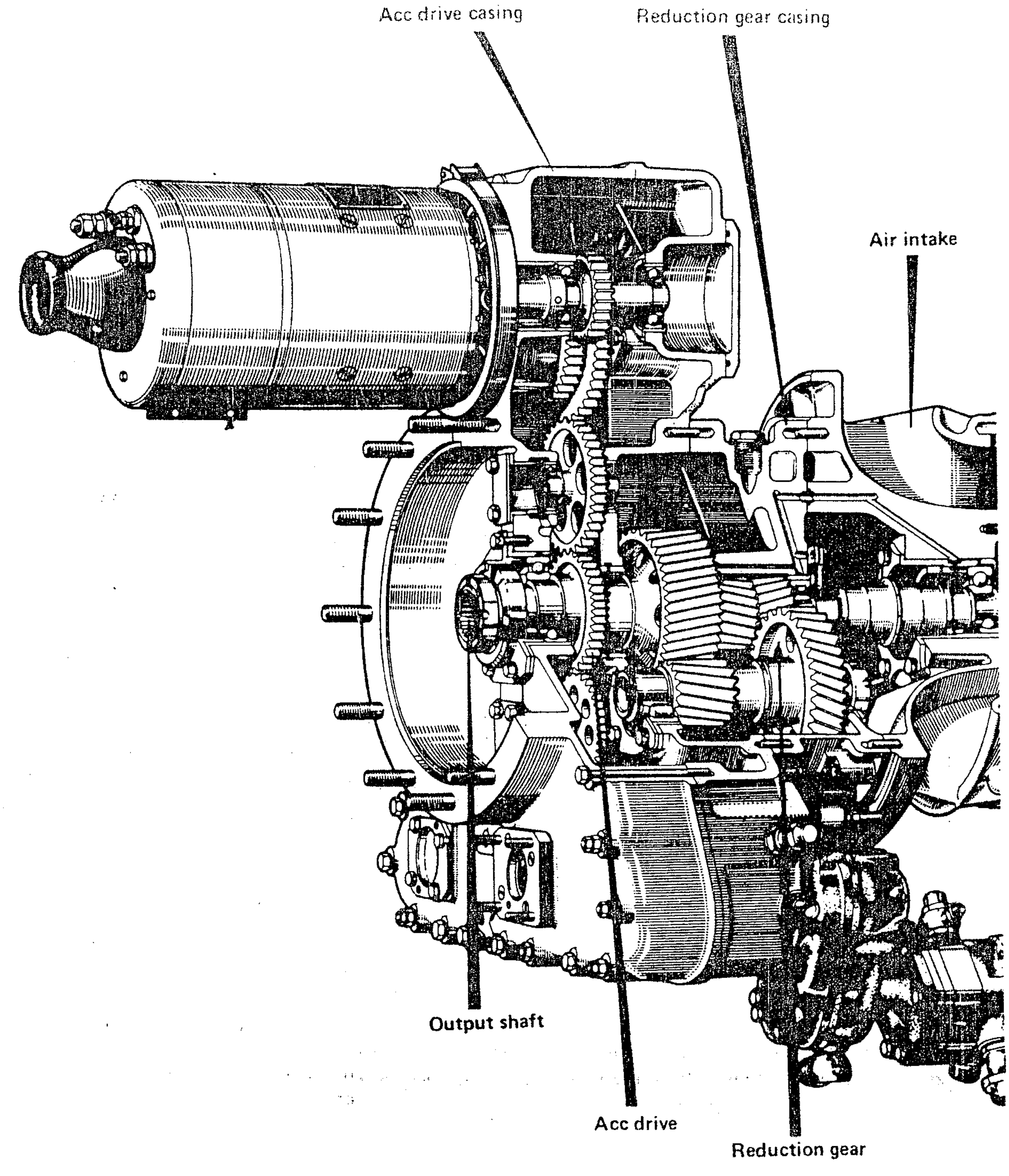
It is supported by a bearing whose oil sealing is ensured by a "sealol" type seal.

ACCESSORY DRIVE

The accessory drive is ensured by means of a gear driven by the reduction gear output shaft.

The gear drives two accessory gear trains located in a casing called accessory casing.

The upper gear train includes the driving gear for the starter-generator and a spare drive, and the lower gear train includes the drives for all engine accessories.



FRONT SECTION PERSPECTIVE

REDUCTION GEAR

Its purpose is to ensure the reduction of the generator rotation speed.

It consists essentially of :

- a driving pinion
- two intermediate pinions
- a crown wheel
- a casing.

Driving pinion

It is a double pinion which rotates at the same speed as the generator shaft to which it is connected by means of a muff coupling.

It is composed of two helical gears mounted on a hollow shaft. The shaft is hollow for the fuel tube passage and it is supported by two roller bearings.

Intermediate pinions

The two intermediate pinions are driven by the two gears of the driving pinion and provide the crown wheel with the transmission of rotation.

Each pinion consists of a hollow shaft on which the gears are mounted ; the shaft is supported by a roller-bearing at the front and a ball-bearing at the rear.

Crown wheel

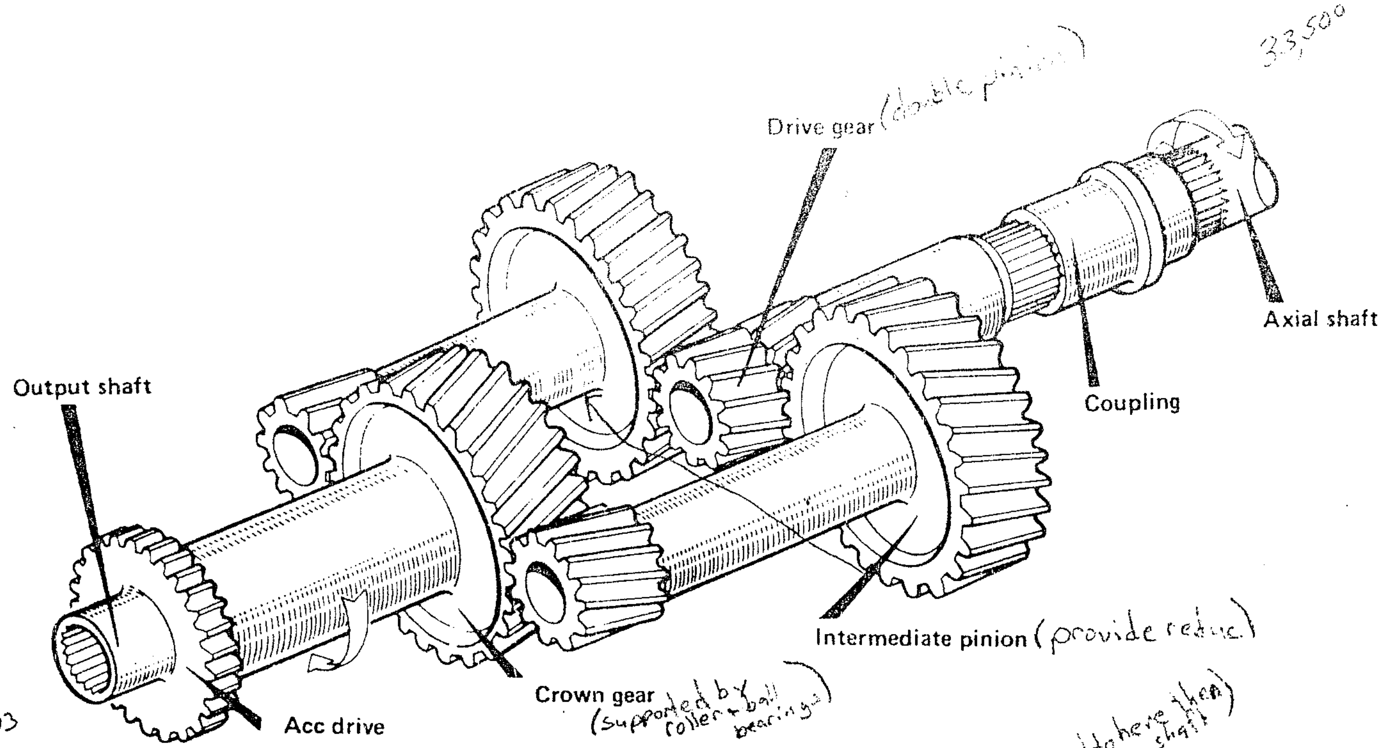
It consists of a helical gear driven by the two intermediate pinions.

It is integral with the output shaft which is supported by a ball-bearing and a needle-bearing.

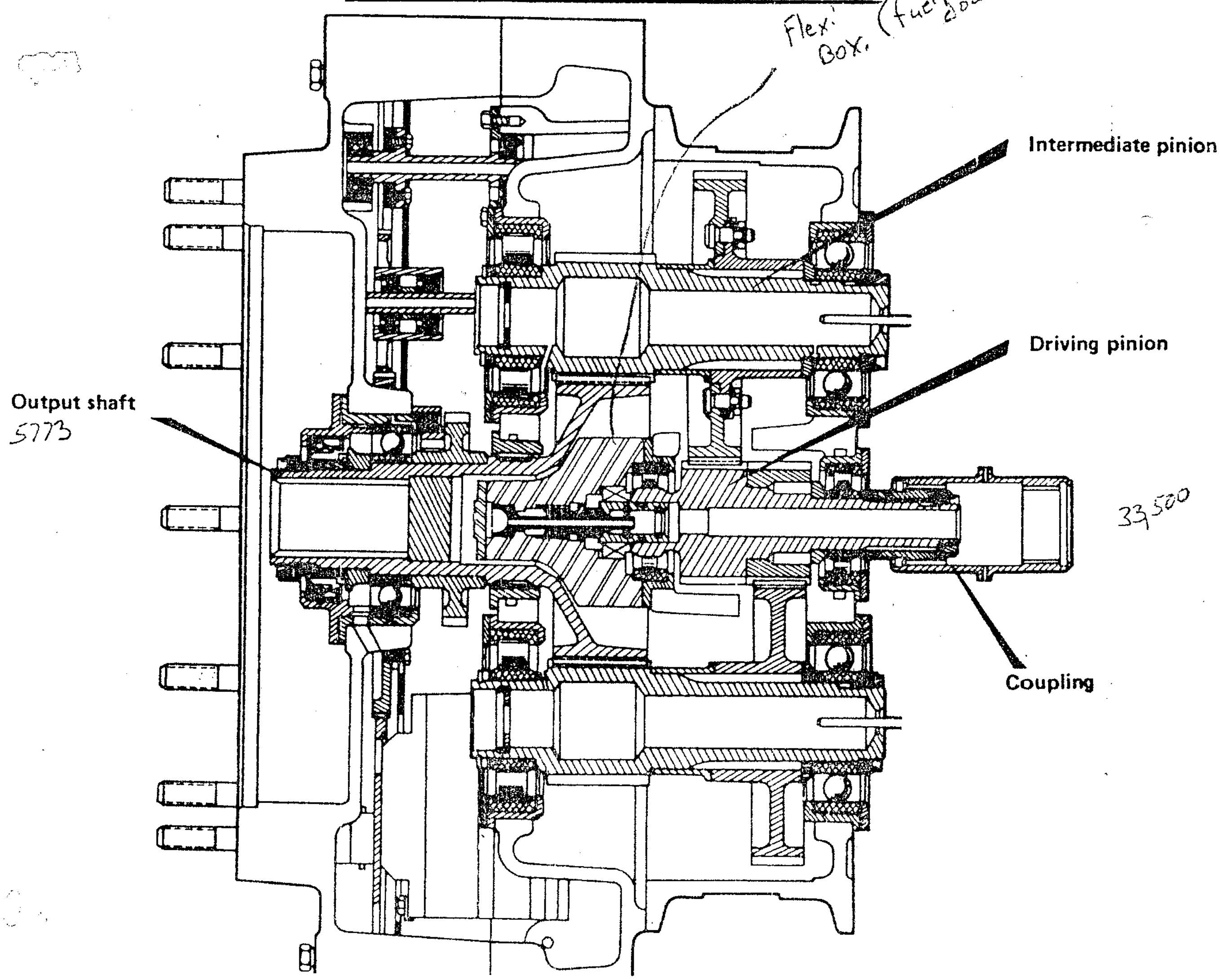
Casing

It houses the moving components of the reduction gear.

It is a casing of light alloy mounted between the air intake casing and the support casing. It is provided with numerous drillings for the circulation of the various circuit fluids.



SCHEMATIC PERSPECTIVE OF REDUCTION GEAR



REDUCTION GEAR CUT–AWAY

OUTPUT SHAFT

The output shaft is integral with the crown wheel of the reduction gear.

Its front end has internal grooves providing the main drive.

It also drives, by means of a gear, the two accessory gear trains.

It is located in a casing called "support casing" which is mounted on the front flange of the reduction gear casing.

It consists of the following components :

- the output shaft itself
- the output shaft bearing
- the output shaft seal
- the output shaft retaining nut.

Shaft

Integral with the crown wheel, it is provided with internal grooves providing the drive.

Its front end is threaded for the retaining nut installation.

Bearing

It consists of a ball-bearing mounted in a cage centered on the front internal hub of the casing, and a needle-bearing.

Seal

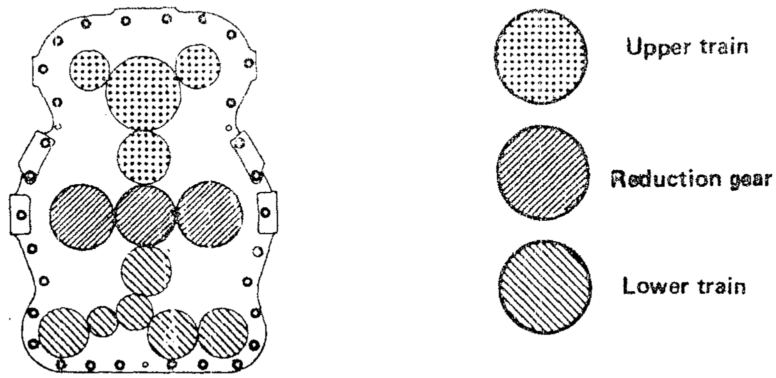
It ensures the sealing of the bearing lubricating oil. It is made up of a graphite seal with release spring resting against a friction washer.

Nut

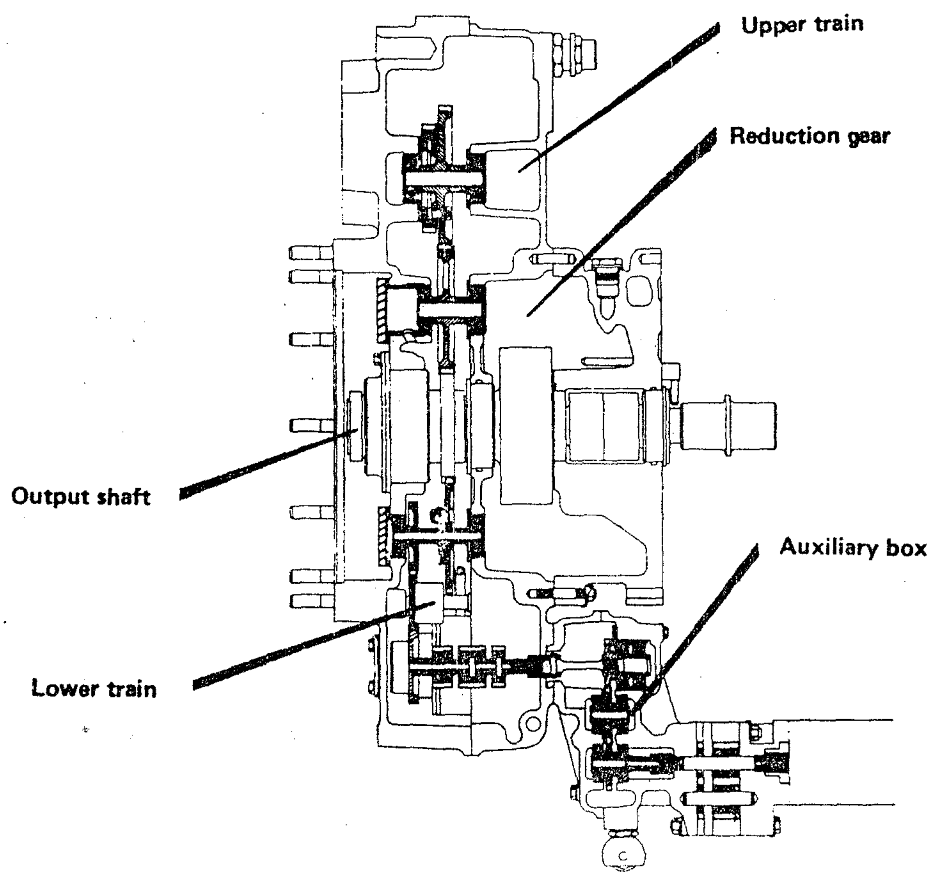
It is screwed on the output shaft end and it ensures the retaining of the assembly.

Note .

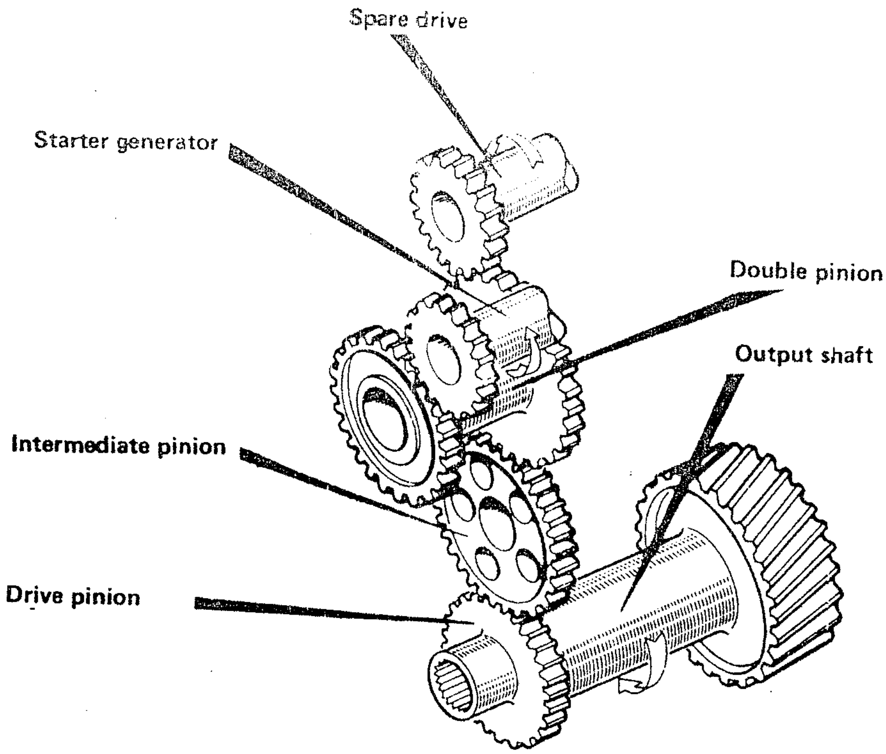
The removal and assembly of the seal is a permitted field maintenance operation.



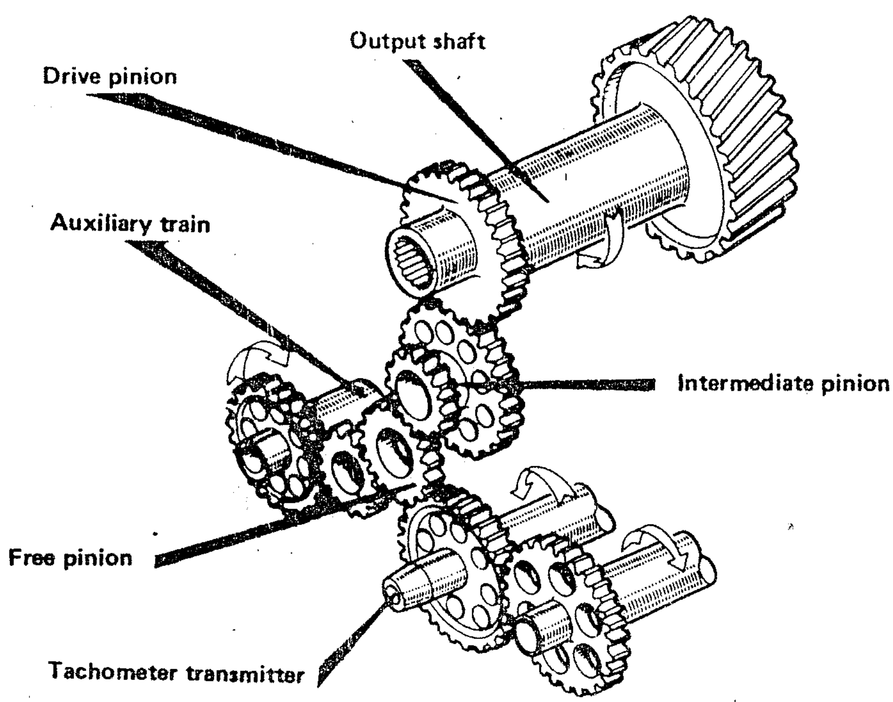
SCHEMATIC DIAGRAM OF THE ACCESSORY DRIVE



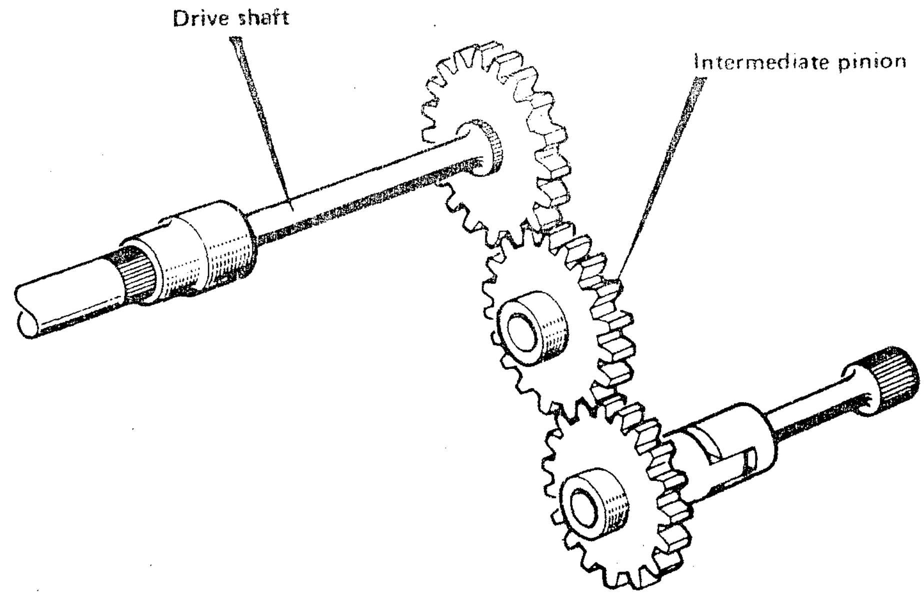
ACCESSORY DRIVE CUT–AWAY



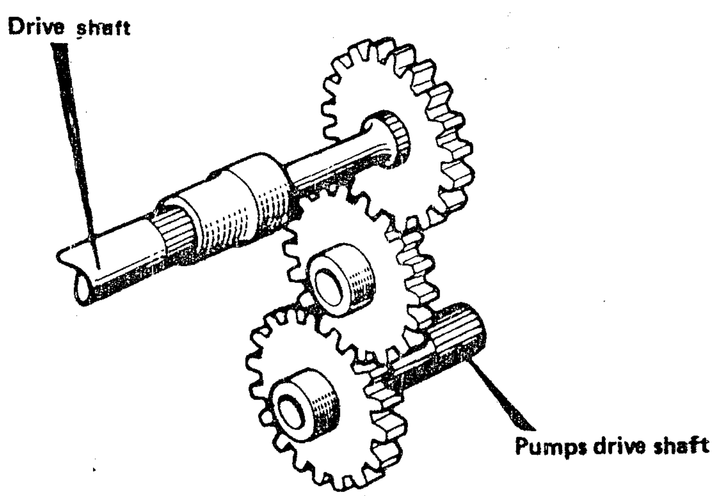
UPPER ACCESSORY DRIVE



LOWER ACCESSORY DRIVE



FUEL CONTROL UNIT DRIVE



OIL PUMPS DRIVE

AIR INTAKE

INTRODUCTION

The ambient air enters the engine through a fairing system and an air intake casing.

The engine air intake then includes :

- the air intake cowling
- the air intake casing.

AIR INTAKE COWLING

The air intake cowling consists of two side inlets formed by an assembly of two fairings of boiled iron.

The two parts are secured together round the engine air intake casing.

AIR INTAKE CASING

The engine annular air intake is made up of a casing of light alloy.

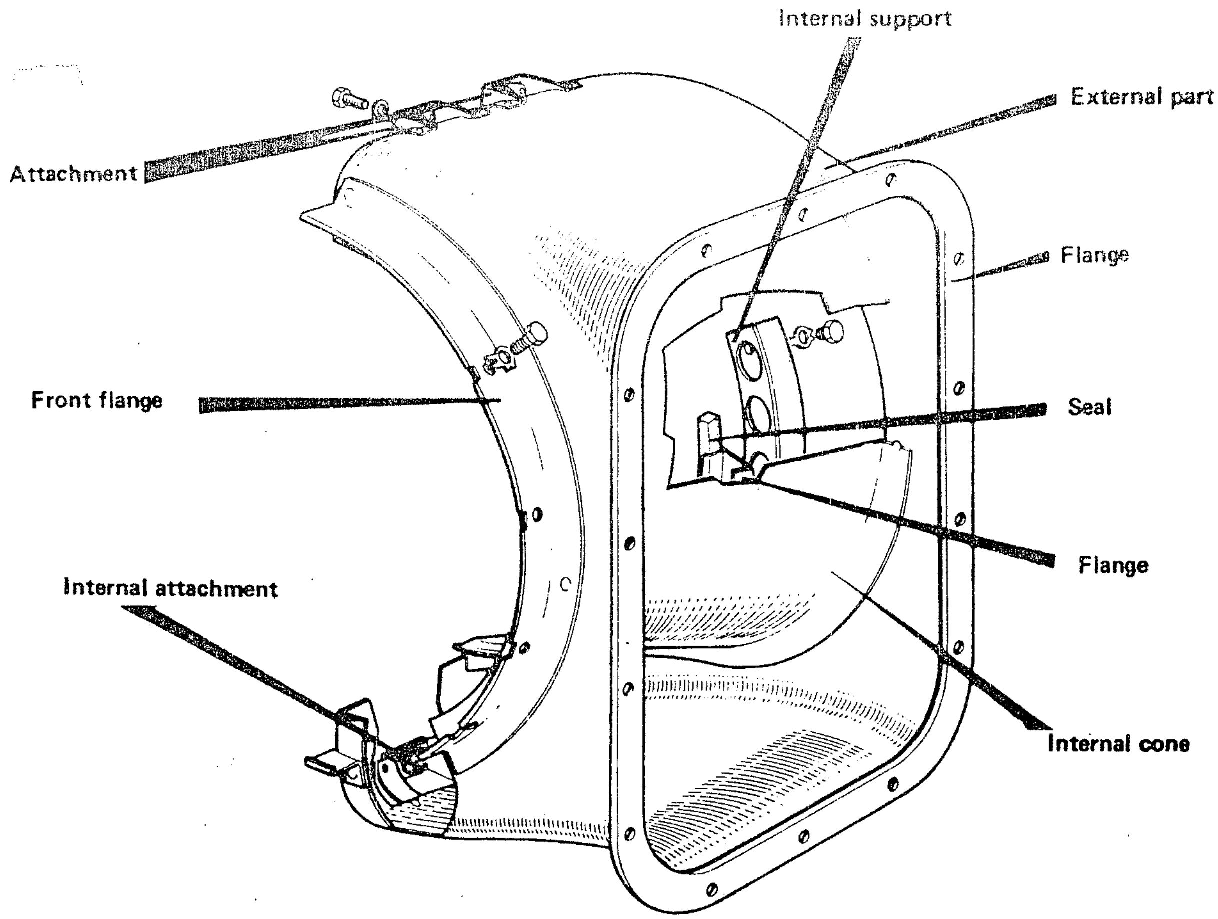
It is assembled between the reduction gear casing and the counter casing of the compressors.

Its internal hub provides a housing for the axial compressor front bearing.

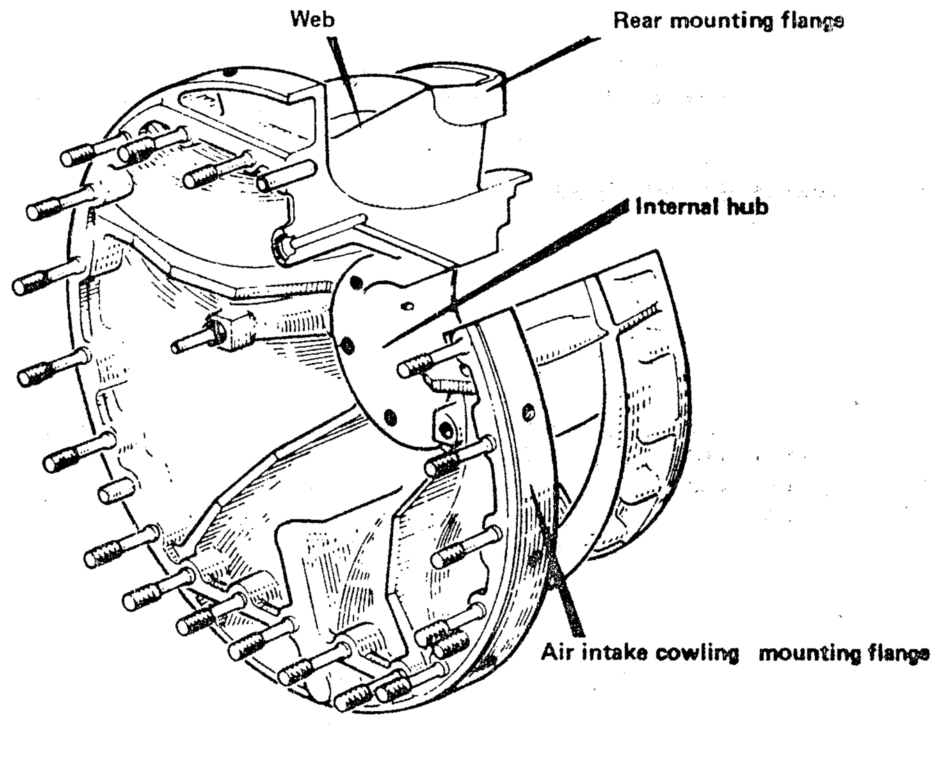
It incorporates many drillings for the circulation of the various fluids (passage of lubricating oil).

The axial compressor front bearing located in the internal hub of the casing will be dealt with in full detail in the paragraph "Axial compressor". Nevertheless it is worthy of note that this bearing is lubricated together with the engine front section.

The axial front section which engages into the air intake centre hub is hollow for the fuel tube passage. On mounting, the fuel tube emerges at the front part of the air intake casing.



PERSPECTIVE OF AIR INTAKE HALF COWLING



PERSPECTIVE OF AIR INTAKE CASING

AXIAL COMPRESSOR

INTRODUCTION

It is a transonic compressor whose purpose is to supercharge the centrifugal compressor in order to increase the compression ratio.

The assembly includes the following components :

- the axial wheel
- the diffuser
- the counter-casing.

AXIAL WHEEL

It consists of a disc on which blades of titanium alloy are secured.

The shaft is hollow to provide a passage for the fuel tube. It is supported by a ball-bearing at the front and a roller-bearing at the rear.

The oil sealing of the two support bearings of the compressor is ensured by "sealol" type seals.

The shaft is connected by muff coupling at the front to the reduction gear, at the rear to the centrifugal compressor.

DIFFUSER ASSEMBLY

Its purpose is to ensure the diffusion and the straightening of the air coming from the axial wheel.

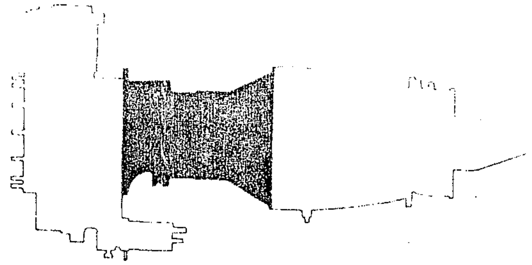
It consists of two rows of vanes with divergent passage section welded on a ring.

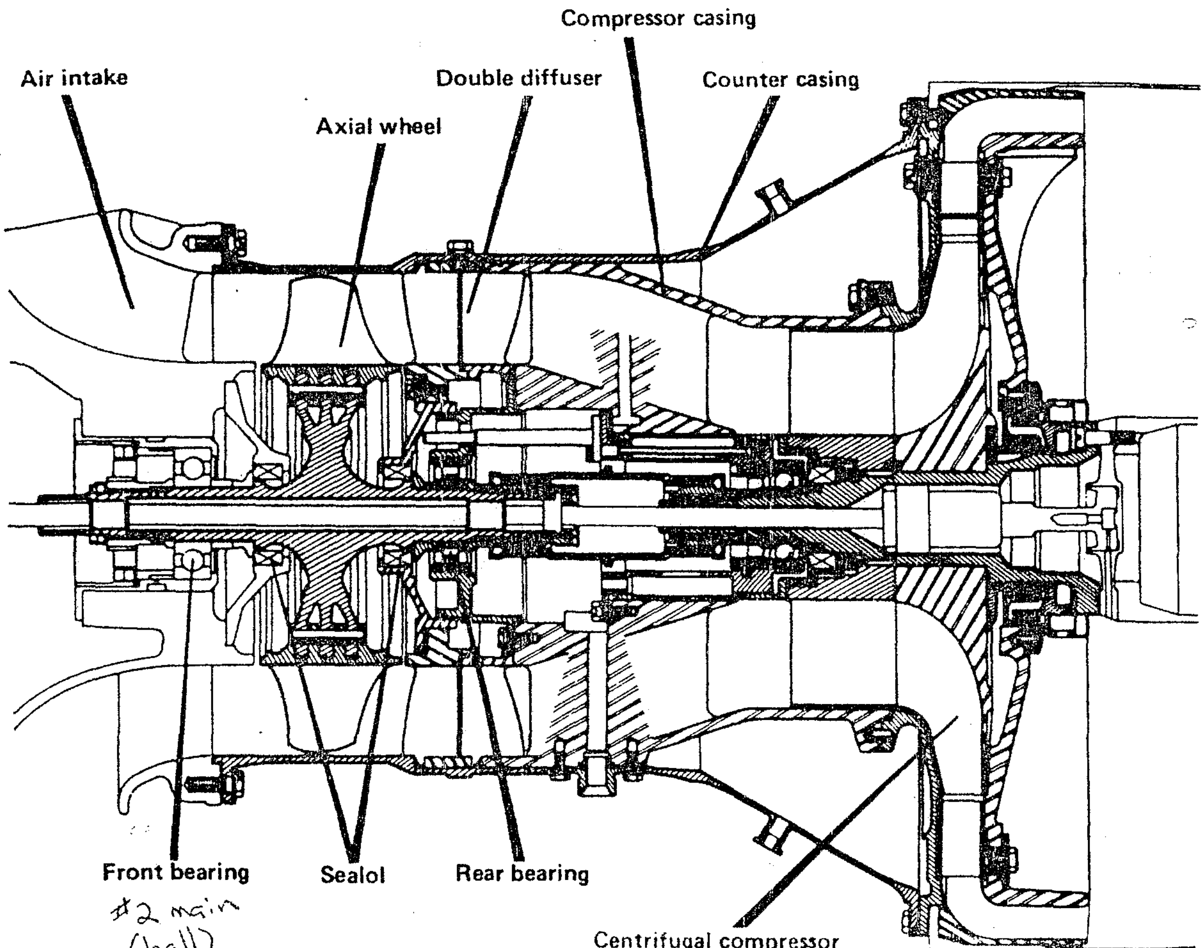
The diffuser assembly is installed inside the counter-casing. Its internal hub provides a location for the seal and for the axial rear bearing.

CASING

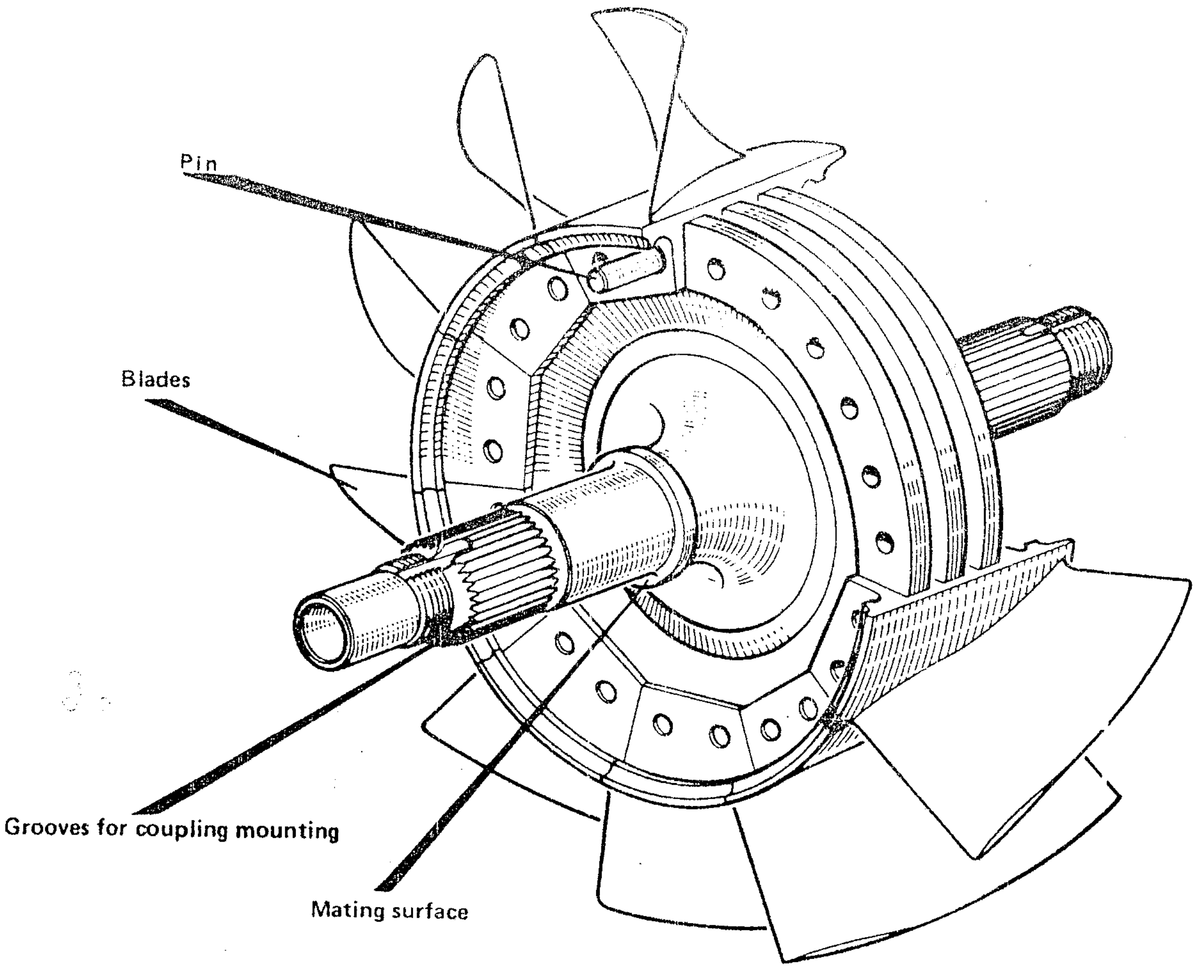
The engine main structure is constituted by a steel casing.

It is secured at the front on the air intake casing and at the rear on the turbine casing.

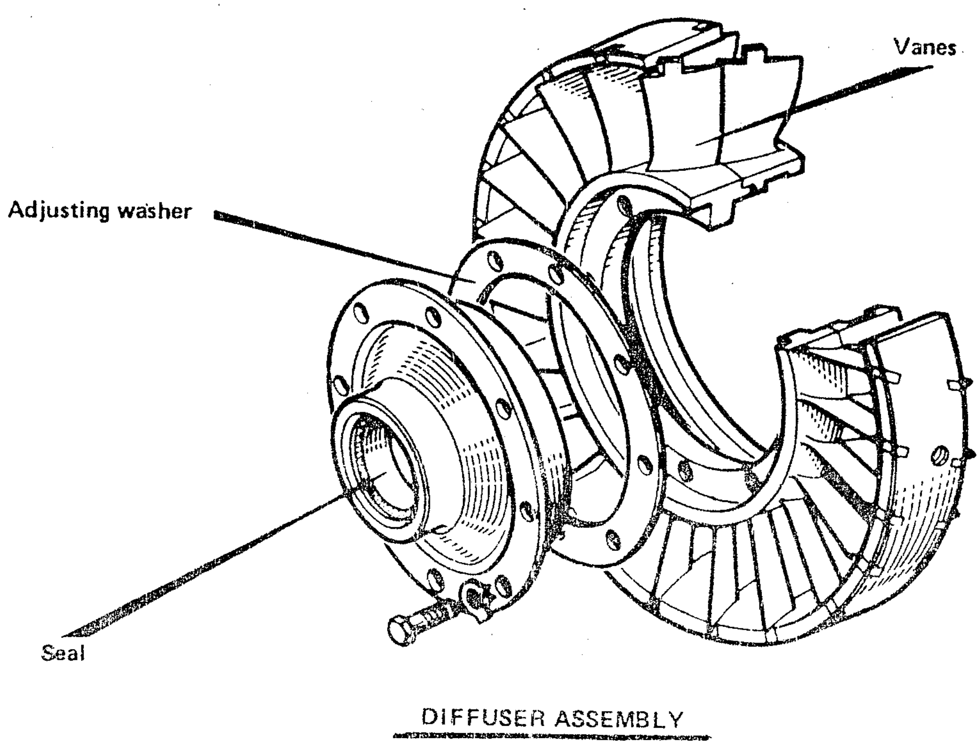




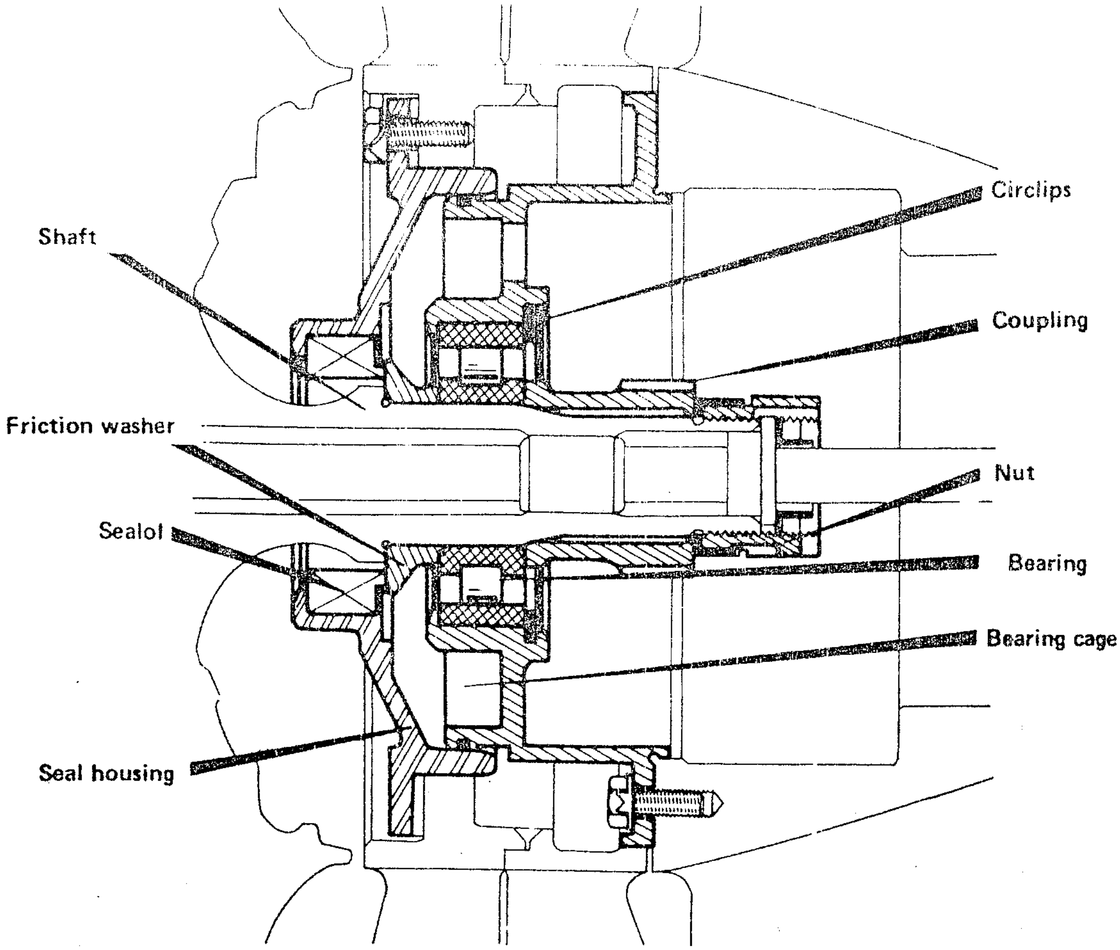
COMPRESSOR ASSEMBLY CUT–AWAY



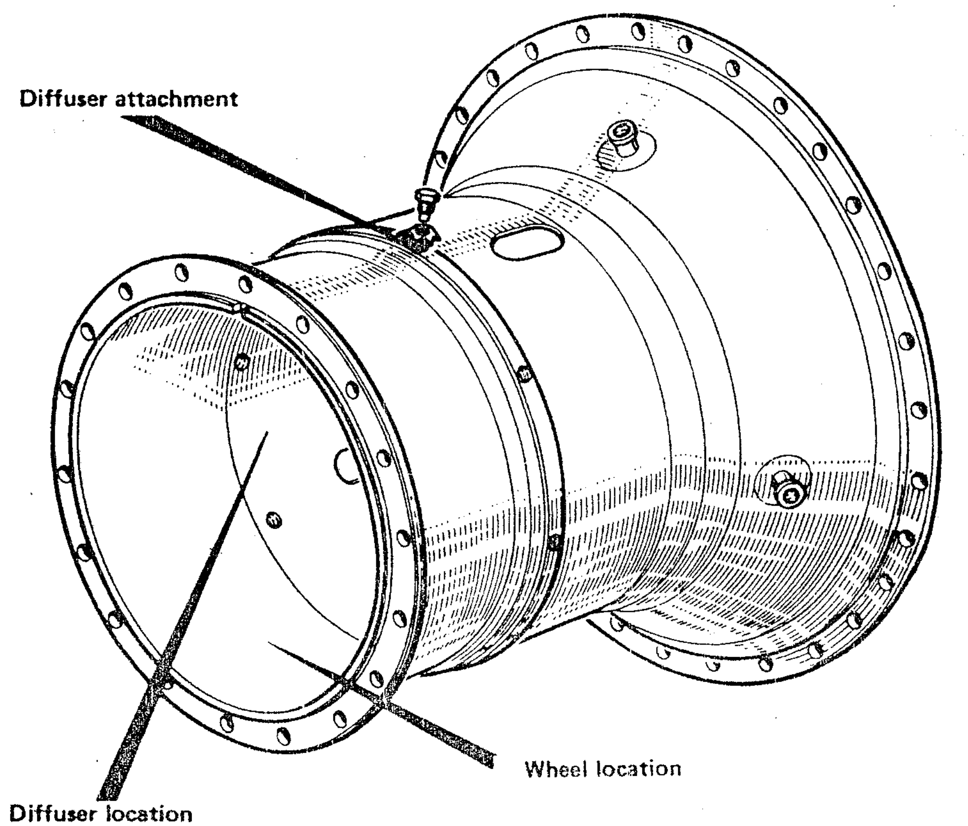
AXIAL WHEEL



DIFFUSER ASSEMBLY



AXIAL COMPRESSOR REAR BEARING



COUNTER CASING

INTRODUCTION

The purpose of the centrifugal compressor is to ensure the main compression.

The assembly incorporates the following components :

- the compressor wheel
- the compressor shaft
- the diffusers
- the casings and covers.

COMPRESSOR WHEEL

The compressor wheel is assembled on the shaft after being heated up and placing a labyrinth ring and a toothed washer where the rear face of the wheel is centered. A nut screwed on the threaded part of the shaft ensures the securing of the assembly.

In consists of an entry wheel made of steel alloy and an impeller of light alloy. The entry wheel and the impeller are secured together by means of three centering dowels. The sealing between the blades of the entry wheel and the centrifugal impeller blades is ensured by a "neoprene" bonding.

COMPRESSOR SHAFT

The compressor shaft (or nose shaft) constitutes the front section of the rotating assembly main shaft.

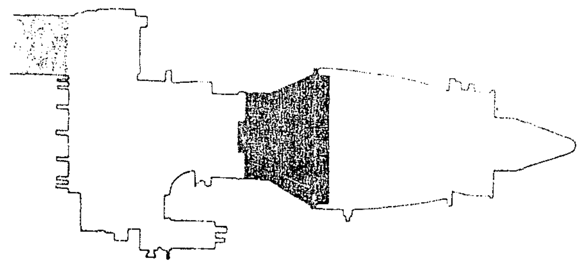
It includes the shaft itself and the centrifugal injection wheel secured by means of screws on the main shaft. Its front section is provided with a boss where the centrifugal compressor bearing is mounted. This bearing consists of a deep groove type ball-bearing mounted in a special flexible cage. On the front face of the flexible bearing, the cage and the axial compressor rear bearing are secured.

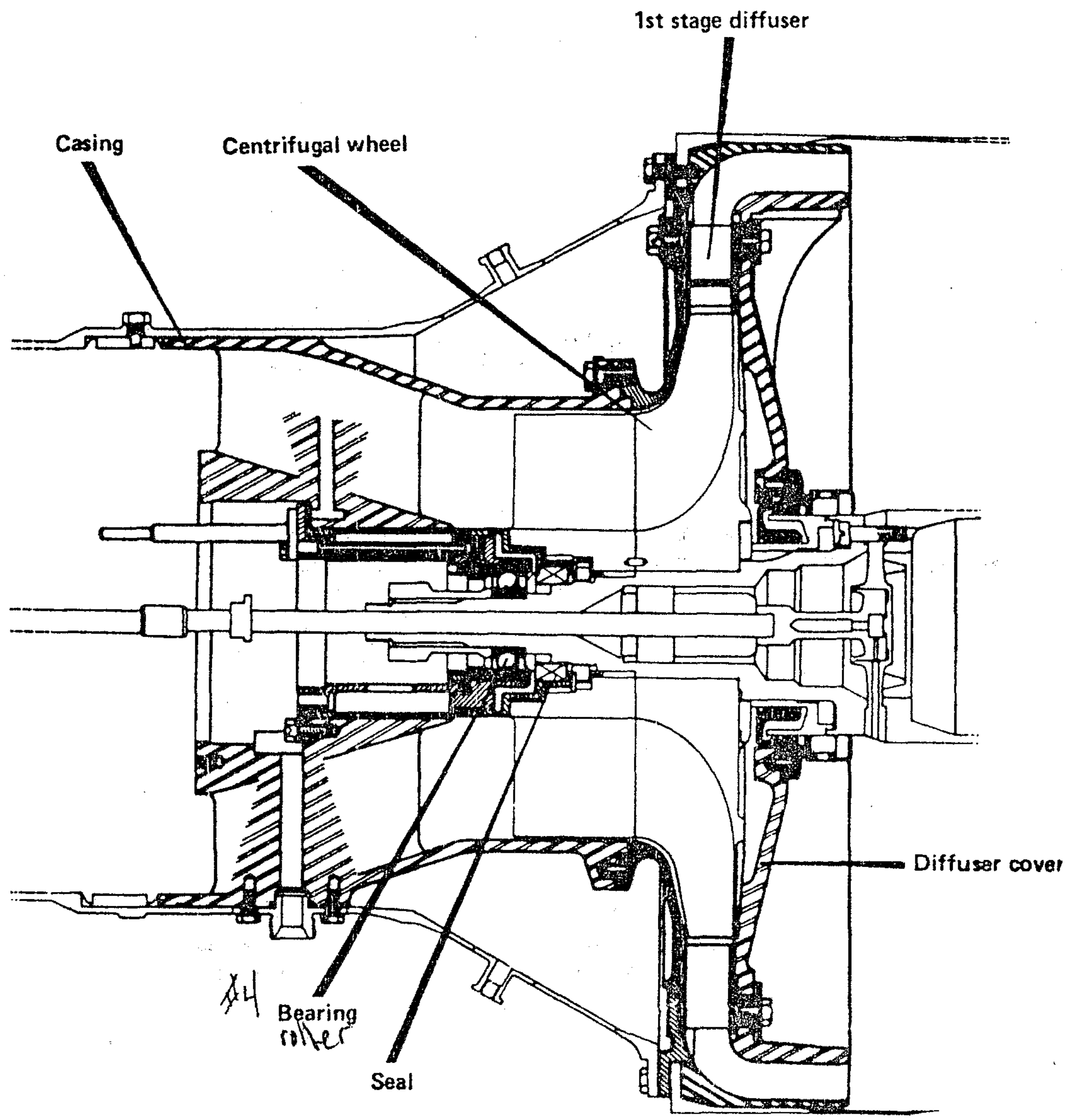
DIFFUSERS

The diffuser assembly consists of the first stage radial diffuser made of steel and the second stage axial diffuser made of light alloy.

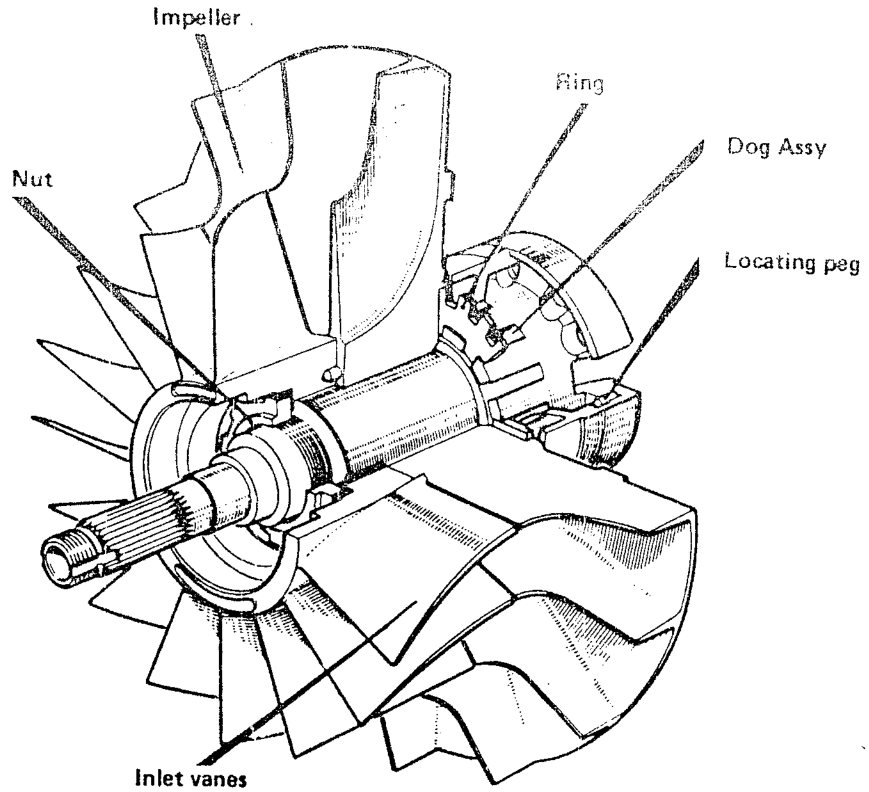
CASINGS AND COVERS

The assembly includes : the centrifugal compressor casing made of light alloy and mounted inside the counter-casing, the compressor front cover and the rear cover or "diffuser holder plate" supporting the two labyrinth seals on the nose shaft.

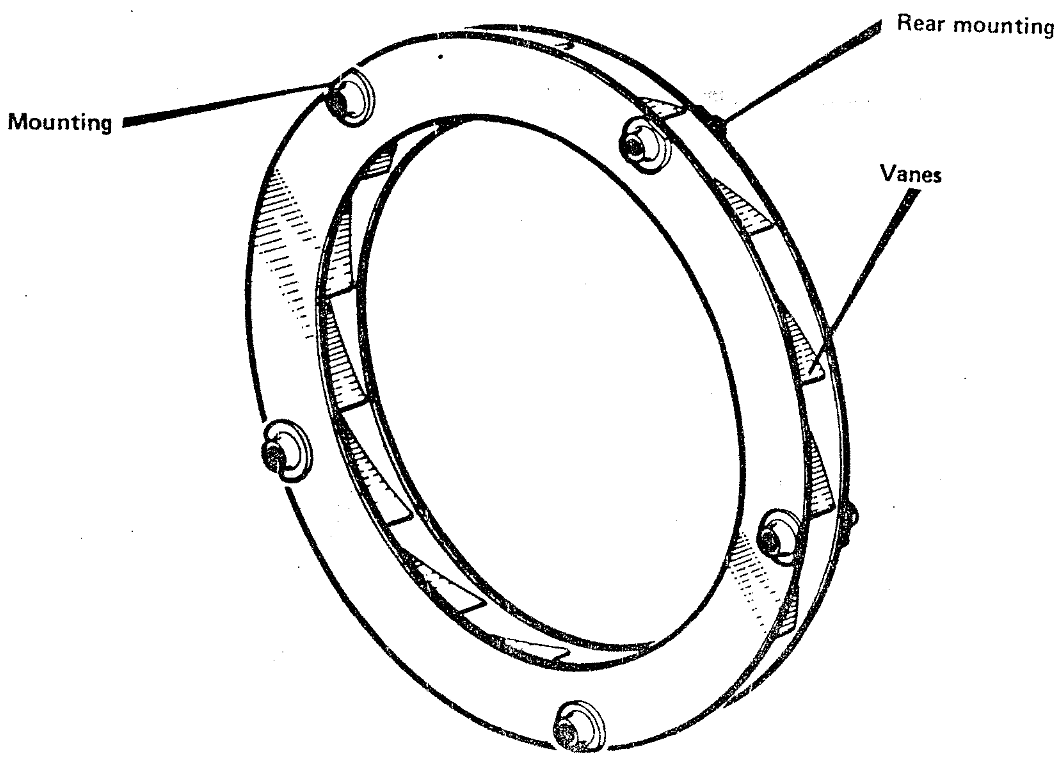




CENTRIFUGAL COMPRESSOR CUT–AWAY



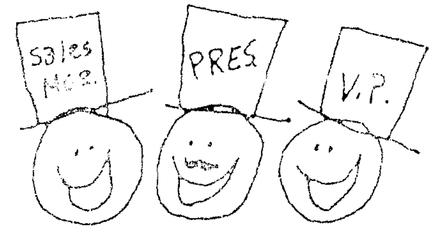
CENTRIFUGAL COMPRESSOR WHEEL



FIRST STAGE DIFFUSER

AVIATION POWER SUPPLY, INC.
111 KENWOOD STREET, BURBANK, CALIFORNIA (213) 842-5207

Distrib. from the above



Shop Talk

Turbomeca Series

Vol. 1 No. 2 July 28, 1975

IS YOUR ENGINE'S TAIL DRAGGING?

Several engines received by APS for repair or overhaul have had turbine rear bearing and/or bearing housing distress. These bearings were in failure stages ranging from slight wear to complete disintegration. To detect in-process failure, calculate turbine rotor droop by periodically measuring third stage turbine wheel tip clearance. Using feeler gages (longer style gages are more desirable), calculate the amount of turbine rotor droop as follows:

1. Install the correct thickness of gages to fill the void between the 3rd stage turbine case (blade tip path) and the third stage turbine wheel blade tip at the 12 o'clock position.

2. Install the correct thickness of gages to fill the void between the turbine case and the third stage turbine wheel blade tip at the 6 o'clock position. Record this thickness.

3. Remove the gages from the 12 o'clock position and add sufficient gages at the 6 o'clock position to raise the turbine rotor the maximum amount possible. Record this thickness.

4. Subtract the thickness obtained in step 2 from the thickness obtained in step 3. The remainder is the amount of turbine rotor droop present.

How can you effectively use this information?

1. At the time of overhaul, APS allows no measurable turbine rotor droop.

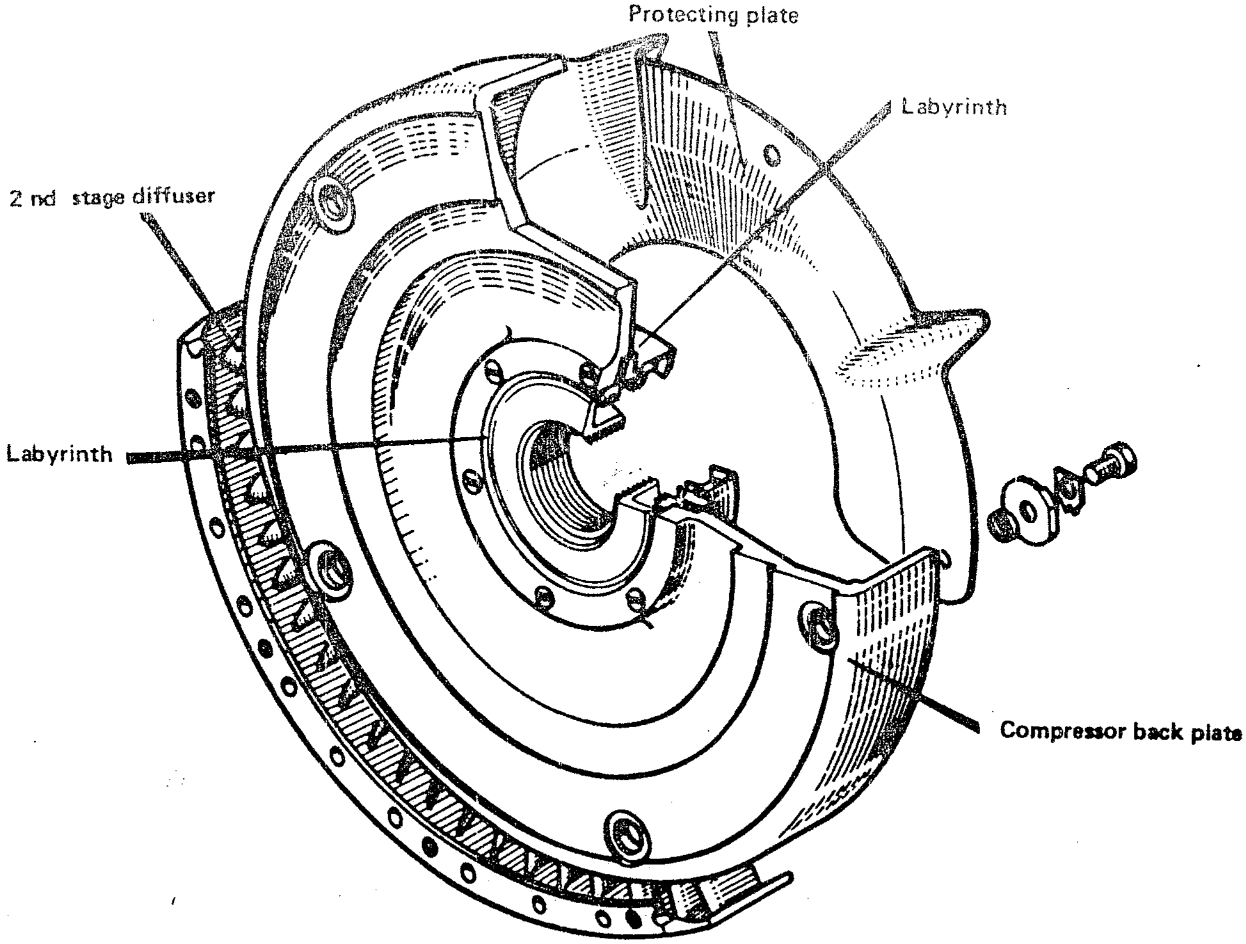
2. During repair, turbine rotor droo[illegible] excess of 0.001" is not acceptable.

3. If the turbine rotor has drooped in excess of 0.002" remedial action should be taken. The wear may be in the bearing housing support arm pins, the support arms, or in the bearing itself.

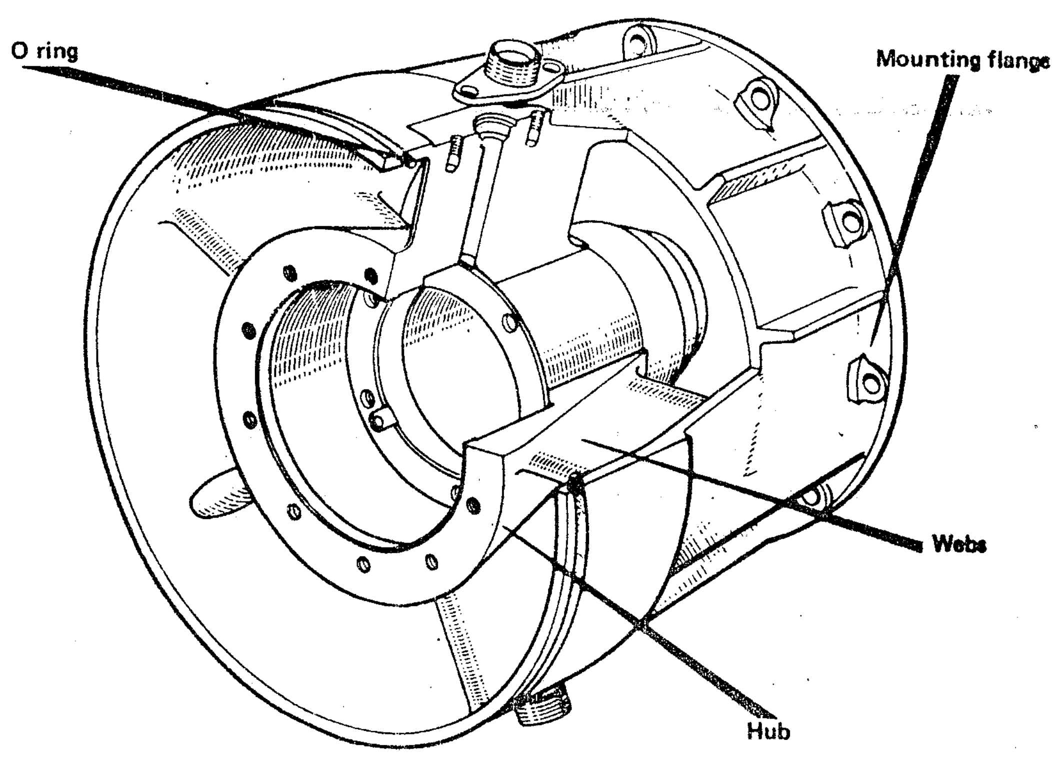
APS recommends that this tip clearance check be made after each 100 hours of engine operation. Severe turbine rotor droop may result in damage necessitating replacement of all the turbine wheels. There is also a danger of turbine case ovalization from temperature cycles resulting in blade tip rub even though there is no turbine rotor droop.

If third stage turbine tip clearance is below normal values (i.e., 0.018 for Astazou II and III; 0.026 for Artouste IIIB), and turbine rotor droop is not present, the engine may be kept in service as long as there is no turbine tip rub during coast down or after shutdown.

Close attention to this important detail can prevent a premature engine removal with lost revenue and the corresponding high operating cost per flight hour.



DIFFUSER HOLDER COVER AND SECOND STAGE DIFFUSER



CENTRIFUGAL COMPRESSOR CASING

COMBUSTION CHAMBER

INTRODUCTION

The combustion chamber is of annular type with direct flow and centrifugal fuel injection.

In the chamber, the air coming from the compressor is divided in two flows : a primary air flow for the combustion and a secondary air flow for the dilution.

It includes the following components :

- an internal part
- an external part
- the fuel injection wheel
- the casing.

COMBUSTION CHAMBER INTERNAL PART

It consists of the "rear swirl plate" with calibrated slots for the passage of primary air and a labyrinth assembly.

These two components are secured by means of bolts on the first stage turbine nozzle guide vane and they house the generator main shaft.

COMBUSTION CHAMBER EXTERNAL PART

It consists of the "front swirl plate" with calibrated slots for the passage of primary air and a mixing unit incorporating the dilution tubes.

The external part is secured by means of bolts on the first stage turbine nozzle guide vane.

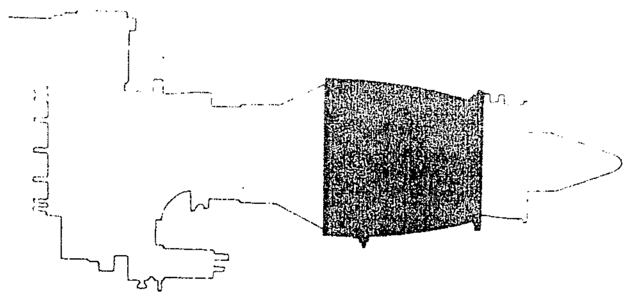
FUEL INJECTION WHEEL

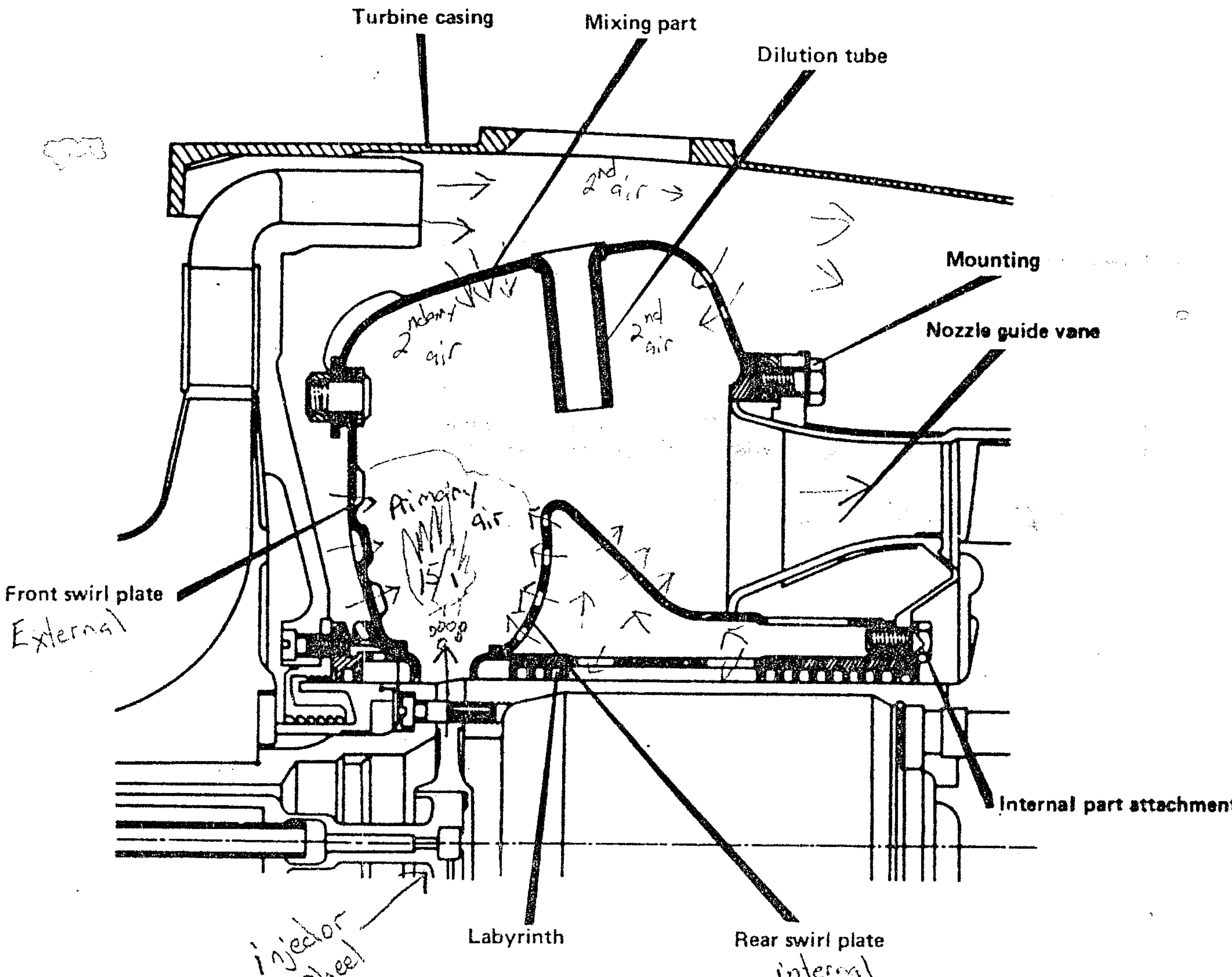
Driven by the generator shaft, it atomizes the fuel between the two swirl plates. It is secured between the compressor shaft and the main hollow shaft by means of screws.

COMBUSTION CHAMBER CASING (OR TURBINE CASING)

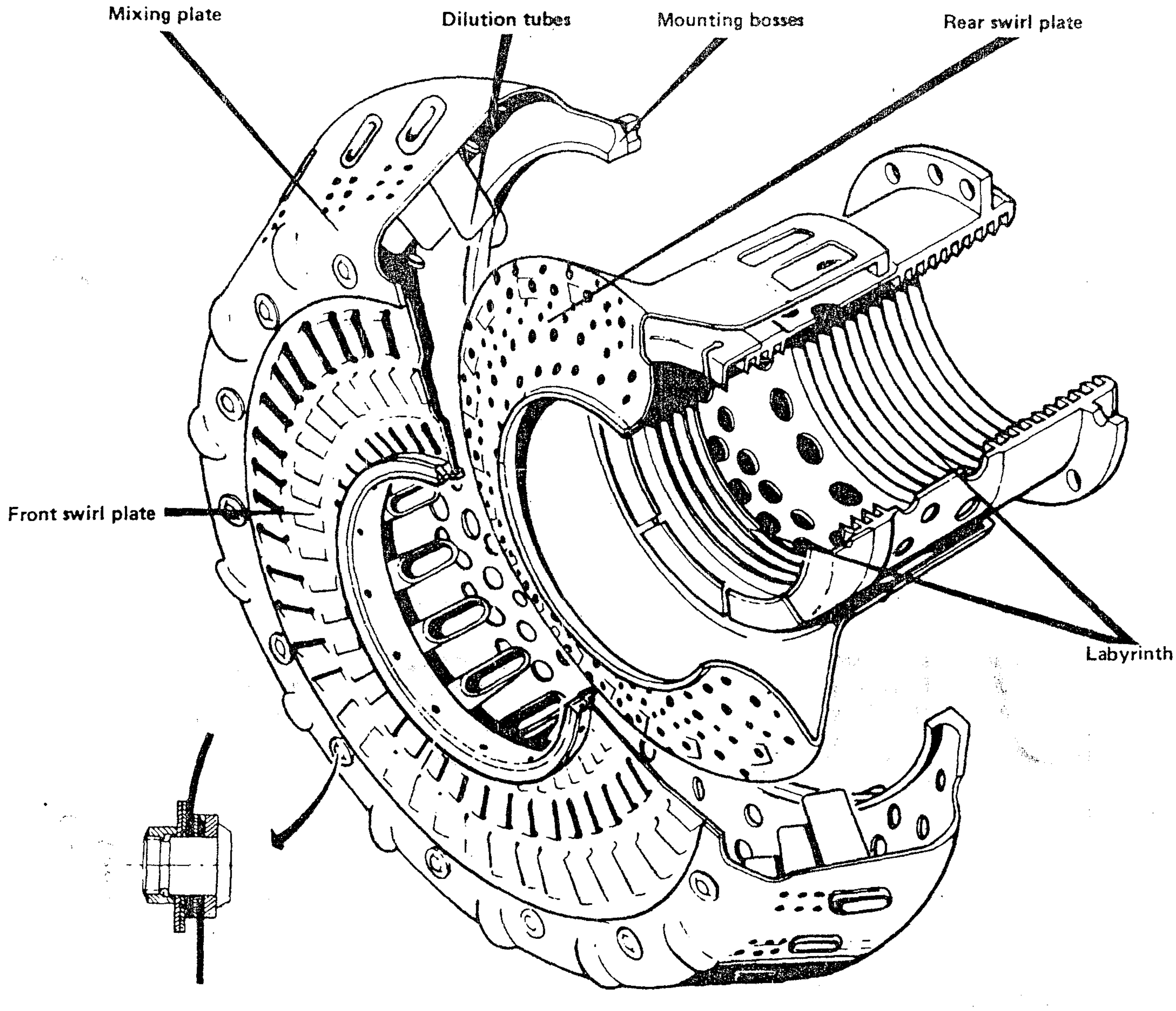
The casing provides a location for the combustion chamber as well as for the turbines.

It incorporates many bosses meant for the assembly of various components. The chamber draining line is mounted on its lower section.

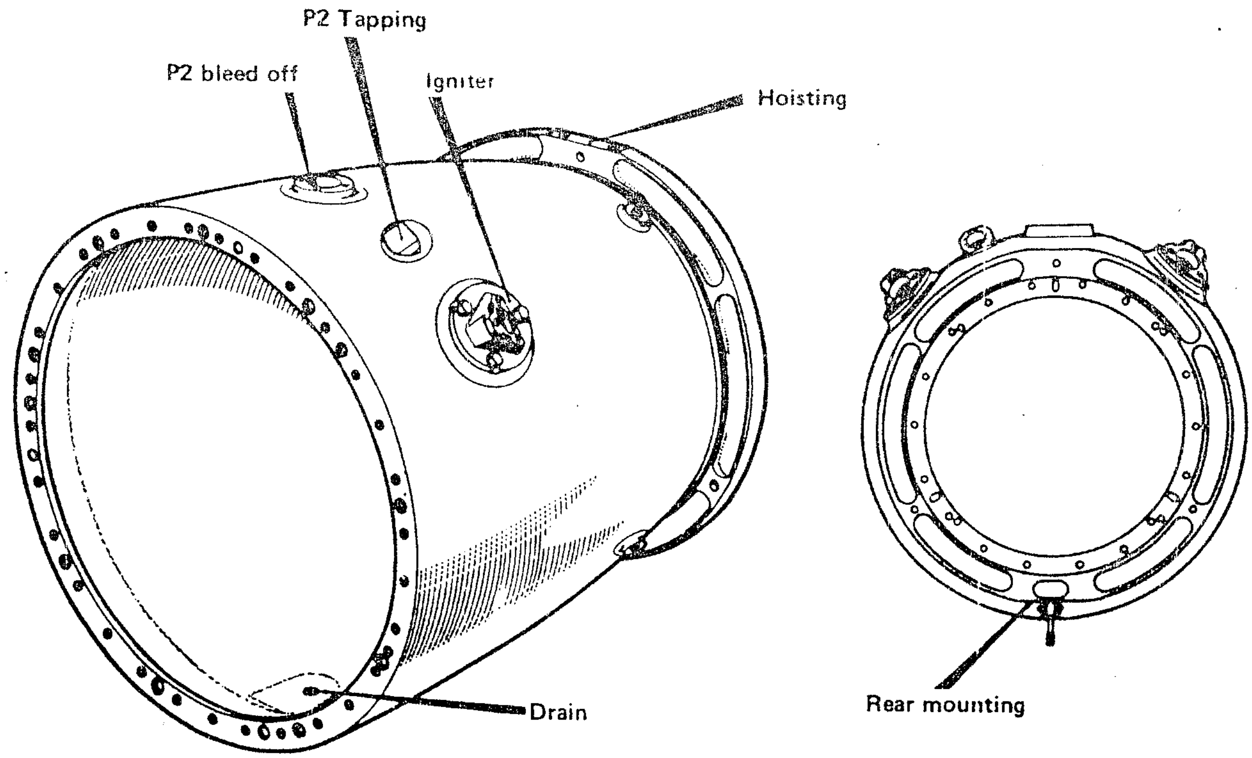




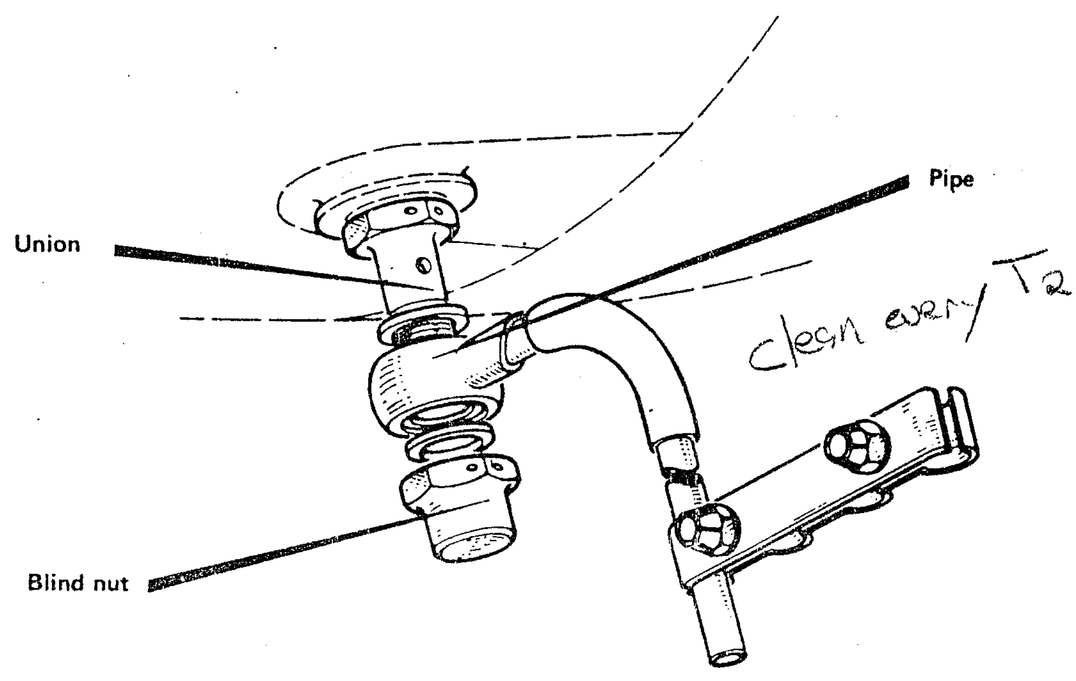
HALF CUT—AWAY OF THE COMBUSTION CHAMBER



COMBUSTION CHAMBER PERSPECTIVE CUT-AWAY



TURBINE CASING



COMBUSTION CHAMBER DRAIN

TURBINE AND EXHAUST SYSTEM

INTRODUCTION

The purpose of the assembly is to ensure the expansion of the gases. It is composed of :

- a three-stage turbine of axial type
- a support bearing
- an exhaust diffuser.

TURBINE

It is a three-stage turbine of axial type constituted of moving parts and of fixed ones.

Moving components of the turbine

The moving components consist of : the main hollow shaft, the three turbine wheels, a rear shaft.

All the moving components are assembled by means of a toothed system of "curvic-coupling" type and four tie bolts.

The blades of the turbine wheels are cut from the solid in a disc of special alloy.

Fixed components of the turbine

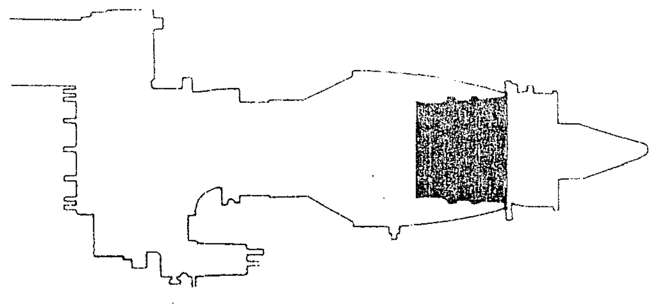
The fixed components consist of : the first stage nozzle guide vane, the second stage nozzle guide vane, the third stage nozzle guide vane and the exhaust diffuser.

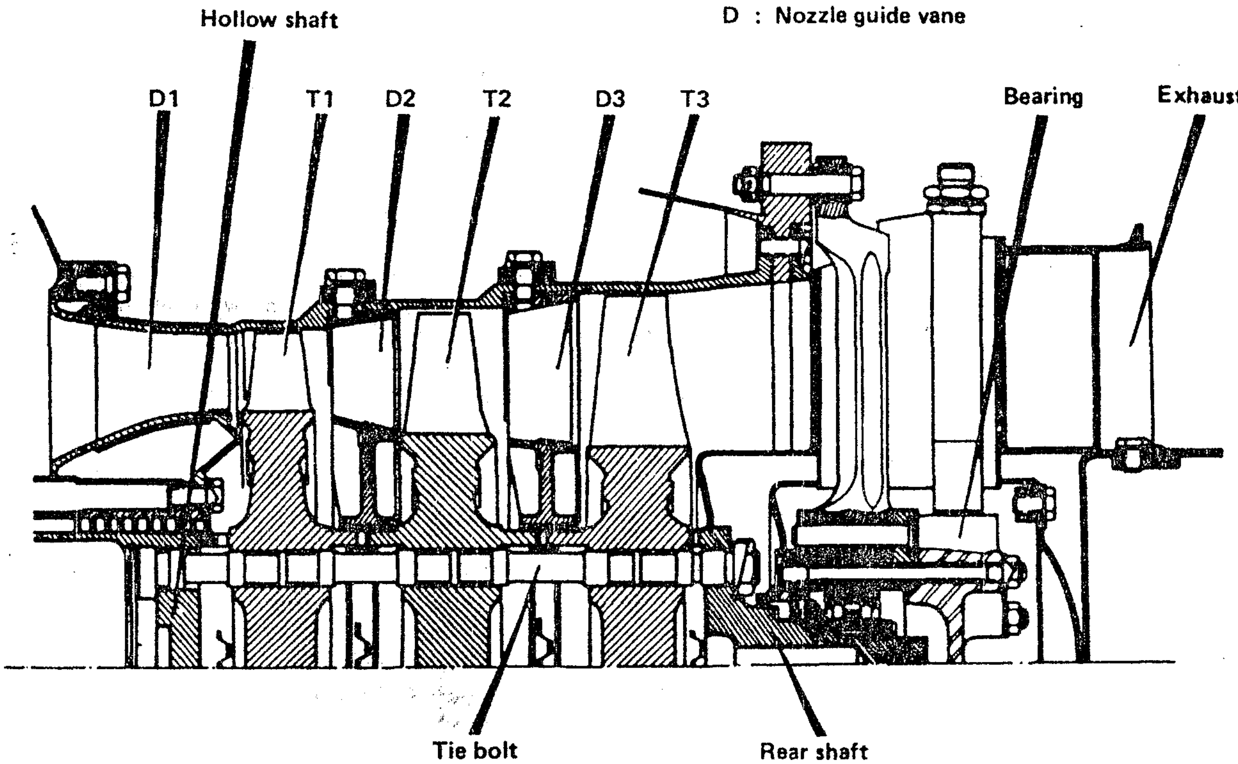
The first stage nozzle guide vane is made up of hollow vanes welded on the turbine ring.

The turbine ring is secured at the front, on the combustion chamber, at the rear on the turbine casing.

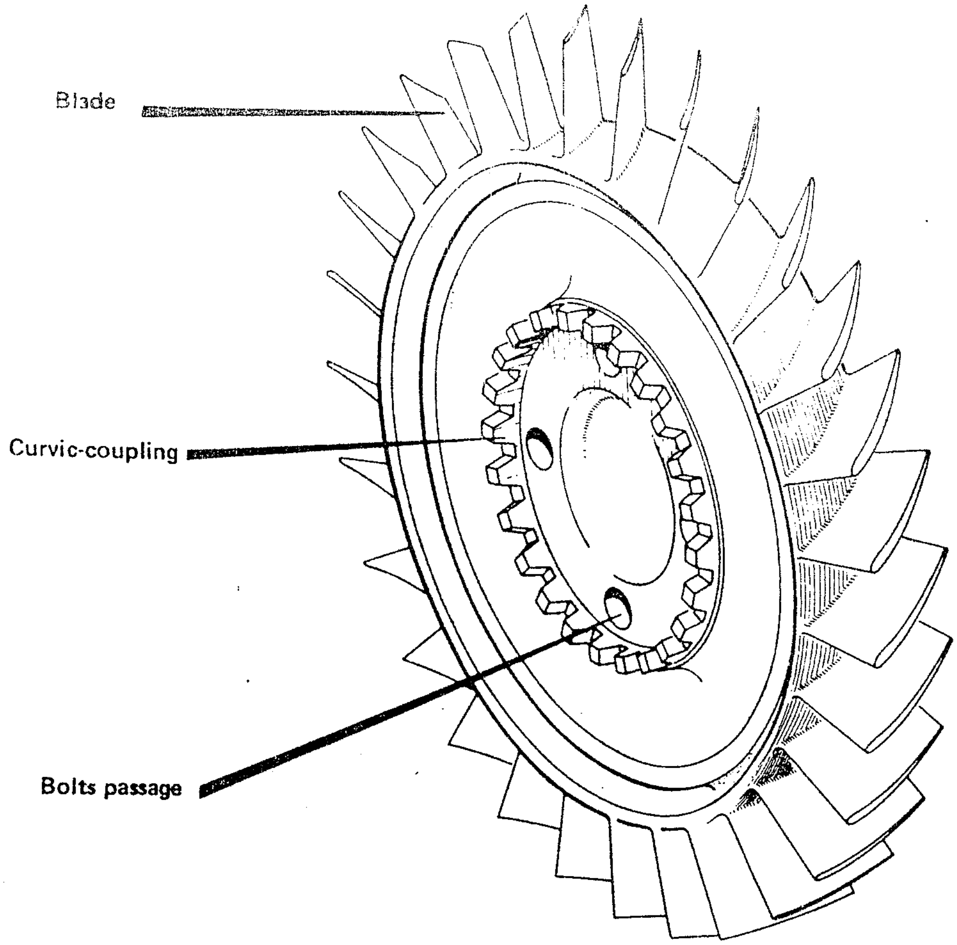
The second stage nozzle guide vane is made up of vanes fixed on a ring mounted inside the turbine ring. Its internal hub includes a labyrinth seal.

The third stage nozzle guide vane is of similar construction as the second stage nozzle guide vane.

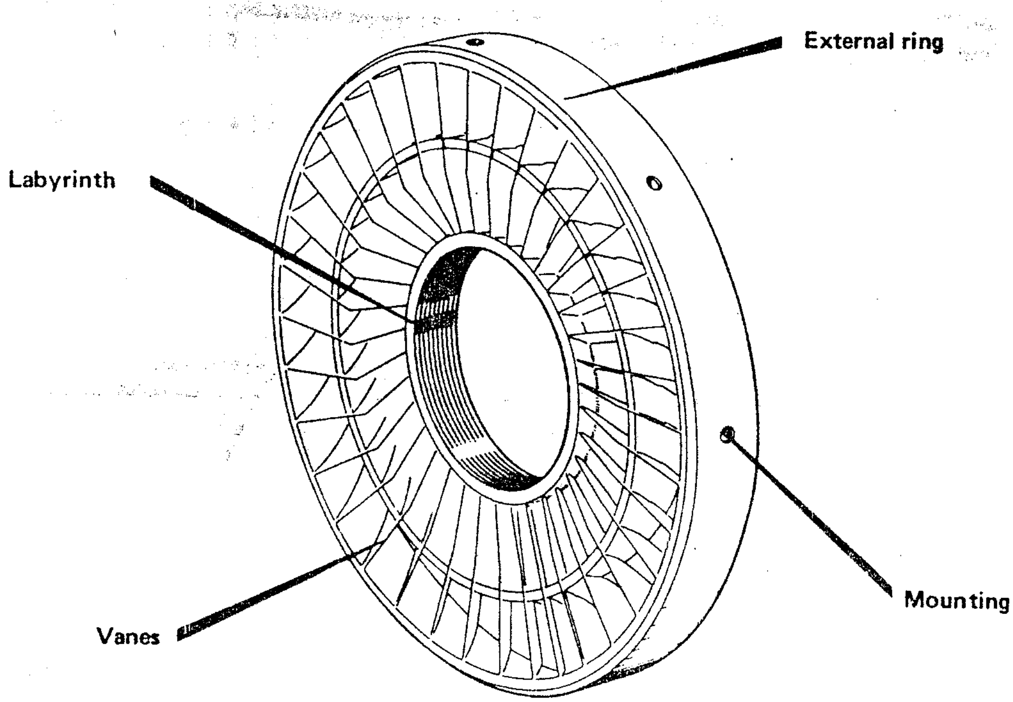




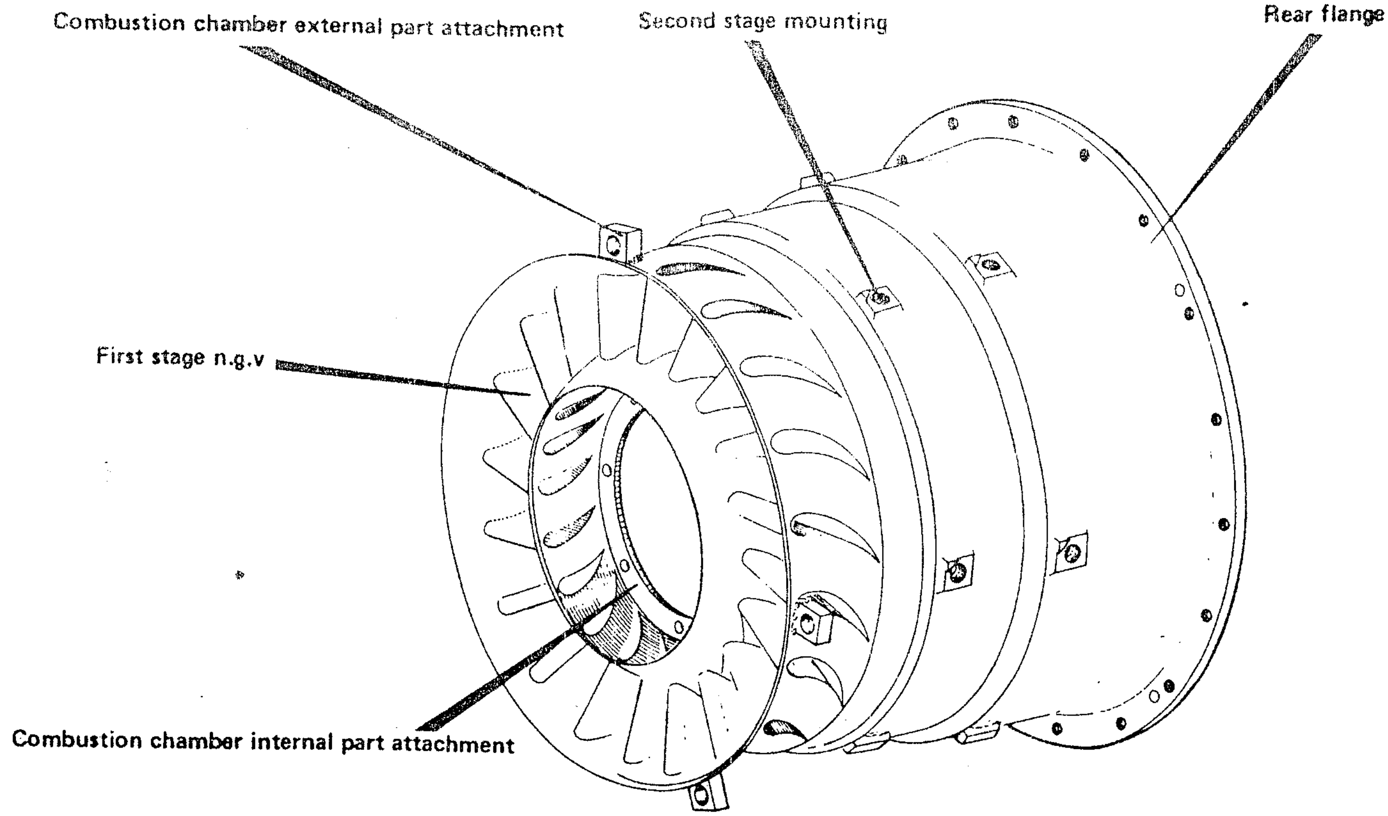
TURBINE ASSEMBLY CUT–AWAY



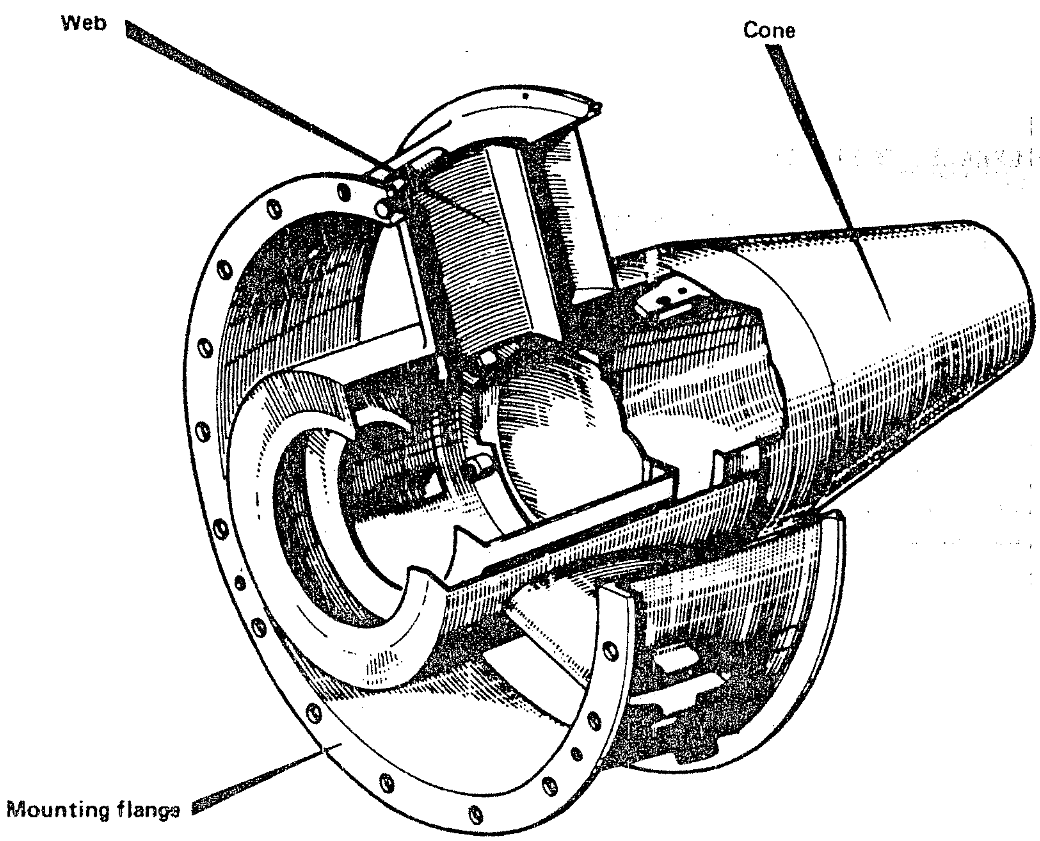
PERSPECTIVE OF A TURBINE WHEEL



NOZZLE GUIDE VANES PERSPECTIVE



TURBINE RING AND FIRST STAGE N.G.V ASSEMBLY



EXHAUST DIFFUSER

TURBINE SUPPORT BEARING (REAR BEARING)

It is a roller-bearing mounted in a cage supported by three mounting arms.

It is installed so as to hold particularly the radial efforts and to compensate for expansion.

It incorporates :

- the bearing of roller type retained in the cage between two circlips.

- the bearing cage maintained between two covers and supported by three arms.

- the front cover incorporating the mounting studs of the box and, in its internal hub a labyrinth seal.

- the rear cover which receives the lubricating tubes (three).

- the supporting arms which are articulated by dowel-pins on the bearing box and secured on the rear face of the turbine casing.

- the paper gaskets : two paper gaskets which ensure the sealing between the covers and the bearing box.

- a flinger ring mounted between the rear cover and the bearing improves the sealing.

- the retaining nut screwed at the shaft end and locked by means of a washer.

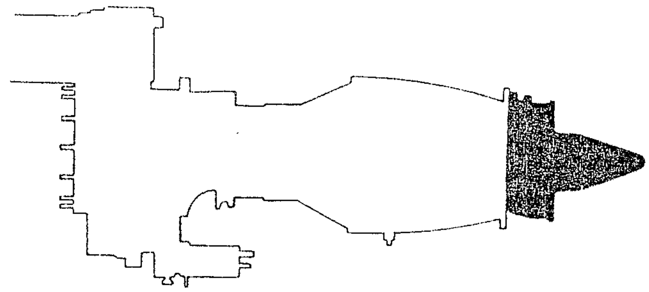
EXHAUST DIFFUSER

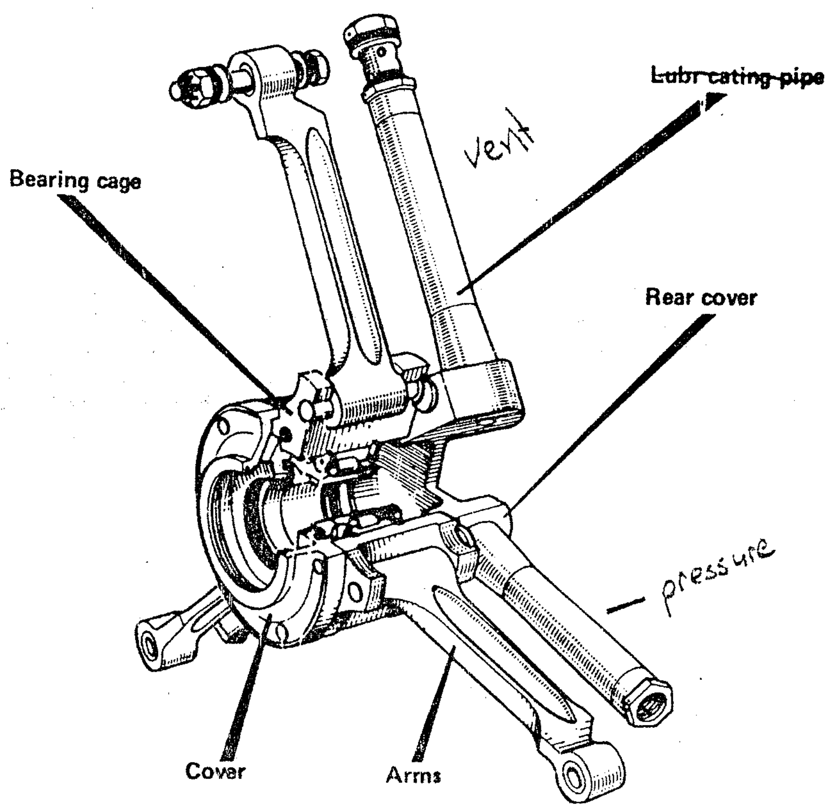
It is an assembly of iron sheet metal which forms the divergent channel for gas exhaust. Its inner hub constitutes a box which houses the rear bearing.

The bearing support arms and the lubricating tubes pass through three "webs" connecting the inner and outer part of the exhaust diffuser.

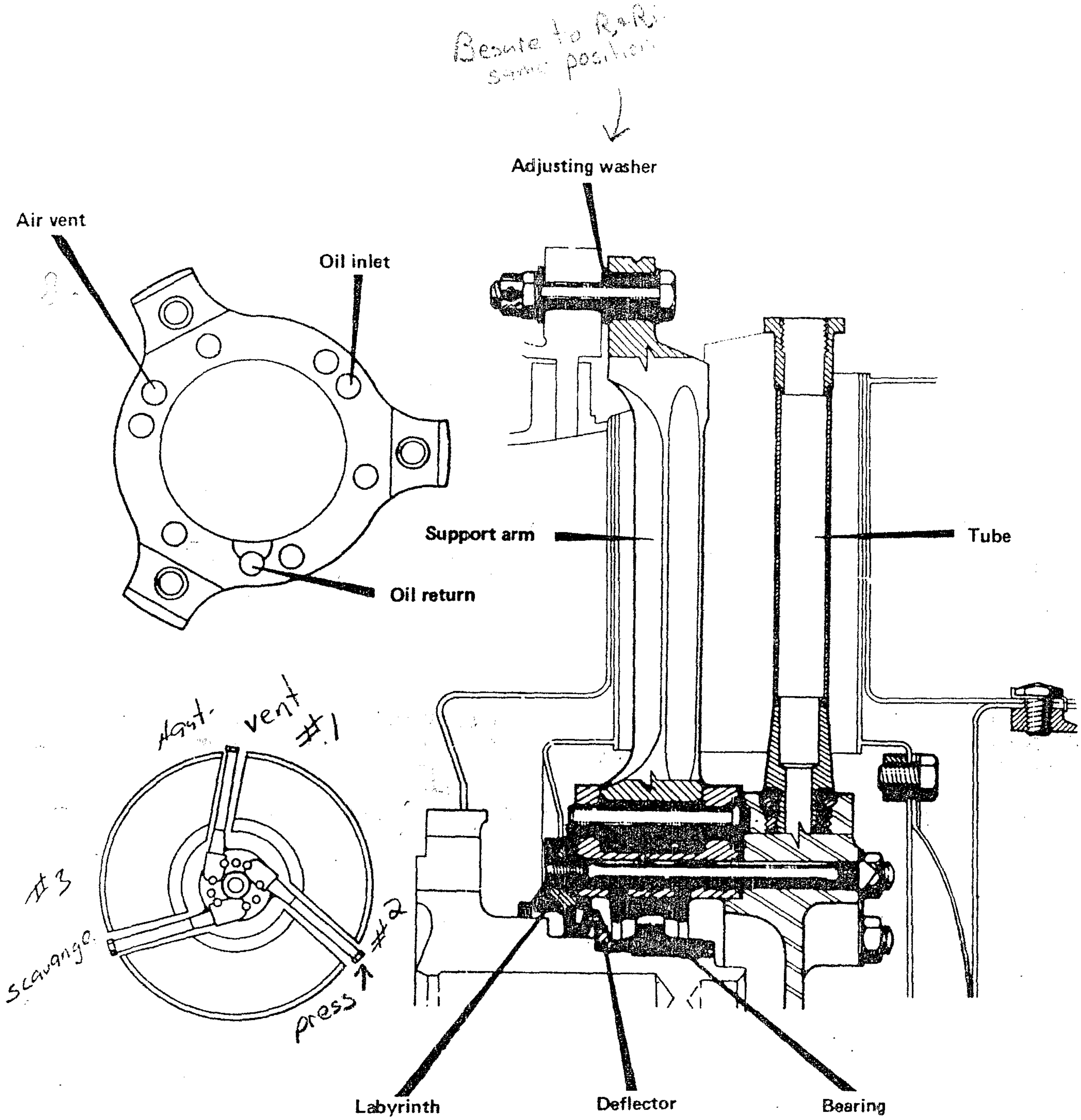
The front flange of the diffuser allows the assembly on the rear flange of the turbine casing and the rear flange allows the assembly of the jet pipe.

A shaped cone is mounted on the internal rear section to guide the flow of gases.

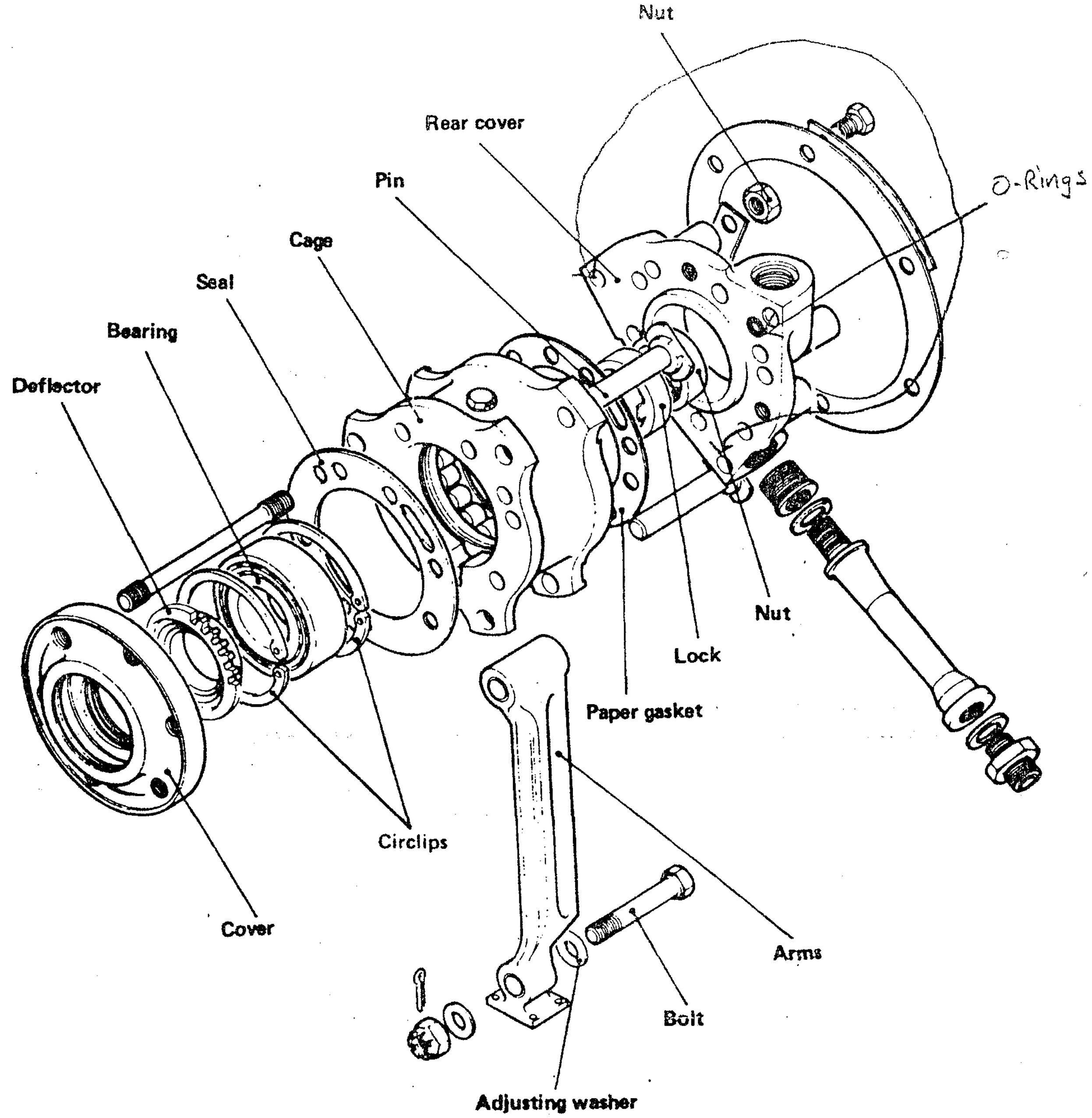




PERSPECTIVE OF THE TURBINE REAR BEARING



TURBINE REAR BEARING



PERSPECTIVE OF THE TURBINE REAR BEARING

INTERNAL FUEL SYSTEM

INTRODUCTION

The engine internal system to supply the injection wheel includes the following components :

- the fuel supply duct
- the jet-holder
- the fuel tube
- the injection wheel.

FUEL SUPPLY DUCT

The engine fuel supply is made through a union installed at the lower section of the reduction gear casing.

The fuel is supplied to the jet-holder through a drilling in the reduction gear casing.

JET-HOLDER

The purpose of the jet-holder is to ensure the sealing between the fuel static supply and the fuel tube which is rotating at a high speed.

The fuel sealing is ensured by a graphite seal called "Flexibox" and the oil sealing of the bearing is ensured by a graphite seal of "sealol" type. It is provided with a duct allowing the draining overboard of the possible leaks. (draining stopped at the moment). A defective sealing at the level of this component may result in passage of fuel into oil.

FUEL TUBE

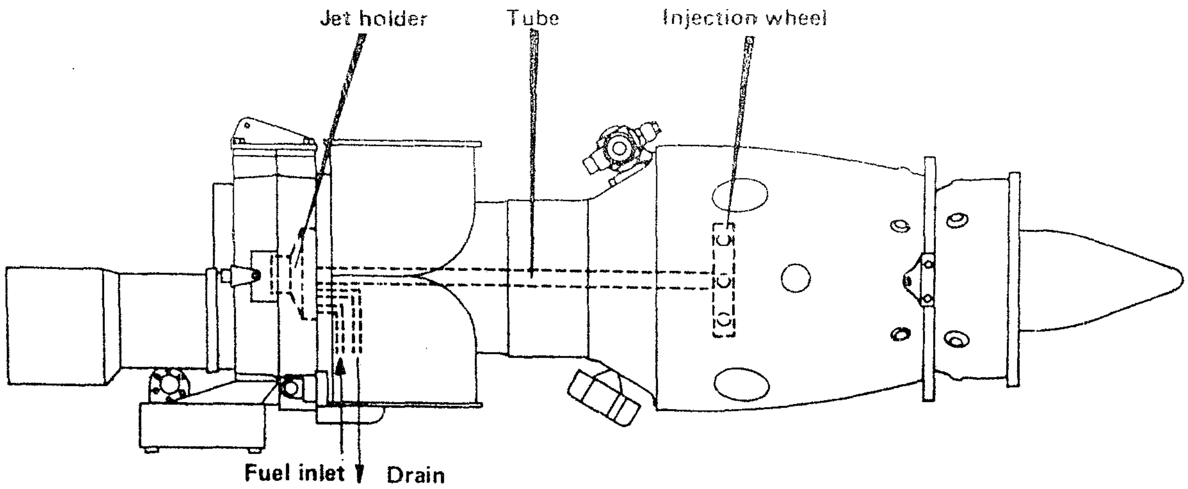
It is a tube made of steel, the front part of which is fitted in the jet-holder and the rear part in the injection wheel.

It includes two journal bearings which maintain it inside the shaft and it is integral with the shaft by means of a securing device. It is provided with an inner plate called "fuel splitter".

INJECTION WHEEL

It is mounted between the main hollow shaft and the compressor shaft by means of screws.

The sealing of the tube rear end is ensured by means of "Simrit" type seals and "O'rings".



INTERNAL FUEL SYSTEM LAY–OUT

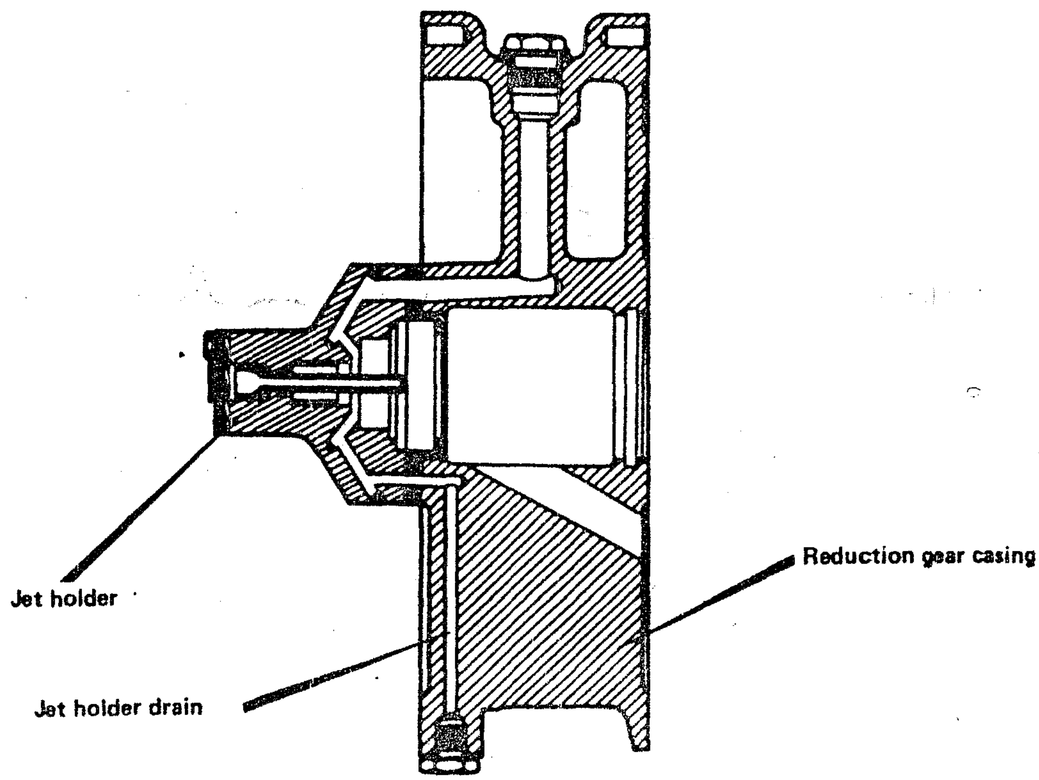
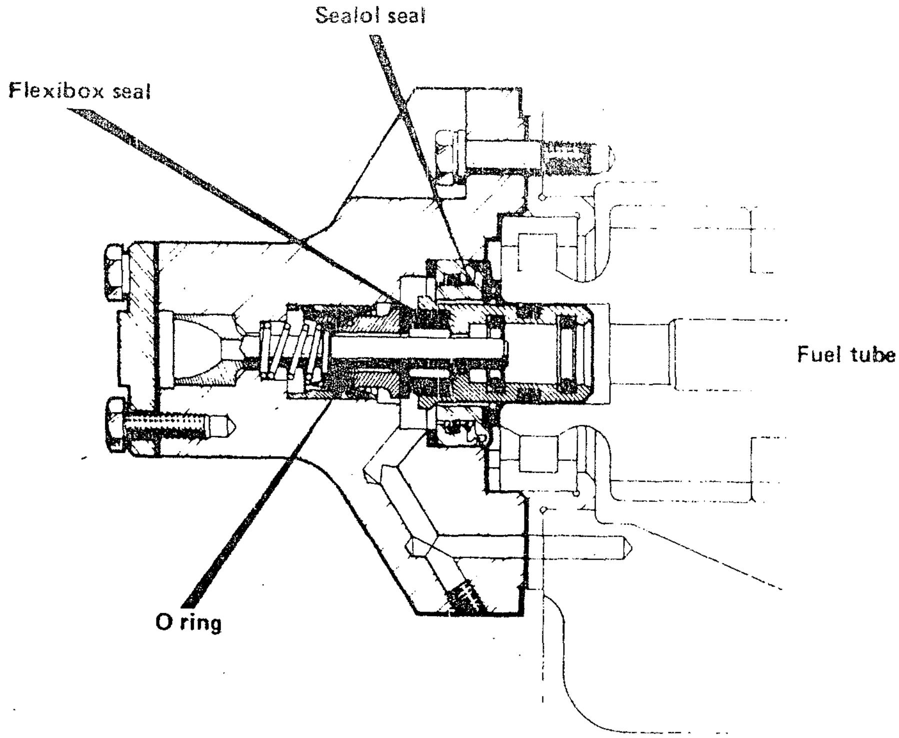
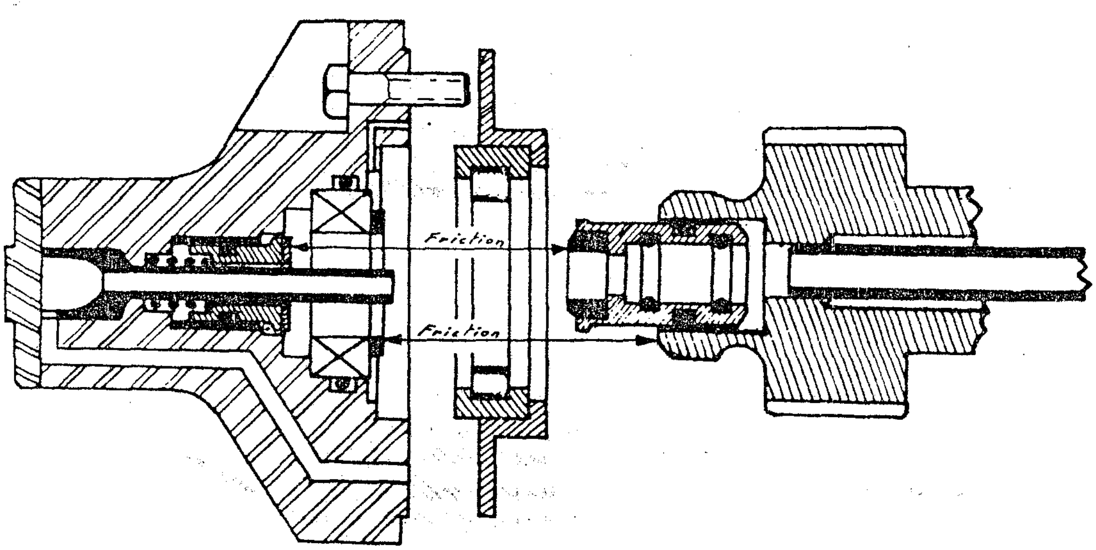
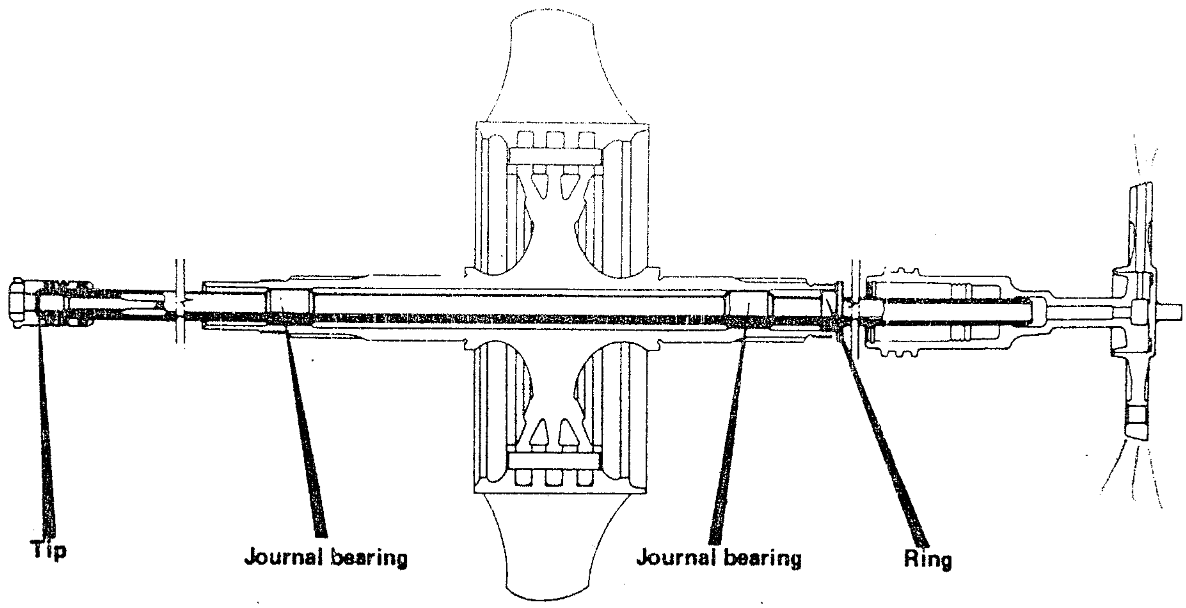


DIAGRAM OF THE INTERNAL FUEL SYSTEM

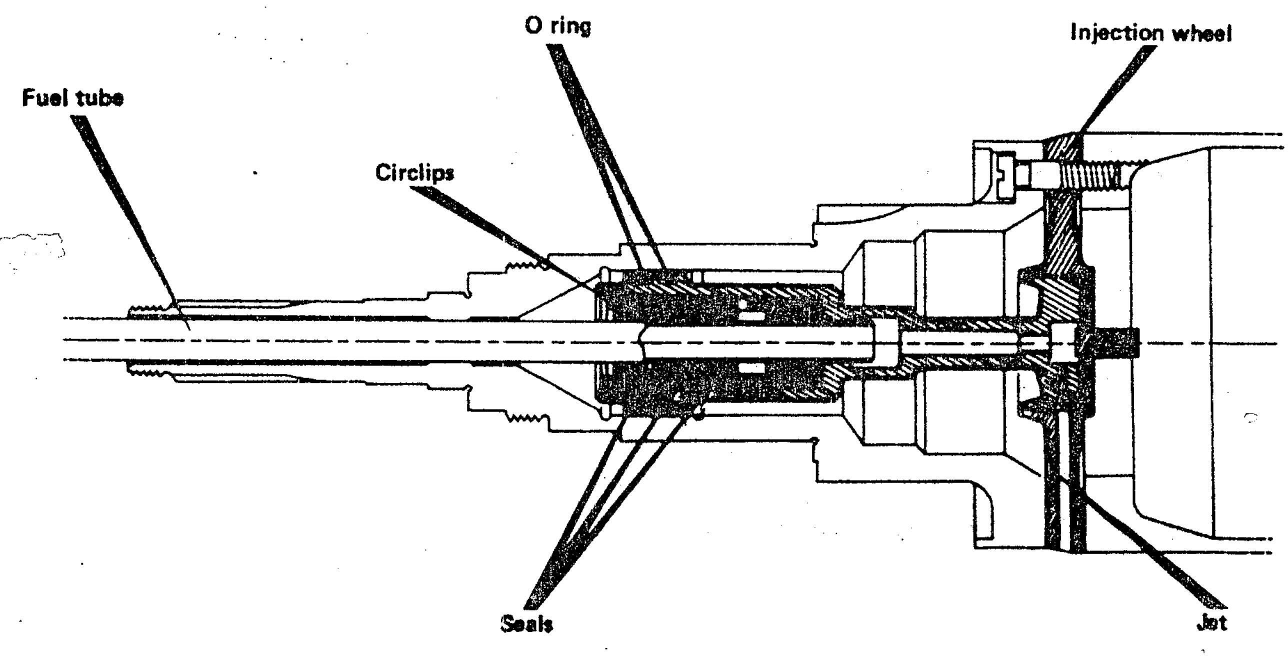




FUEL JET HOLDER CUT–AWAY



FUEL TUBE



CENTRIFUGAL INJECTION WHEEL

MAINTENANCE

OPERATION

Engine parameters check. Particularly check :

- the rotation speed
- the gas temperature
- the run-down time during stopping.

DAILY INSPECTION

Daily, pre-flight and post-flight inspection.

- check the external aspect
- check the air intake
- check engine mountings

PERIODIC INSPECTION

Recommended frequency of 100 hours including :

- general aspect check
- axial compressor wheel condition check
- 3rd stage turbine wheel check
- exhaust diffuser condition check
- rotating assembly free rotation check (turn the rotating assembly by hand in both directions, make sure of the free rotation and of the absence of abnormal noises).

MAINTENANCE WORKS

- Rear bearing

  Removal, inspection and assembly

- Output shaft seal

  Removal, inspection and assembly

- Fuel injection wheel

  Cleaning procedure

- Combustion chamber

  Endoscopic inspection

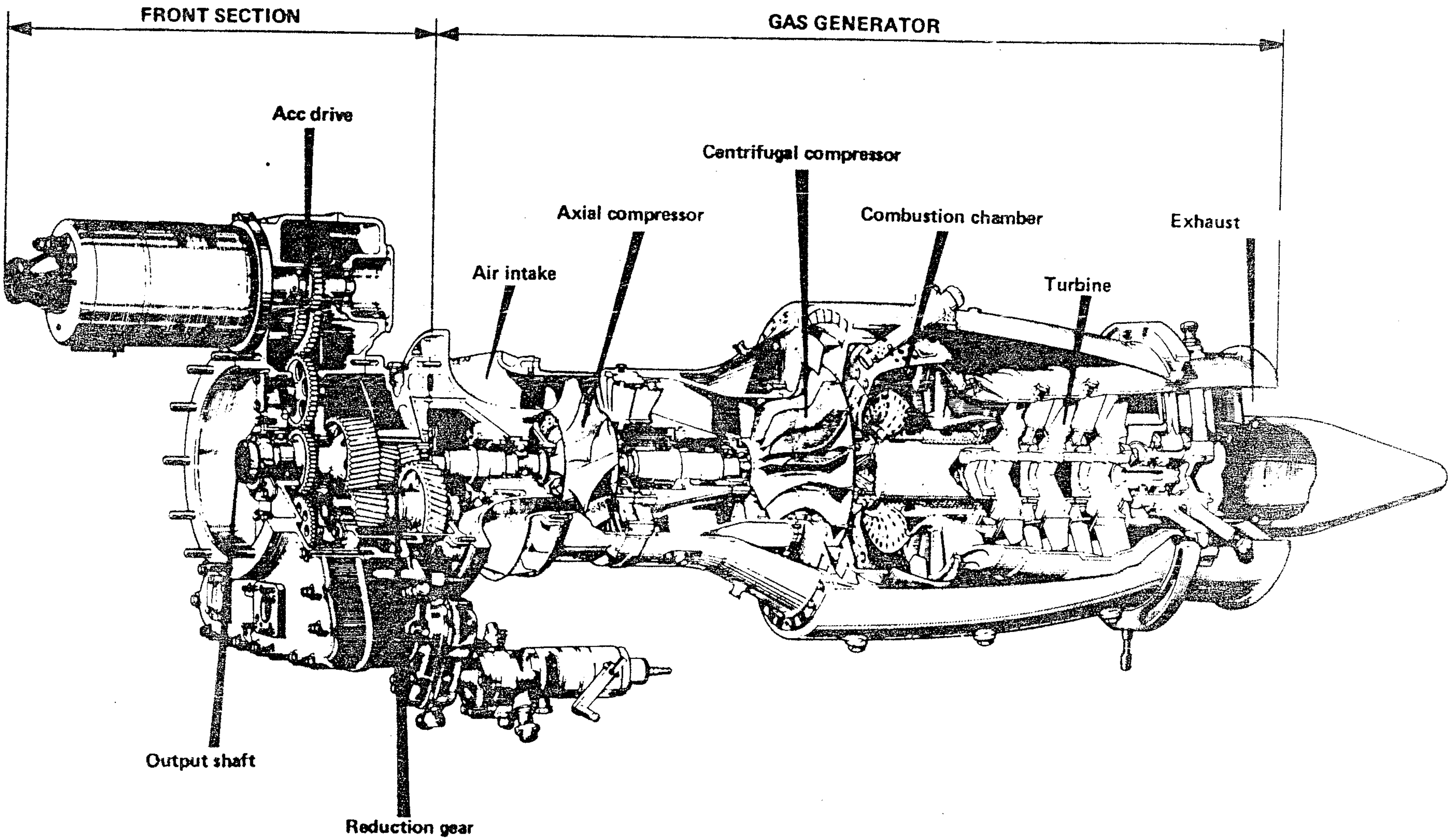
- Jet-holder (with special authorization)

  Removal, inspection and assembly

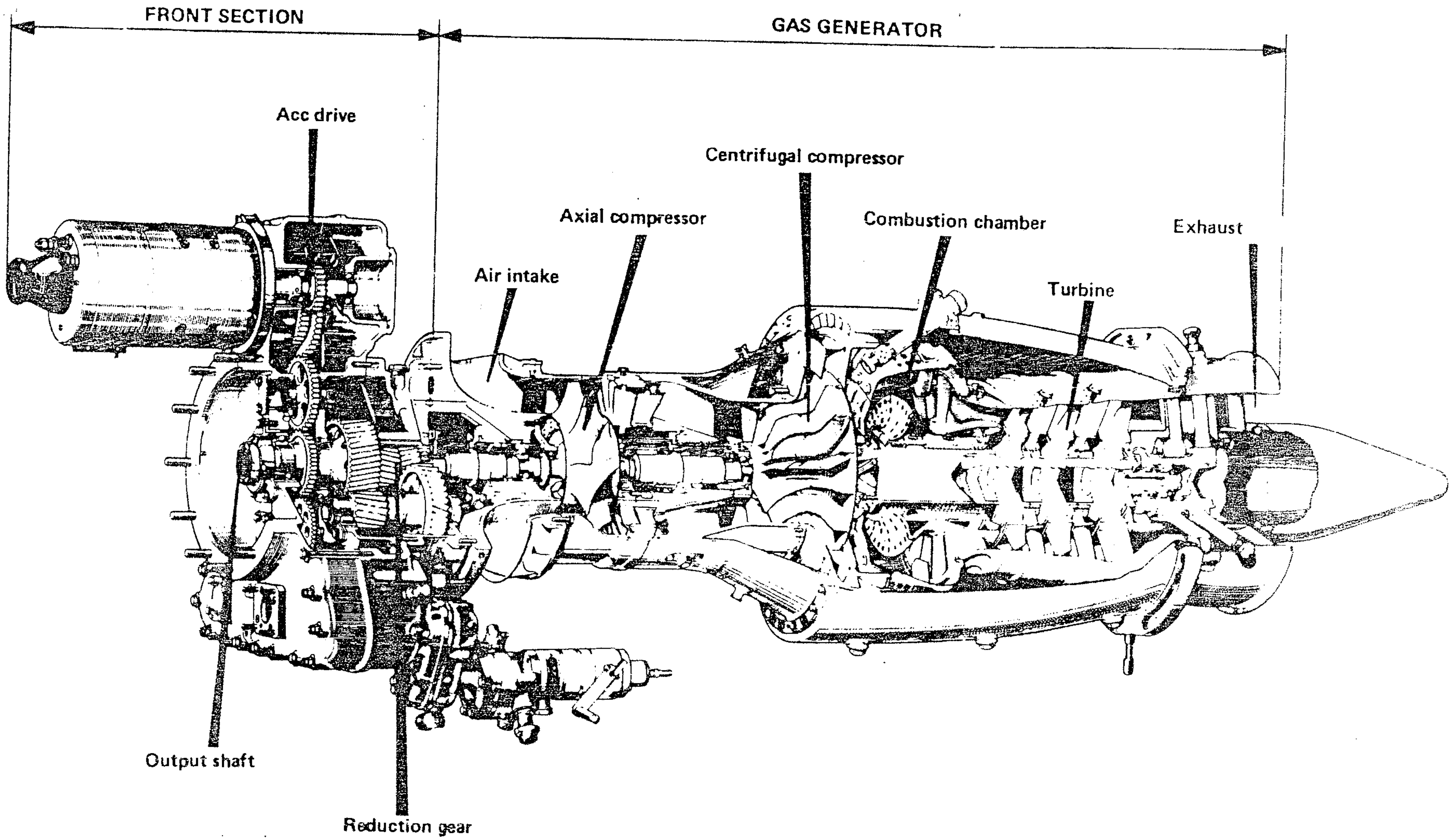
- Compressor field cleaning

  Rinsing procedure
  Cleaning procedure.

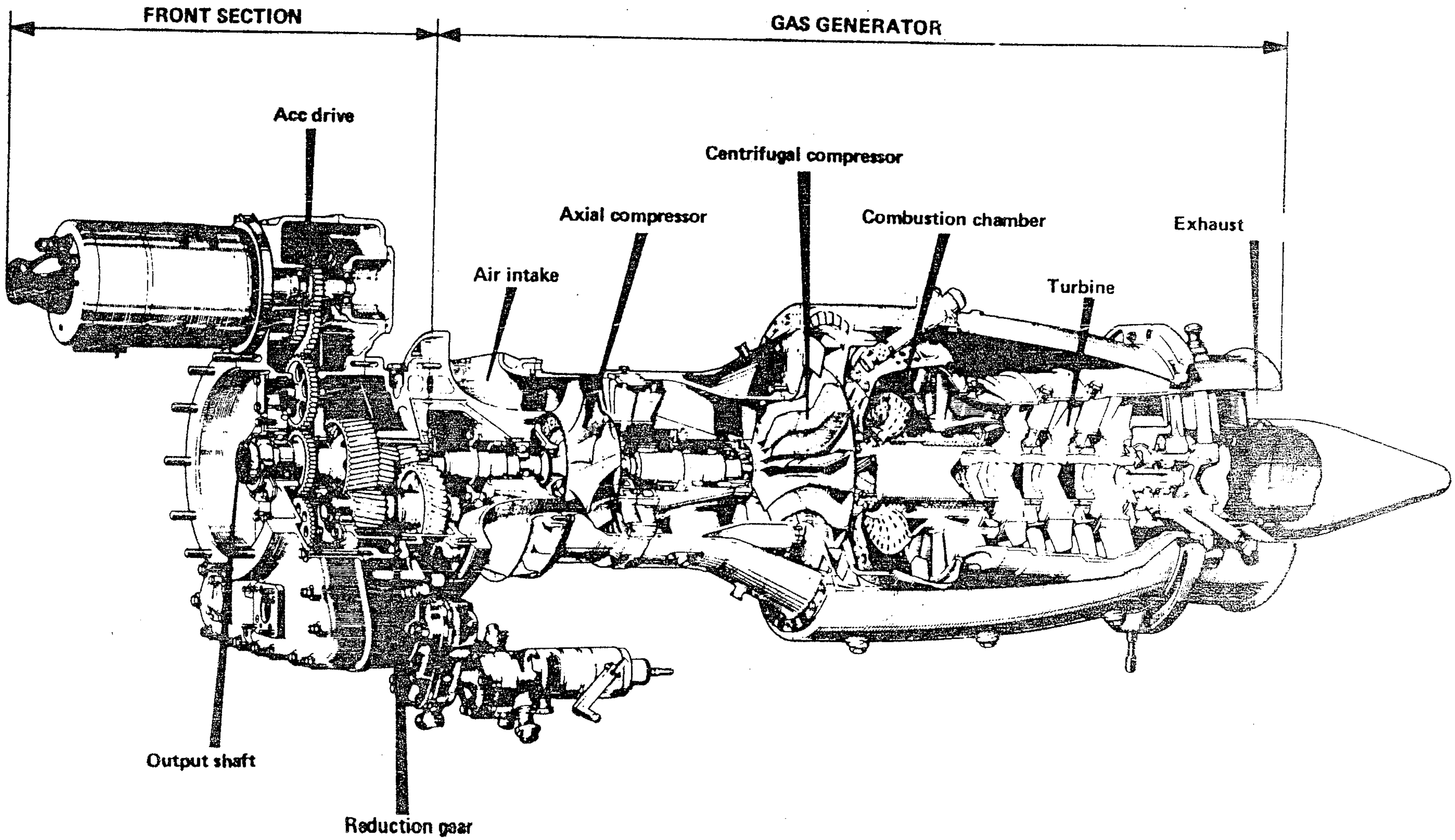
Note These notes affect maintenance of the "bare" engine only.
These practices are considered in practical work during a training course.



ARTOUSTE III PERSPECTIVE CUT—AWAY



ARTOUSTE III PERSPECTIVE CUT—AWAY



ARTOUSTE III PERSPECTIVE CUT-AWAY

NOTES

AD NOTES

SERVICE BULLETINS

72.218.0030	Use of Shell Turbine Oil 390
72.218.0054	TU-72 Addition of Labem Oil Press Transmitter
72.218.0064	TU-160 Addition of Mag Plug
72.218.0047	TU-78 Fitting Metal Oil Cartridge
72.218.0036	TU-58 Oil Low Press Switch Inst.

SERVICE LETTERS

SL 71/68/ART/18	Inspection of Oil Flow Rear Bearing
SL 100/69/ART/22	Use of Synthetic Oil Esso 2389
SL 108/69/ART/22	Use of Synthetic Oil Shell 390
SL 260/71/ART/46	Engine Lube Oil
SL 550/76/ART/73	Mag Plug Preventive Maintenance
SL 573/76/ART/77	Spectrometric Oil Analysis
SL 589/77/ART/79	Dilution of Oil by Fuel
SL 611/77/ART/81	Spectrometric Oil Analysis
SL 657/78/ART/88	Passage of Fuel in Oil
SL 667/78	Use of Lubrication Oil Turony Coil TN 150 NA

APS LETTERS

Operator Memo	TM-10
	Approved Lube Oil for ART III B

CHAPTER 4

LUBRICATION

- INTRODUCTION
- GENERAL DESCRIPTION
- OPERATION OF THE SYSTEM
- LUBRICATION OF THE FRONT SECTION
- LUBRICATION OF THE INTERMEDIATE SECTION
- LUBRICATION OF THE REAR BEARING
- DESCRIPTION OF ACCESSORIES
- MAINTENANCE

INTRODUCTION

LUBRICATION OF THE ENGINE COMPONENTS

Lubrication is required for the following engine components :

Front section

- axial compressor front bearing
- accessory drive
- reduction gear
- output shaft bearing.

Intermediate section

- axial compressor rear bearing
- centrifugal compressor bearing.

Rear section

- turbine rear bearing.

FUNCTIONS OF THE SYSTEM

The lubrication is ensured by means of an oil system which must perform the following functions :

- supply under pressure and filtering
- scavenge and cooling
- breathering and air vent
- operation indicating
- sealing of the system.

Moreover, the lubricating oil is used to operate the isochronous speed governor.

The engine may be lubricated either with synthetic oil or with mineral oil.

The oil specification must correspond to the French standard AIR 3 515 for mineral oil, and AIR 3 513 for synthetic oil.

GENERAL DESCRIPTION

The lubricating oil system incorporates the following components :

- An oil tank

The oil tank is not incorporated to the engine and it is provided by the aircraft manufacturer. 1.85 gal. capacity

- An oil cooler

In the same way, the oil cooler is not incorporated to the engine and it is provided by the aircraft manufacturer.

- Oil pumps

Gear type pumps driven by the lower train of the accessory drive. The set is composed of a pressure pump and scavenge pumps which are assembled in two units : an internal one and an external one.

- A pressure relief valve

5 bars not adj. It is a pressure relief valve which controls the supply pump pressure. It is installed on the rear surface of the support casing and it is provided with an adjusting screw.

- An oil filter

paper or metal 30 u cleaned T. It filters the oil delivered by the pressure pump. Of cartridge type, it is installed on the rear surface of the support casing and it is provided with a by-pass valve operating in case of clogging. differential press of ↑2.7 bars

- An oil pressure transmitter

It ensures the oil pressure indication at filter outlet.

A temperature bulb is installed at the lower section of the oil tank to indicate the oil temperature.

- Internal pipes and jets

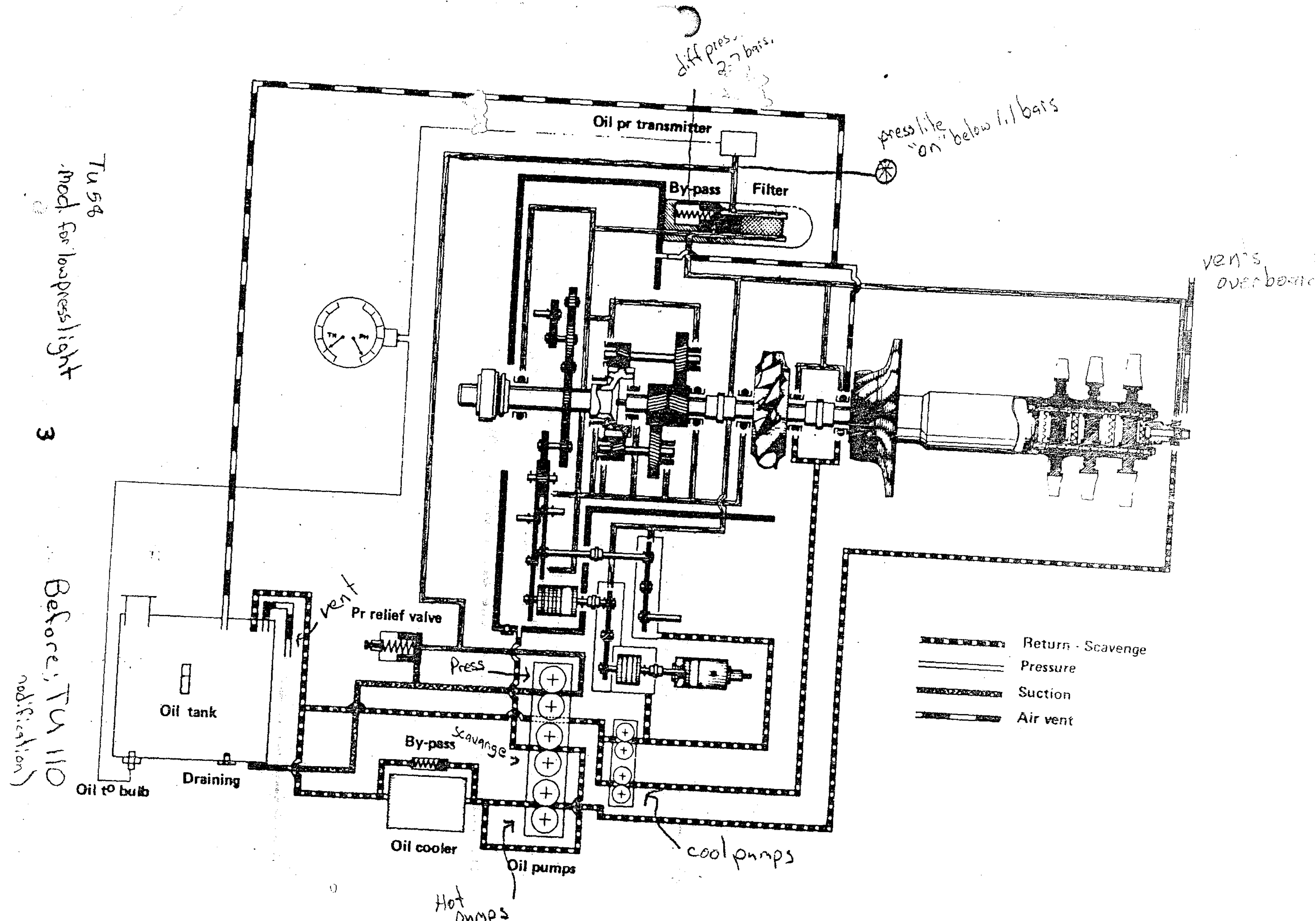
Pipes, internal drillings and jets being part of engine internal components.

- External pipes

Pressure pipes, scavenge pipes and air vent pipes.

Specs. on pg. 15

(entire sys. cap. 2.6 gal.)



OIL SYSTEM SCHEMATIC DIAGRAM

OPERATION OF THE SYSTEM

PRESSURE

The pressure pump sucks the oil from the tank and delivers it towards the filter.

From the filter, the oil under pressure is directed to the various components to be lubricated. A pressure tapping point allows also the supply to the isochronous speed governor.

At the end of "line" of pressure, nozzles ensure the spraying of the oil on the components to be lubricated.

The pressure relief valve subjected to the pump delivery pressure drives the excess oil back to the pump inlet.

In case of filter clogging, the subsequent increase in pressure difference causes the by-pass valve opening and the oil circulation in deviation of the filtering cartridge.

SCAVENGE

The oil scavenge is carried out by means of four pumps of the internal and external groups.

The scavenging oil is driven back to the tank after passing through the oil cooler for the two internal pumps, and directly for the two external pumps.

The two pumps of the internal group scavenge the oil from the rear bearing and from engine front sections, and the two pumps of the external group scavenge the oil from the intermediate section and from the two auxiliary accessory drive boxes.

BREATHERING AND AIR VENT

The vapours resulting from lubrication are driven back to the tank which is provided with an air vent.

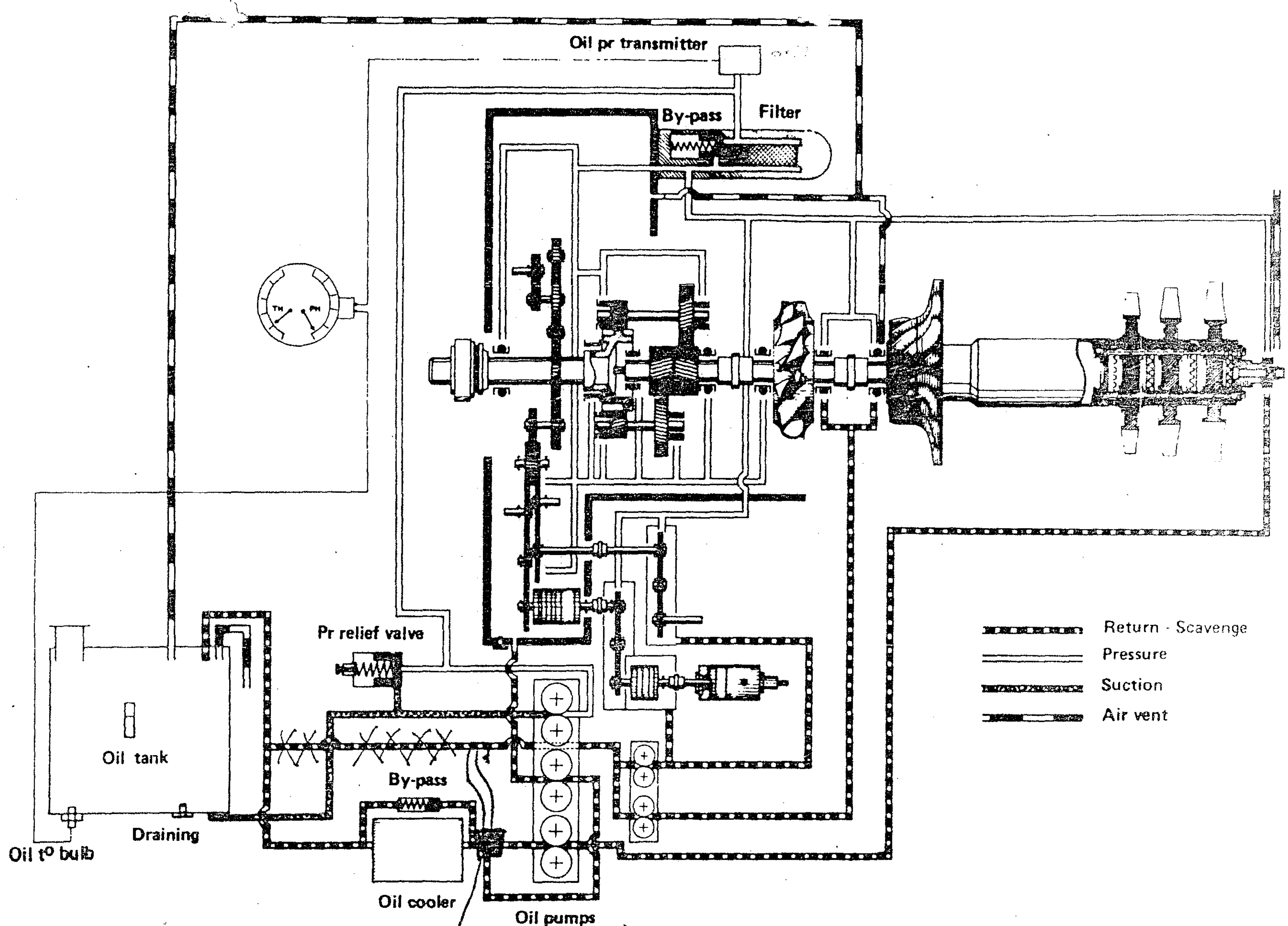
The rear bearing breathering is ensured by a direct air vent.

SEALING OF THE SYSTEM

Various types of seals are used : "sealol" seals, "simrit" seals, "O'rings", paper gaskets, "surface" seals.

INDICATING

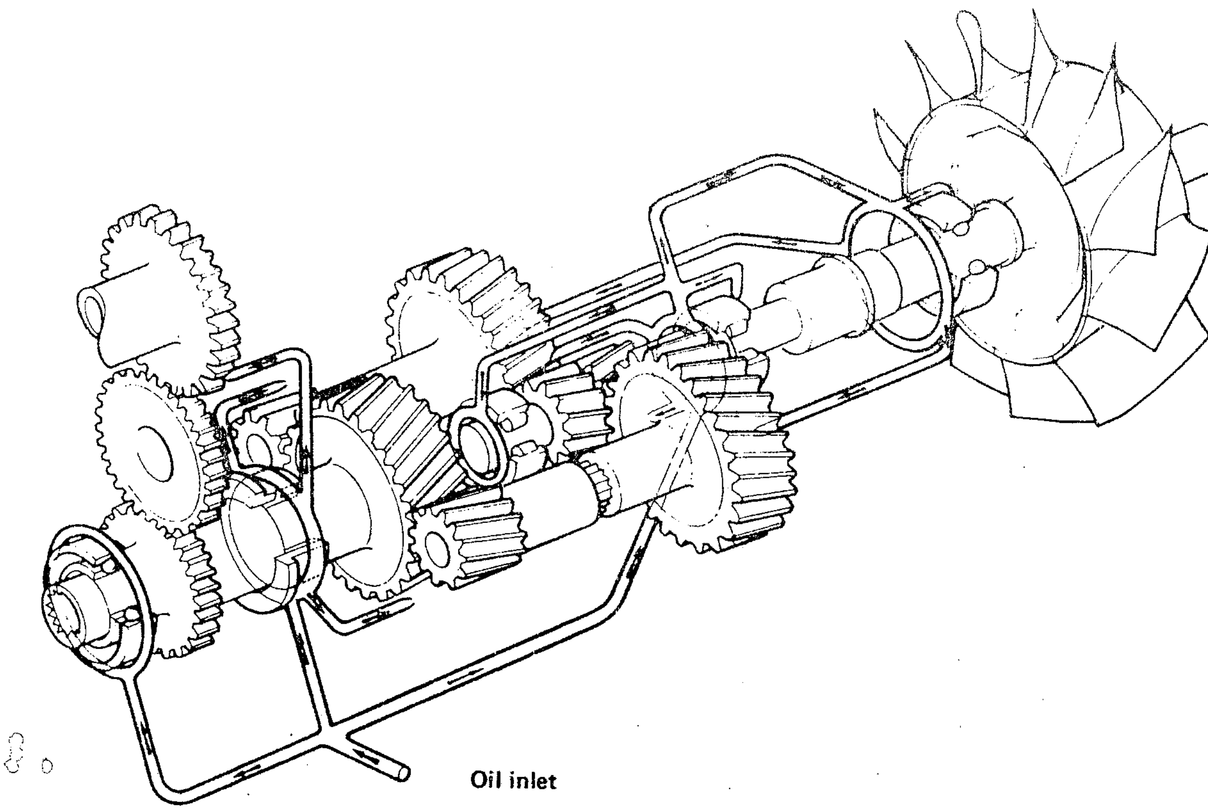
The operation indicating is obtained by means of the oil pressure indication and the oil temperature indication.



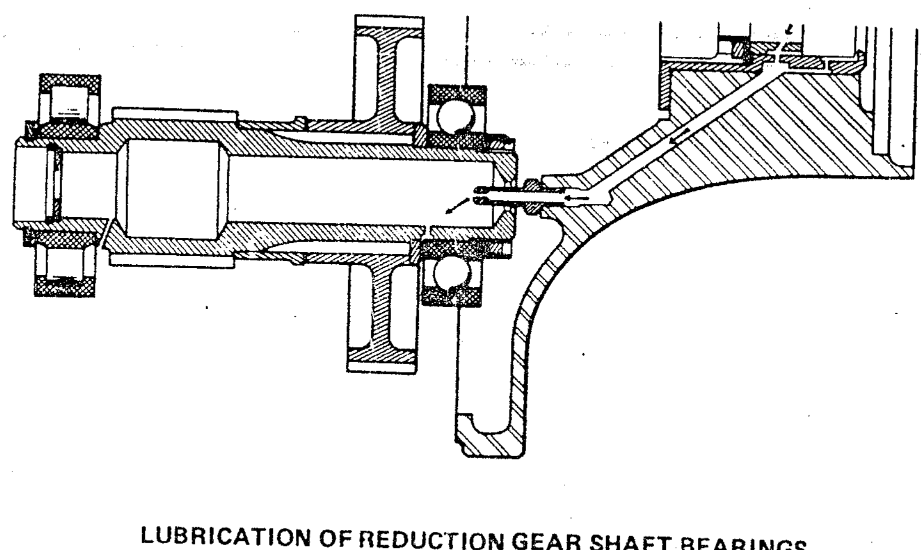
Mag. chip (mag. plug) detector
inspected daily, or every 10 hrs
clean only when changing oil

OIL SYSTEM SCHEMATIC DIAGRAM

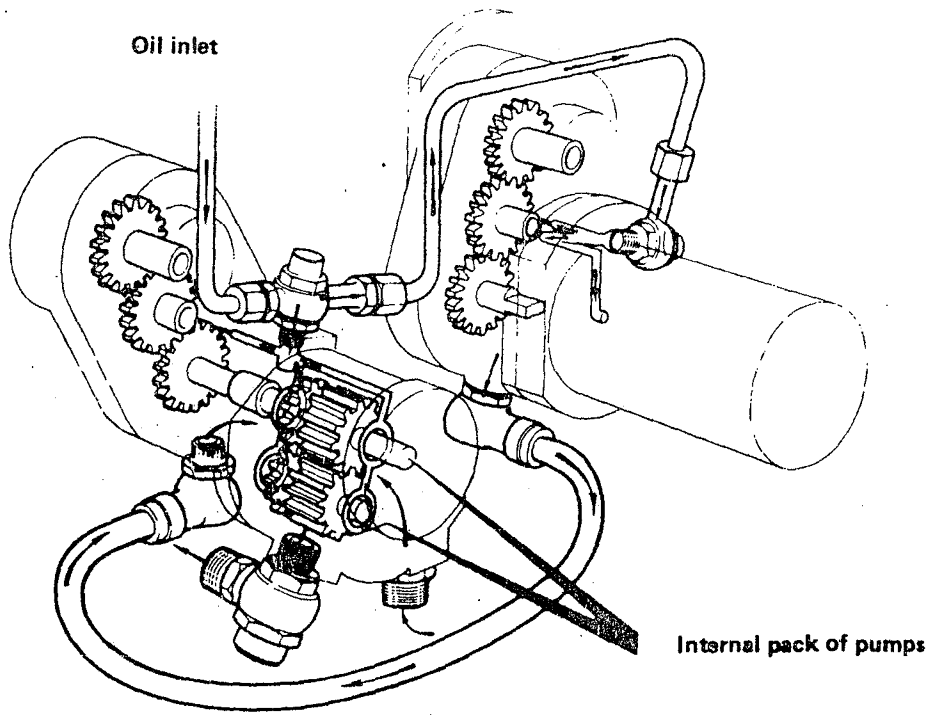
After TU 110



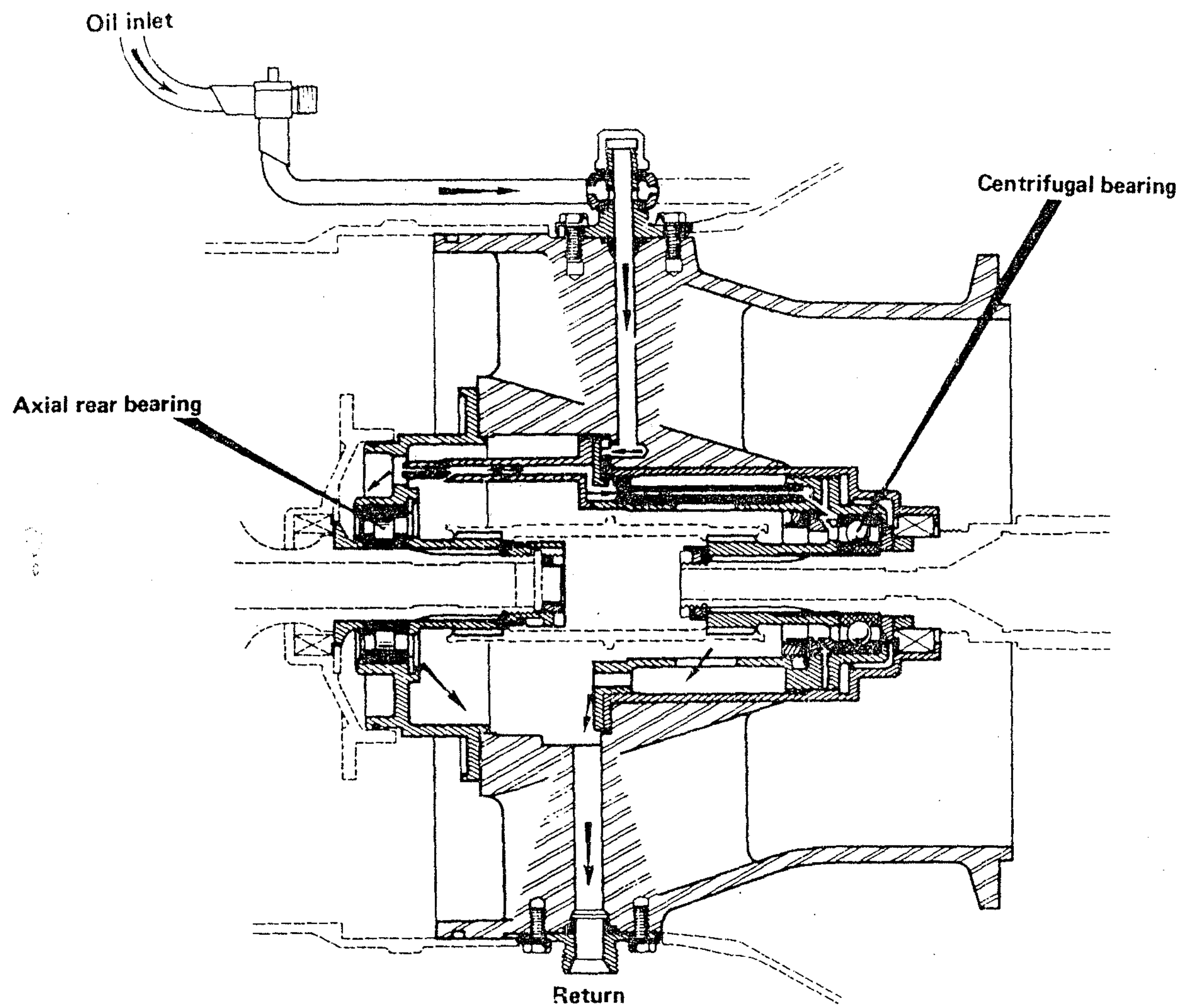
FRONT SECTION LUBRICATION



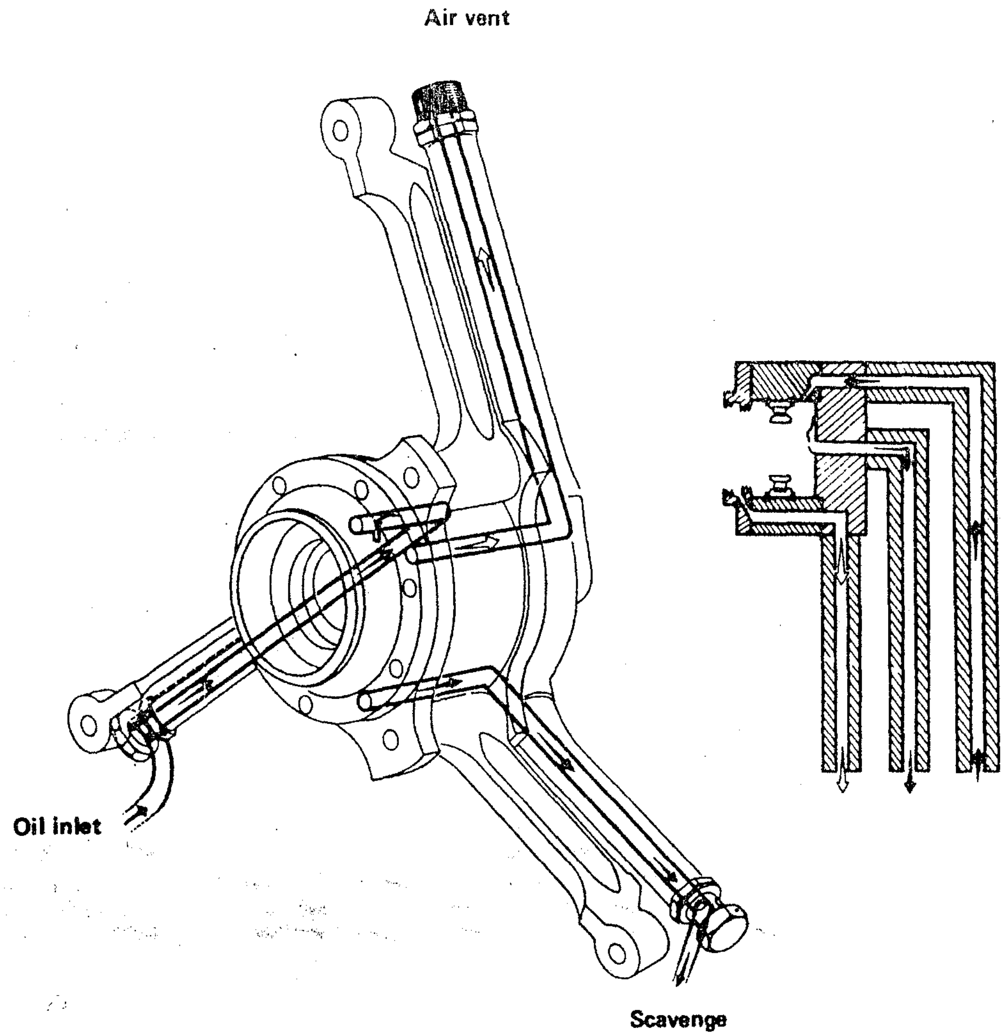
LUBRICATION OF REDUCTION GEAR SHAFT BEARINGS



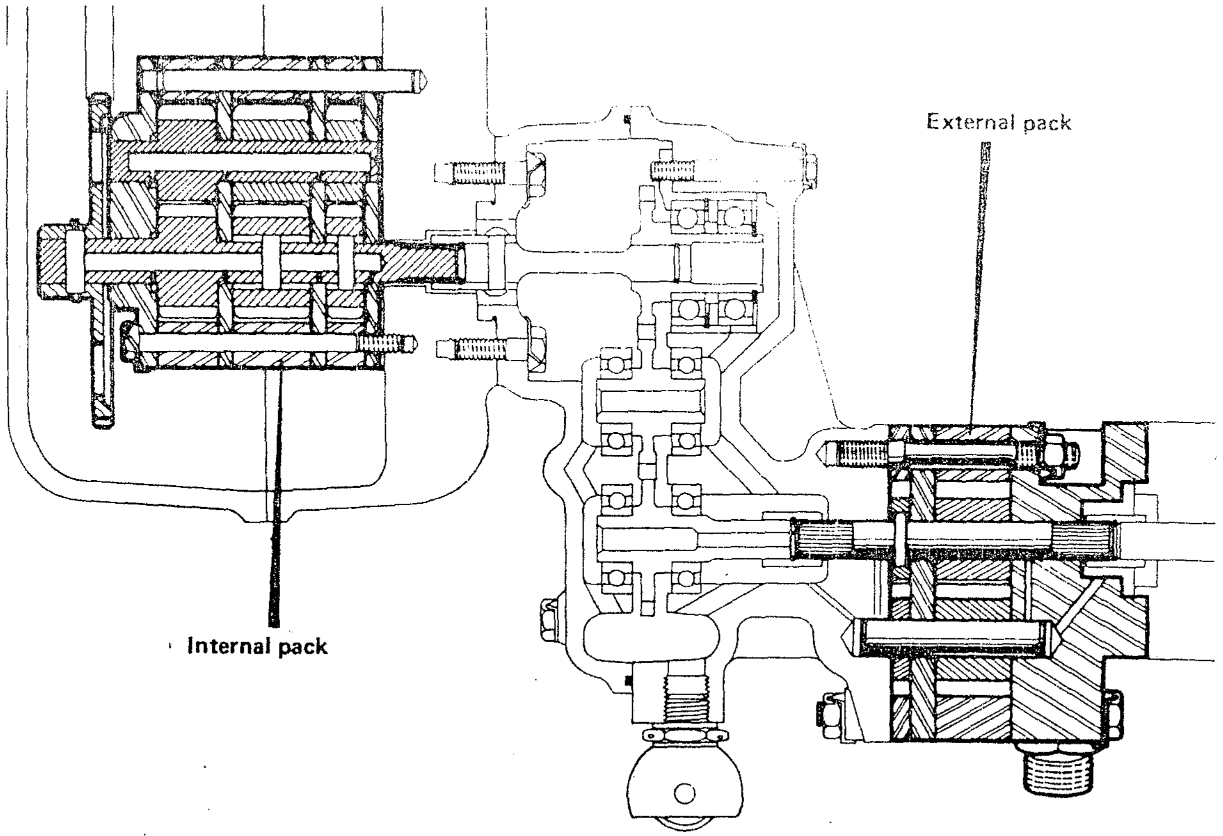
LUBRICATION OF ACCESSORY DRIVE – AUXILIARY DRIVE BOXES



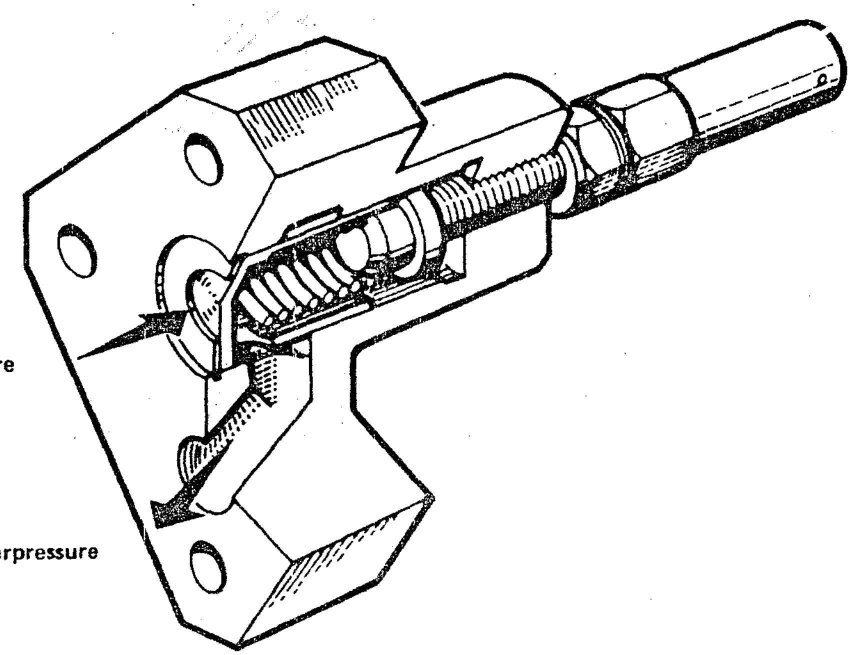
LUBRICATION OF ENGINE INTERMEDIATE BEARINGS



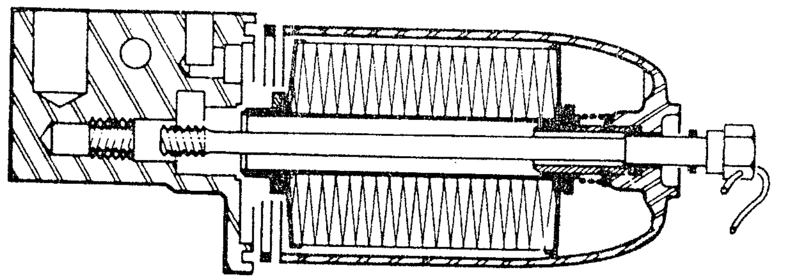
LUBRICATION OF REAR BEARING



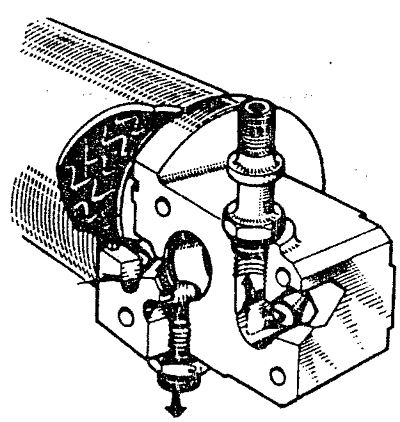
OIL PUMPS CUT–AWAY

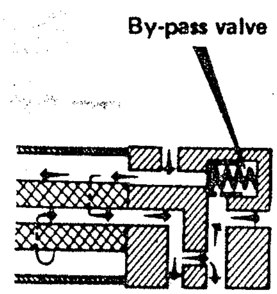


OIL PRESSURE RELIEF VALVE

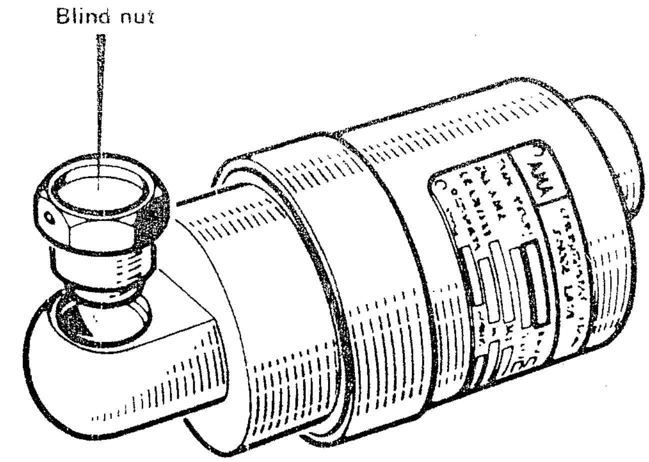


OIL FILTER—FILTER ELEMENT

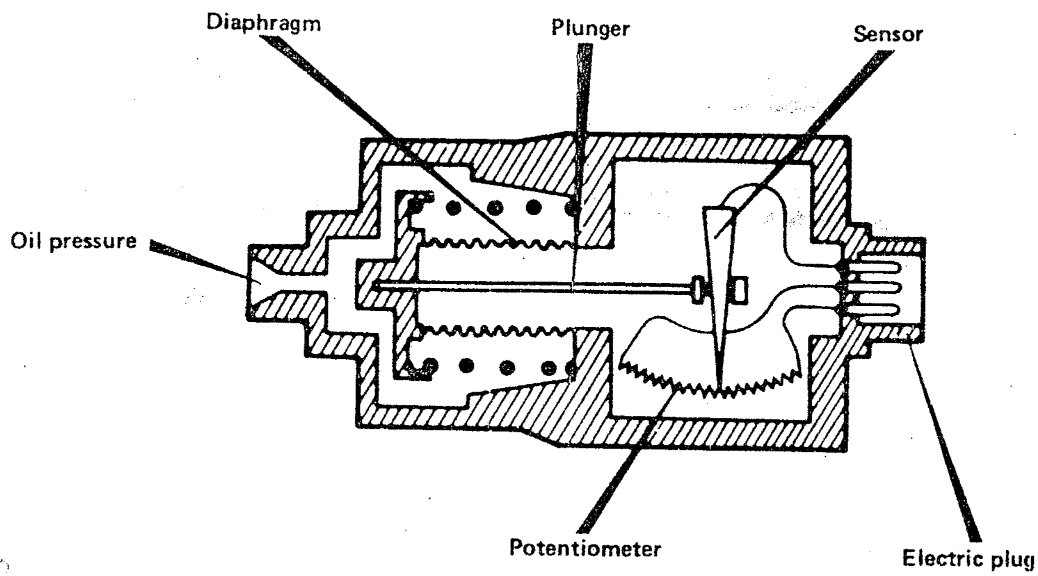




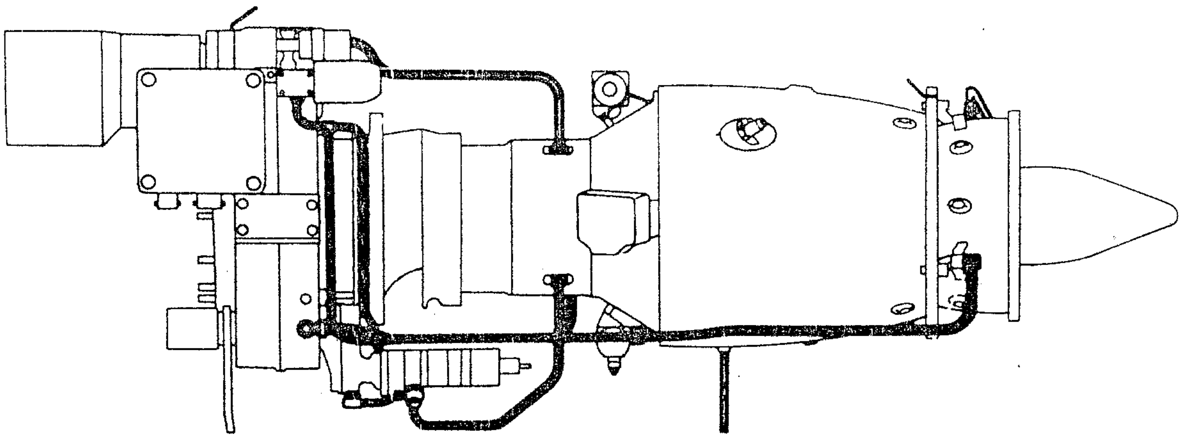
OIL FILTER—FILTER BASE



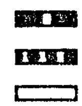
OIL PRESSURE TRANSMITTER–EXTERNAL VIEW

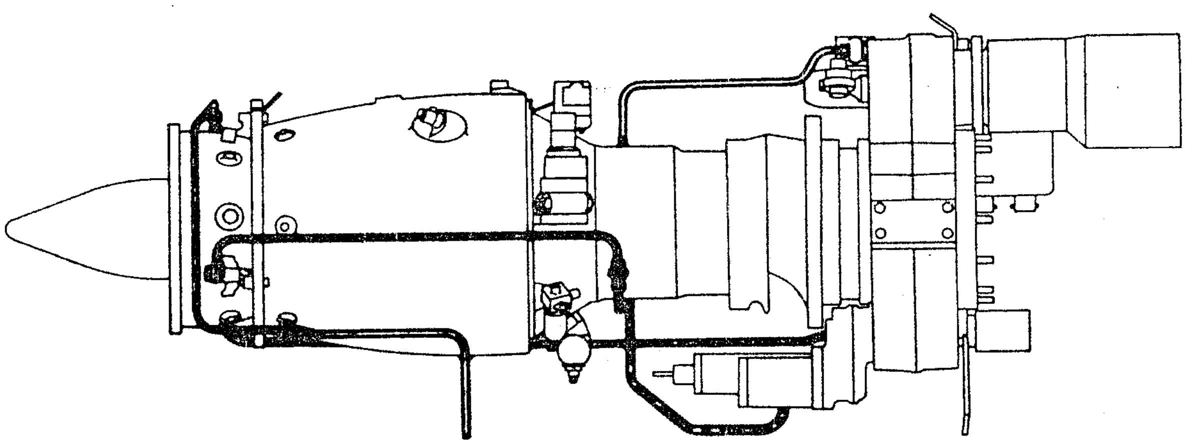


OIL PRESSURE TRANSMITTER–SCHEMATIC DIAGRAM

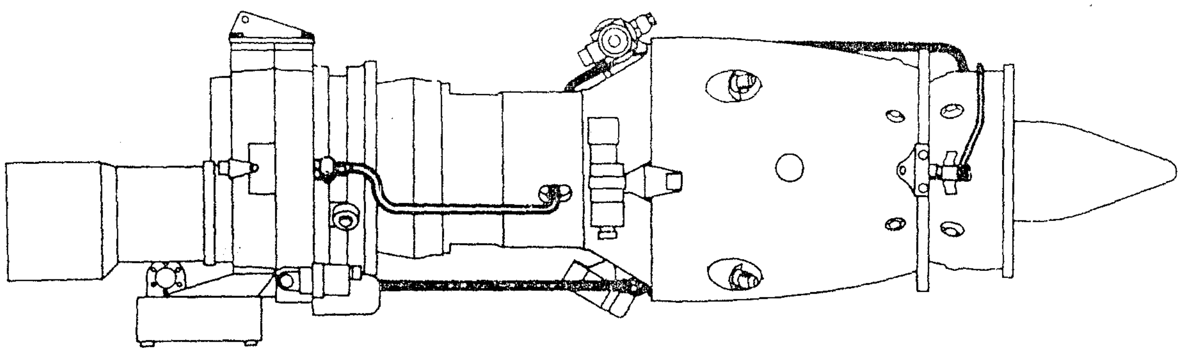


OIL PIPES—ENGINE LEFT SIDE



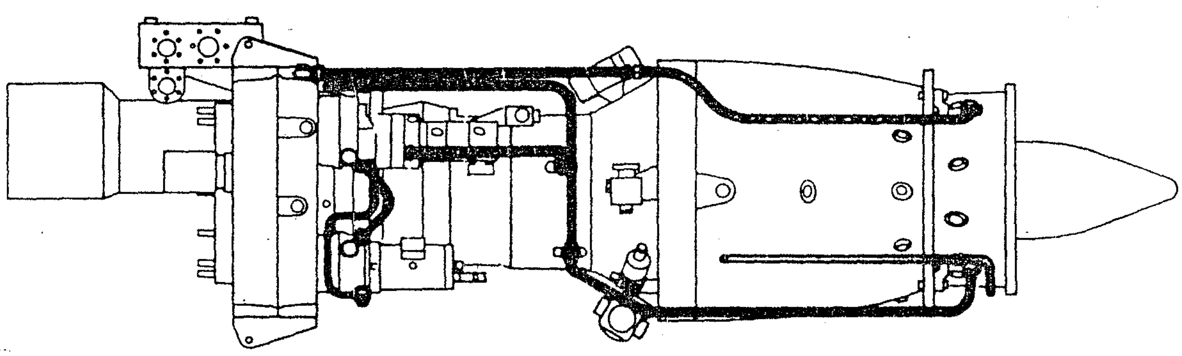


OIL PIPES—ENGINE RIGHT SIDE



OIL PIPES—ENGINE VIEW FROM THE TOP

Pressure
Scavenge
Breather



OIL PIPES—ENGINE VIEW FROM THE BOTTOM

MAINTENANCE

INTRODUCTION

This paragraph, devoted to the oil system maintenance, is arranged according to the following scheme :

- characteristics and limitations
- servicing and maintenance
- checks and adjustments
- fault analysis
- maintenance works.

CHARACTERISTICS

- Mineral oil specification .... AIR 3 515
- Synthetic oil specification .... AIR 3 513
- Tank content .... 7 l
- Oil cooler capacity .... 1 l
- Total capacity of the system .... 8 to 9 l
- Usable volume of oil .... 5 l
- Maximum consumption .... 0,5 l/h
- * Oil pressure ....1,4 to 5 b(0.8min at idling) below 1.1 bars light come on
- Max. oil temperature .... 85° C
- Min. oil temperature (before setting power). + ~~1~~0° C
- Setting of the pressure relief valve .... 5 b
- Setting of the filter by-pass valve .... ΔP = 2,7 b
- Setting of the cooler by-pass valve ....
- Filtering power .... 30 μ

Note

Mineral and synthetic oil must not be mixed.

The maximum dilution ratio of fuel in oil is 10 %.

SERVICING AND MAINTENANCE

During operation, check that oil pressure and temperature are within the limits.

During pre-flight inspections check the level in the oil tank and make sure that there is no leak.

During periodic inspections, carry out :

- the oil draining (only when operating with mineral oil ; refer to maintenance manual)
- the sampling for analysis (optional)
- the replacement of the filtering cartridge
- the general inspection of the system.

CHECK-OUT PROCEDURES AND ADJUSTMENTS

Oil pressure check

The check-out procedure consists in the fitting of a pressure gauge on the filter outlet pressure tapping point and in the pressure checking during a ground run test (moreover, the comparison between the pressure gauge indication and the aircraft transmitter indication allows to check the oil pressure indicating system).

Cleaning (or rinsing) procedure of the system

This procedure may be carried out in case of clogging of the system or in case of change in oil specification. It is carried out in the following way :

- Drain the system (engine warm)
- "Clean" the filter cartridge
- Fill with "new" oil (no need to fill the tank fully)
- Carry out a ground run
- Drain out the system
- Replace the filtering cartridge
- Fill up with new oil
- Carry out a ground run test
- Check pressure and temperature
- Check for leaks
- Check the oil level.

Oil filling, oil level check and draining

Classical procedure (refer to maintenance manual). Pay special attention to oil specification and quality.

Oil tank and cooler check

(see aircraft manufacturer's maintenance manual).

Oil pressure adjustment

The oil pressure adjustment can be carried out on the adjusting screw of the pressure relief valve. Nevertheless, prior to adjustment, it is necessary to undertake the following procedure :

- check the oil pressure indication
- make sure of the correct operation of the system
- check the pressure with an oil temperature high enough (60° C about)
- act cautiously on the adjusting screw : screw in to increase the pressure.

FAULT ANALYSIS

As a general rule, the fault analysis consists in determining the symptoms and effects occuring in case of defect in a component (as a matter of fact the question is to find out the effect(s) from a given cause(s).

In the case of this system, this rule is not rigidly followed and this chapter is dealt with by taking into consideration various cases of faults.

Passage of fuel into oil

The detection of fuel in oil may be carried out by various ways :

- oil level check
- smell from oil
- density check
- oil analysis (sampling and analysis of the flash point in laboratory).

The maximum permissible dilution ratio is 10 % in 25 running hours.

The various possibilities of passage of fuel into oil are the following :

- the jet-holder seal (draining check is a valuable indication about the sealing of this component)
- the seal of the fuel pump drive ("simrit" seal which can be replaced)
- the isochronous speed governor.

Case of abnormal oil pressure

In the case of oil pressure beyond limits, it is first necessary to make sure of the oil pressure indication and then to consider the various causes of the defect. In this case, the following causes can be noted :

- wrong pressure indication
- oil filter clogging
- incorrect oil level
- oil filter by-pass valve faulty
- air entering the system
- leaks
- pump pressure relief valve faulty
- obstruction of the system
- pump faulty
- engine internal defect.

Case of abnormal oil temperature

In the same way, it is first necessary to check the temperature indication. Then the following causes can be noted :

- wrong indication
- oil not corresponding to specification
- dilution of fuel into oil
- oil cooler faulty
- engine internal defect.

Case of "foaming" in oil tank

Oil foaming in the tank may have the following causes :

- oil level too high
- oil temperature too high
- oil tank air vent clogged
- oil tank being under pressure (through the breathering line of engine intermediate bearings when there is a faulty sealing of the "sealol" seals of these bearings).

Case of abnormal oil consumption

If the consumption is nil or if the oil level increases in the tank, there is passage of fuel into oil.

If the consumption is excessive this indicates an engine leak ; cases of engine internal leaks and engine external leaks are to be considered.

Case of external leaks

It is worth to mention : pipes, accessories, starter drive shaft, tachometer generator drive shaft, rear bearing, output shaft seal ...

Case of internal leaks

"Sealol" seals of the axial compressor bearings, "sealol" seal of the centrifugal compressor bearing.

Sealing of the oil system

Let us recall the various types of seals used :

Flexibox seal - graphite seal used for jet-holder fuel sealing.

"Sealol" seal - graphite seal used for the three front bearings of the gas generator and for the output shaft.

"Simrit" seal - rubber-spring used for the sealing of : fuel pump drive shaft, starter-generator drive shaft, tachometer-generator drive shaft.

Labyrinth seal - seal used for the sealing of the turbine rear bearing.

Paper gasket - seal used in particular for the sealing of the turbine rear bearing.

"O'ring", surface/surface seal - in various places.

Note

In order to obtain a better sealing, when mounting some components, a special jointing compound may be used.

MAINTENANCE WORKS ON THE OIL SYSTEM

Being covered in practical works :

- checks and adjustments
- removal and installation of accessories
- removal of pressure relief valve.

NOTES

CHAPTER 5

FUEL SYSTEM

- INTRODUCTION
- GENERAL DESCRIPTION
- GENERAL OPERATION
- IGNITION FUEL SYSTEM
- MAIN FUEL SYSTEM
- FUEL PUMP ASSEMBLY
- IDLING DEVICE
- STARTING VALVE
- ELECTRIC FUEL COCK
- STARTER CUT–OUT SWITCH
- INSTALLATION AND INTERNAL CIRCUIT
- OPERATION OF THE SYSTEMS

INTRODUCTION

GENERAL

The purpose of the system is to ensure a fuel supply allowing the engine operation within prescribed conditions.

Various systems are to be considered ; they ensure the following functions :

- Supply to the power plant
- Supply for ignition and starting
- Supply in normal operation
- Fuel injection.

SUPPLY TO THE POWER PLANT

This function consists in driving the fuel contained in the tank to the power plant in conditions allowing the operation of the engine circuits.

It is carried out by means of a system provided by the aircraft manufacturer and called "Aircraft fuel system". A typical system incorporates : a tank, a booster pump, a filter assembly, stop and safety devices, indicating systems.

SUPPLY FOR IGNITION AND STARTING

This function consists in ensuring the fuel supply required to engine ignition and starting.

It involves an independent supply and injection system and also the normal fuel supply system.

SUPPLY IN NORMAL OPERATION

This is the function which consists in ensuring the fuel supply and the fuel flow control in all engine operating conditions.

It is carried out by means of a system called "Main fuel system" which, in addition, incorporates operating and safety devices.

The "fuel flow control" function itself will be considered in a particular chapter.

FUEL INJECTION

The fuel injection must allow to obtain a correct combustion in all operating conditions.

GENERAL DESCRIPTION

INTRODUCTION

The following systems are to be considered :

- the aircraft fuel system
- the ignition fuel system
- the main fuel system
- the internal fuel system and injection system.

AIRCRAFT FUEL SYSTEM

It includes :

- a tank
- a booster pump
- a filter assembly
- shut-off and safety devices
- indicating systems.

Start.

IGNITION FUEL SYSTEM

It involves the following components :

- a micro-pump
- a 4-way union
- two torch-igniters
- a ventilation system of the torch-igniters
- an ignition coil.

MAIN FUEL SYSTEM

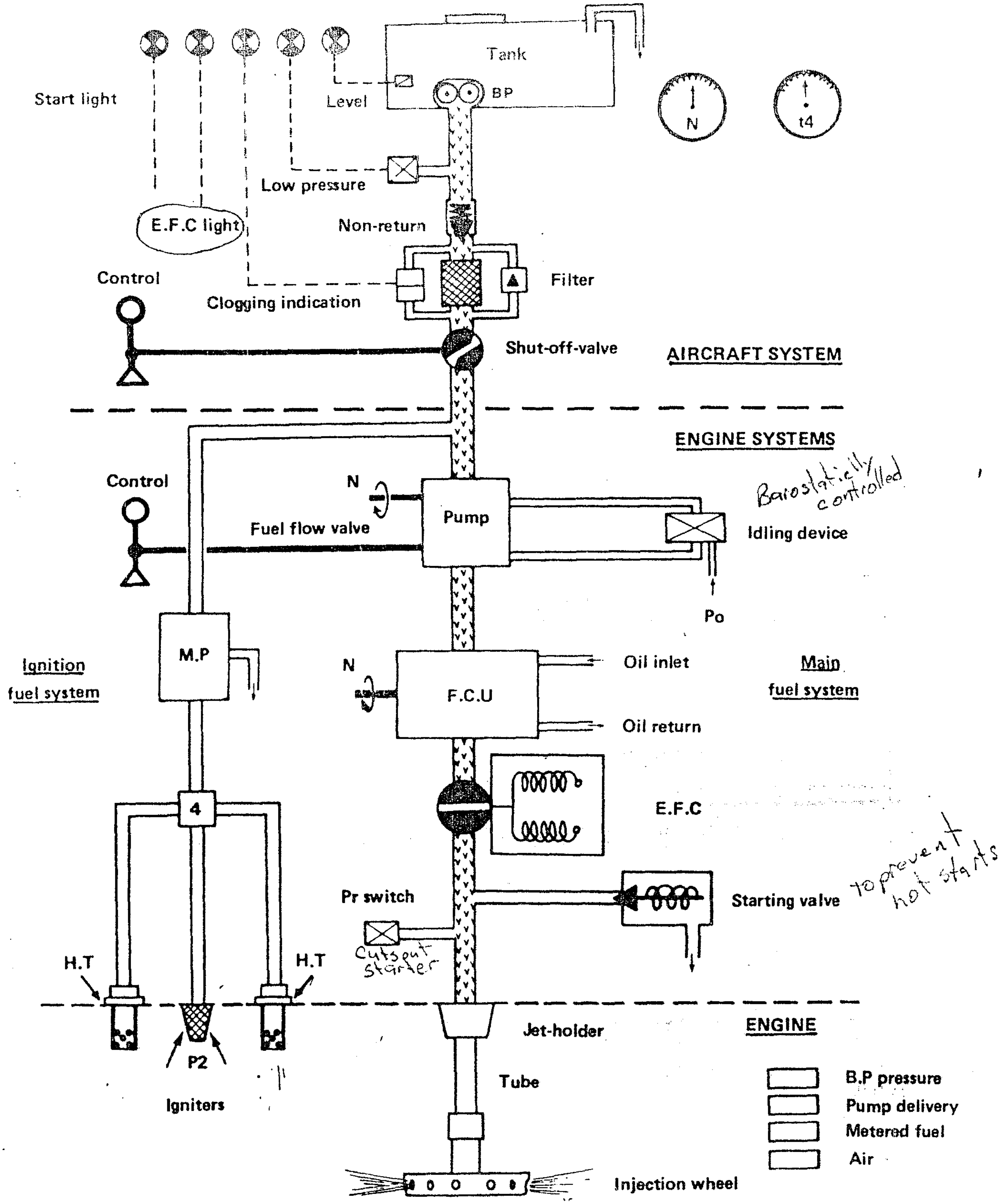
The "main" fuel system consists of the following components :

- a pump assembly
- an idling device
- an electric fuel cock
- a starting fuel valve
- a pressure switch
- a speed governor.

ENGINE INTERNAL SYSTEM

The system incorporates :

- fuel supply pipes
- a jet-holder
- a fuel tube
- a centrifugal injection wheel.



FUEL SYSTEM BLOCK DIAGRAM

GENERAL OPERATION

INTRODUCTION

The study of the general operation of the system induces to consider the following phases :

- engine starting
- acceleration
- operation called "normal"
- engine stopping.

ENGINE STARTING

The "starting" selection initiates the operation of the starter motor, the ignition coil and of the micro-pump.

The pressure building-up of the ~~main~~ micro-pump ensures the fuel supply to the igniters and causes the electric fuel cock opening.

The fuel delivered by the main pump and injected into the chamber is "ignited" by the flame of the torch-igniters ; a few seconds later, the ignition fuel system is automatically cut-out and the engine is accelerated towards the idling speed which is governed by the "idling device".

ACCELERATION

The nominal operating speed is obtained by moving the control lever which actuates the fuel control valve included in the pump assembly.

"NORMAL" OPERATION

The pump ensures the supply with fuel under constant pressure.

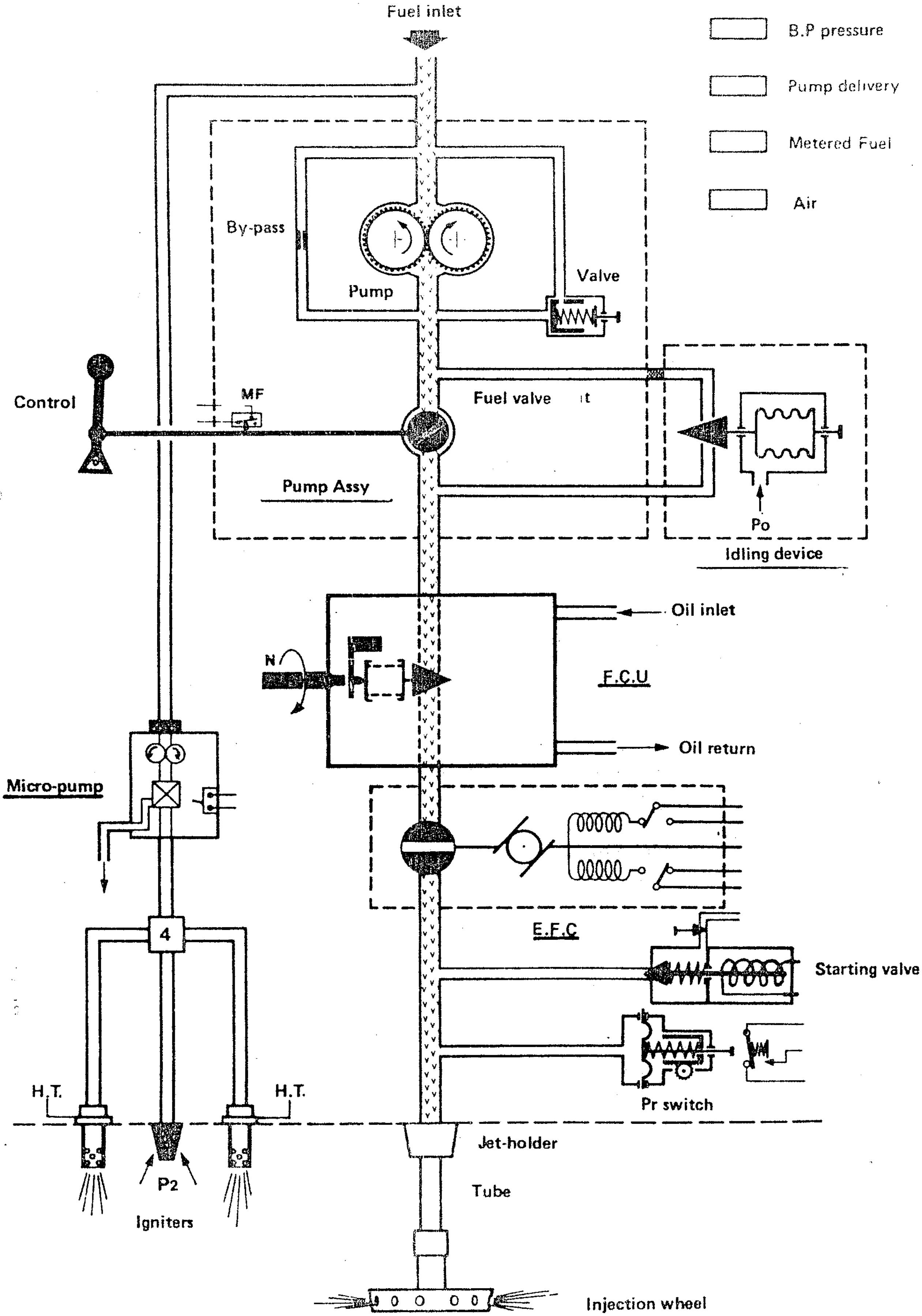
The speed governor meters the fuel delivered by the pump in order to maintain automatically an engine constant rotation speed.

ENGINE STOPPING

The engine "stop" selection causes the electric fuel cock closing. The cock cuts off the fuel supply and the engine stops.

Note

The above statement represents only a general explanation of the operation ; this operation is detailed in the following pages.



FUEL SYSTEM SCHEMATIC DIAGRAM

IGNITION FUEL SYSTEM

INTRODUCTION

The purpose of the system is to ensure the fuel ignition in the combustion chamber during engine starting.

It is used only a few seconds at the beginning of the starting phase and its operation is automatically carried out.

DESCRIPTION OF THE SYSTEM

The ignition fuel system consists of the following components :

- A micro-pump

  This pump supplies the system with fuel under pressure and is driven by an electric motor. 14-30V - 5Amps 5 bars

- A four-way union

  Its purpose is to ensure the distribution of fuel from the micro-pump to the igniters.

- Two torch-igniters

  Igniters mounted on the turbine casing. They are supplied with high voltage current and with fuel under pressure.

- A ventilation system of the igniters

  This system consists of a compressor air tapping (P2) connected to the four-way union.

- An ignition coil

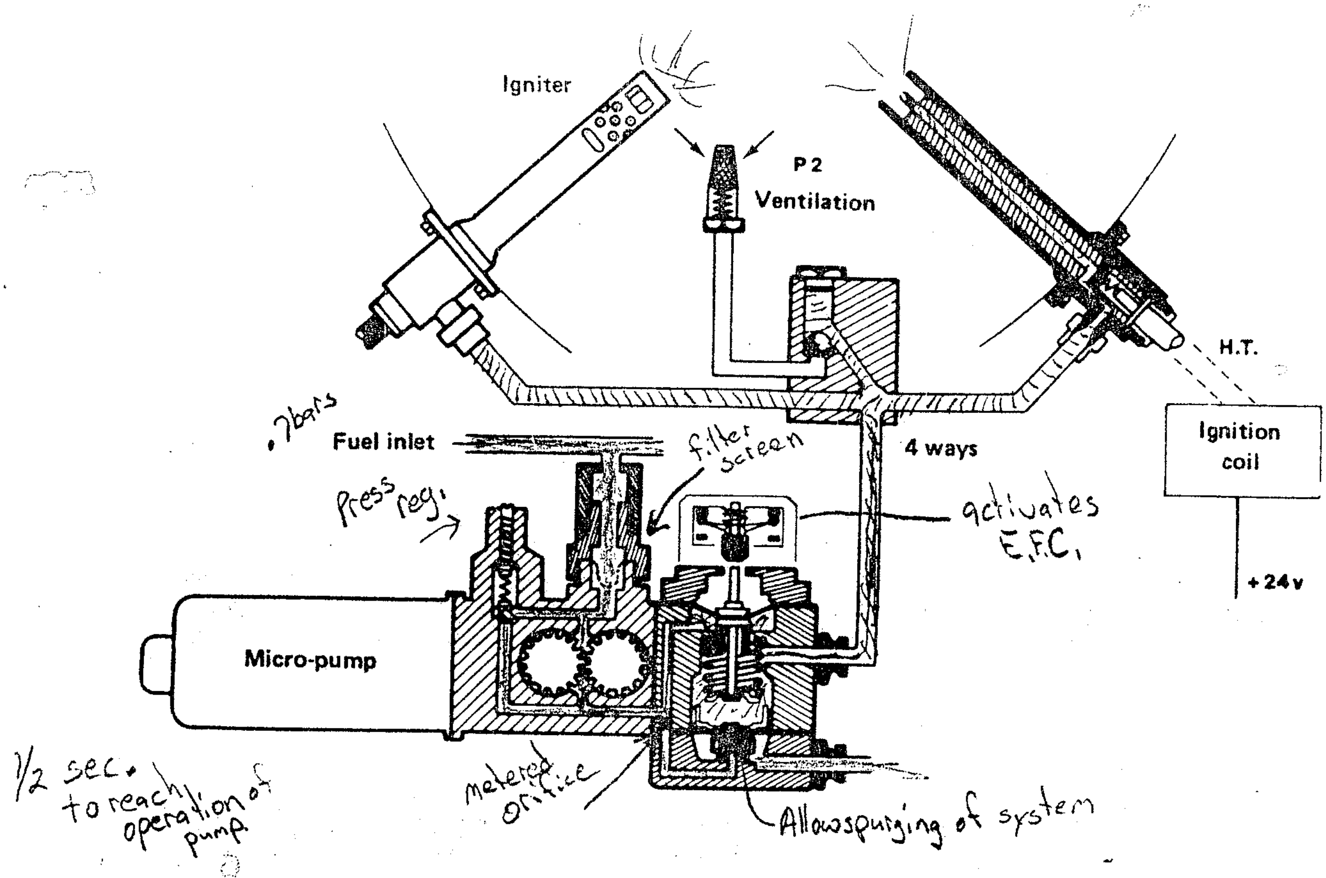
  It is a dual coil which ensures the production of high voltage current to supply the igniters.

- Pipes

  Micro-pump inlet fuel pipe, micro-pump draining pipe, micro-pump delivery pipe, four-way union - igniters pipe, igniters ventilation pipe (P2 tapping - four-way union).

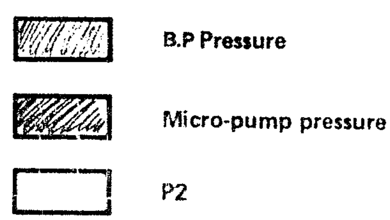
Note

These components are dealt with in full details in the chapter "Fuel system" but it is also considered in other chapters such as "Electric system" chapter, "Starting" chapter.



IGNITION FUEL SYSTEM SCHEMATIC DIAGRAM

refer to pg 15-17



MICRO-PUMP

Its essential purpose is to supply the torch-igniters with fuel under pressure.

The micro-pump assembly incorporates the following components :

An electric motor

It is a "shunt" type motor supplied with direct current. It includes an electric plug with 5 pins and an access door to the carbon holder.

The pump itself

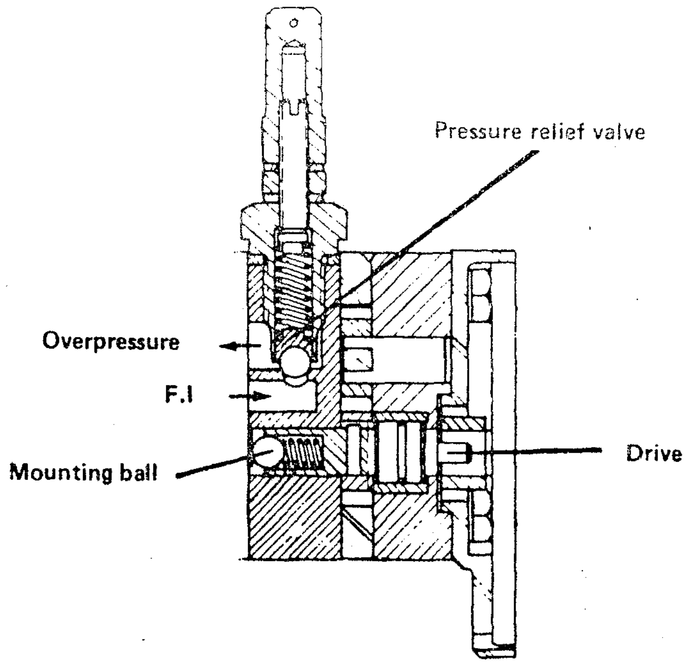
It is a gear type pump which consists of two pinions assembled with a "clearance". It is directly driven by the electric motor on which it is secured by means of screws. The pump is provided with a valve allowing the control of the delivery pressure. The valve is composed of a ball, a spring and an adjusting screw. A filter of "strainer" type is mounted inside the pump fuel inlet union.

A valve assembly

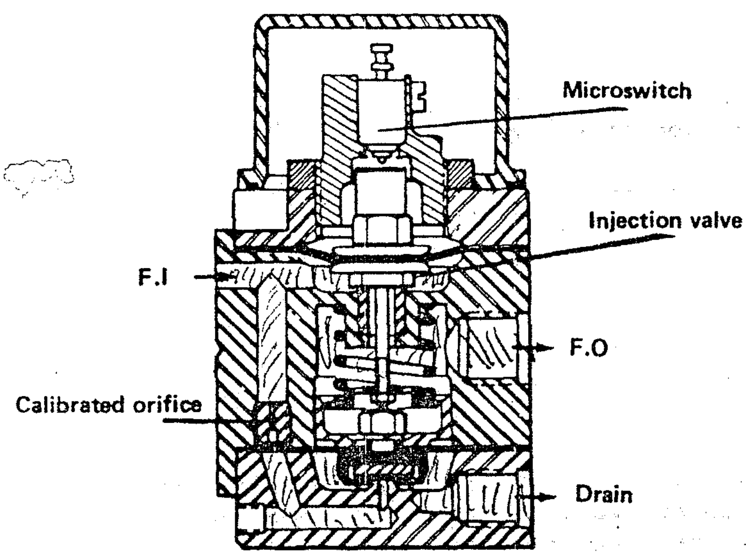
This assembly is installed on the pump body and it essentially includes : an "injection" valve a "drain" valve, and the fuel inlet and outlet unions. The "injection" valve consists of a diaphragm held in position "closing" by means of a spring. The drain valve includes a diaphragm and a spring of low tension which tends to open the valve. A calibrated orifice is mounted inside the body in the line to the drain valve.

A microswitch

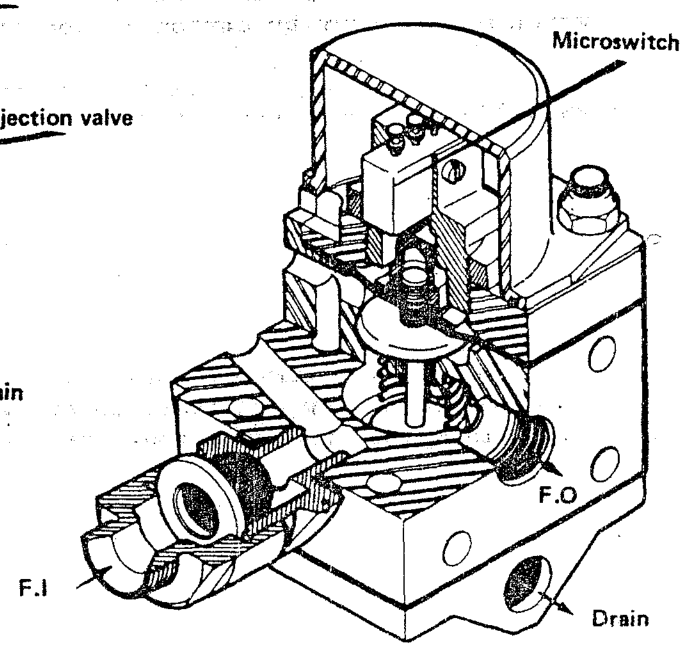
This microswitch is installed at the upper part of the valve assembly. It is actuated by the plunger of the injection valve at the opening of the latter. The electric wiring of the microswitch is incorporated to the driving motor plug.



CUT-AWAY VIEW OF THE PUMP ASSY



CUT-AWAY VIEW OF THE VALVE ASSY



PERSPECTIVE VIEW OF THE VALVE ASSY

FOUR-WAY UNION

The purpose of the four-way union is to ensure the fuel distribution to the torch-igniters.

It consists of a body inside which a single ball rests on its seat by its own weight.

The top of the ball is subjected to the fuel delivery pressure from the micro-pump whereas the lower part is subjected to the P2 compressor pressure. Thus, it allows the passage of fuel towards the igniters when the micro-pump is operating, and the passage of P2 air towards the igniters and towards the micro-pump when the engine is running and the micro-pump is stopped.

A cap screwed on the upper part of the union body allows access to the ball.

VENTILATION SYSTEM

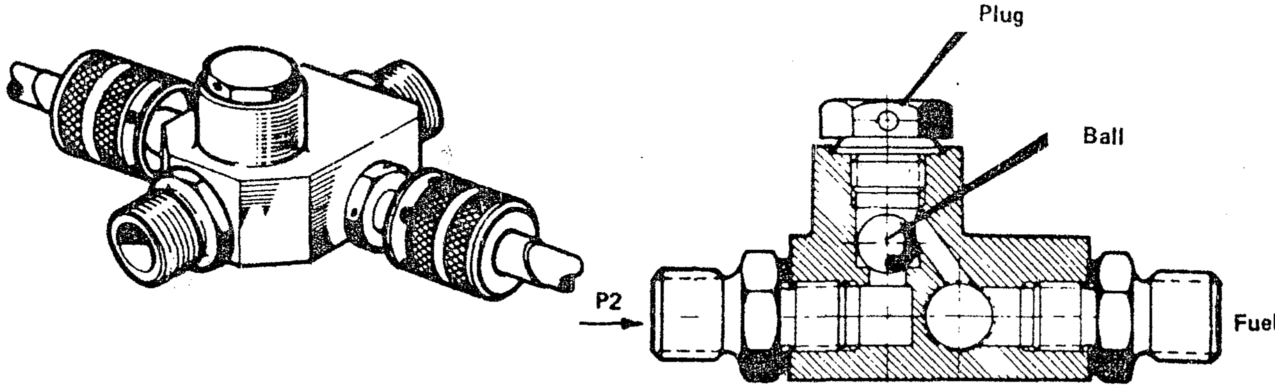
The main purpose of this system is to ensure the ventilation of the torch-igniters.

The ventilation permits to avoid clogging of the igniters which might occur by carbonization of the residual fuel.

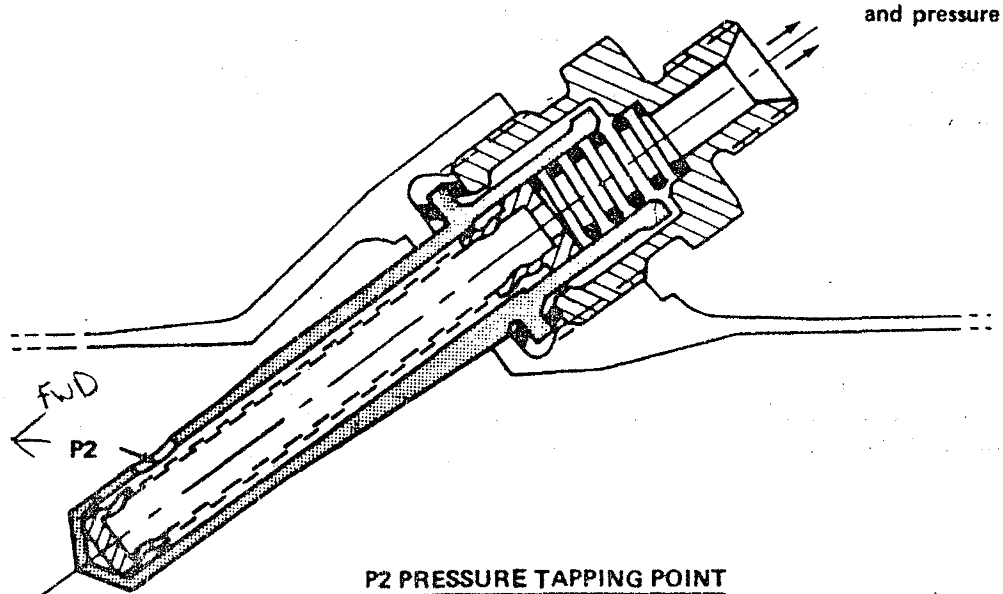
The system is composed of an air tapping point at centrifugal compressor outlet (P2 air) and of a pipe connecting the air tapping point to the four-way union.

The P2 air tapping point is a total pressure tapping ; it includes a filter mounted inside a body (left-handed thread) maintained in position by means of a union screwed on the turbine casing.

It is worthy of note that the P2 air circulation for the ventilation is low and that, in any way, the air is driven back to the combustion chamber through the igniters.



4 WAY UNION



P2 PRESSURE TAPPING POINT

If dirty you can get hot start

TORCH-IGNITERS

They ensure the production of a flame allowing ignition of fuel injected into the combustion chamber during starting.

They are supplied with fuel under pressure through the micro-pump and with high tension current through the ignition coil.

The fuel injection through the igniters is necessary because of the reduced efficacy of the centrifugal injection at low rotation speed and also by reason of the difficulty to ignite the fuel of the injection wheel by using the sparks only.

The igniters are installed on each side of the turbine casing by means of three screws.

The fuel enters through a connection located on the side of the igniter and flows around the body of the latter and through an internal duct ; it is atomized through a jet mounted at the tip of the igniter.

The electric cable of high tension supply current is screwed at the tip of the igniter, the spark is produced at the other end of the igniter between the two electrodes.

IGNITION COIL

The purpose of the coil is to transform the low tension electric current supplied by the battery into high tension electric current required for production of sparks at the tips of the igniters.

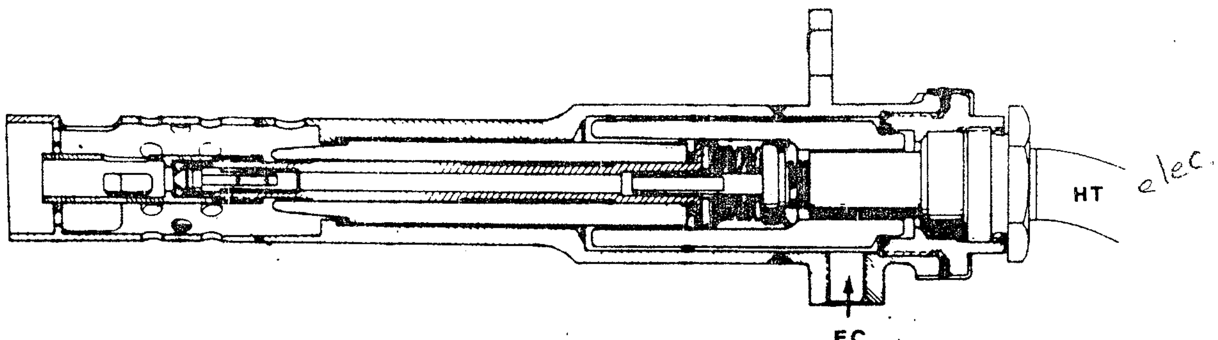
It is a dual coil (one for each igniter) of "high tension" type.

A single coil is composed of : a primary winding, a breaker, a secondary winding and a condenser.

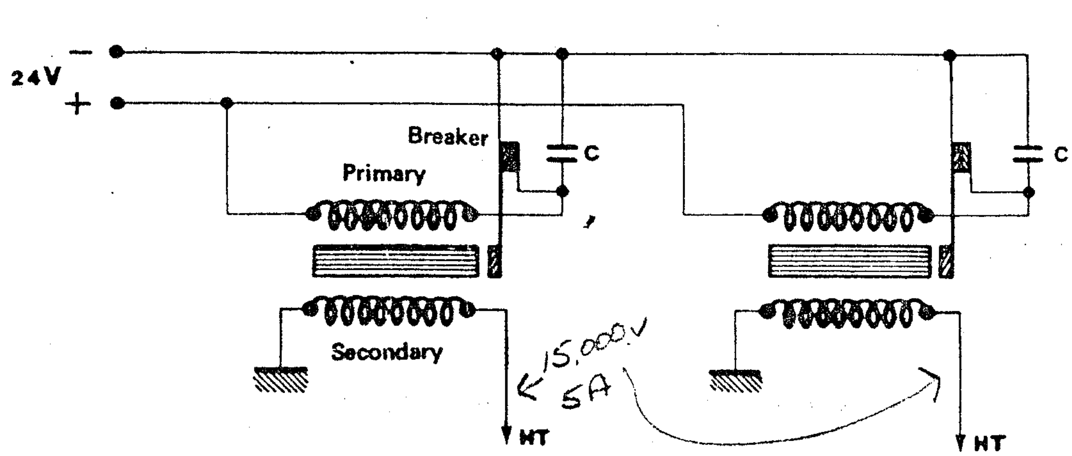
The supply with low tension direct current is made through an electric plug with two pins, and the supply with high tension current to the igniters is made through shrouded cables.

The operation of the coil is dealt with in the chapter "Starting" and in the chapter "Electric system".

Output V = 15,000 V
Intensity = 5 amps.



TORCH IGNITER CUT—AWAY



DUAL IGNITION COIL SCHEMATIC DIAGRAM

OPERATION OF THE IGNITION FUEL SYSTEM

The operation of the ignition fuel system is characterized by the following phases :

- Micro-pump stopped, engine stopped
- Micro-pump draining
- Injection
- Ventilation.

Micro-pump stopped, engine stopped

There is no pressure in the system. Therefore it must be noted that the drain valve is slightly open by means of its spring whereas the injection valve holds this valve closed.

Moreover, the ball of the four-way union rests against its seat by reason of its own weight.

Draining

When the booster pump (aircraft system pump) is operated, the fuel enters the micro-pump and flows through the gears (they are mounted with "clearance").

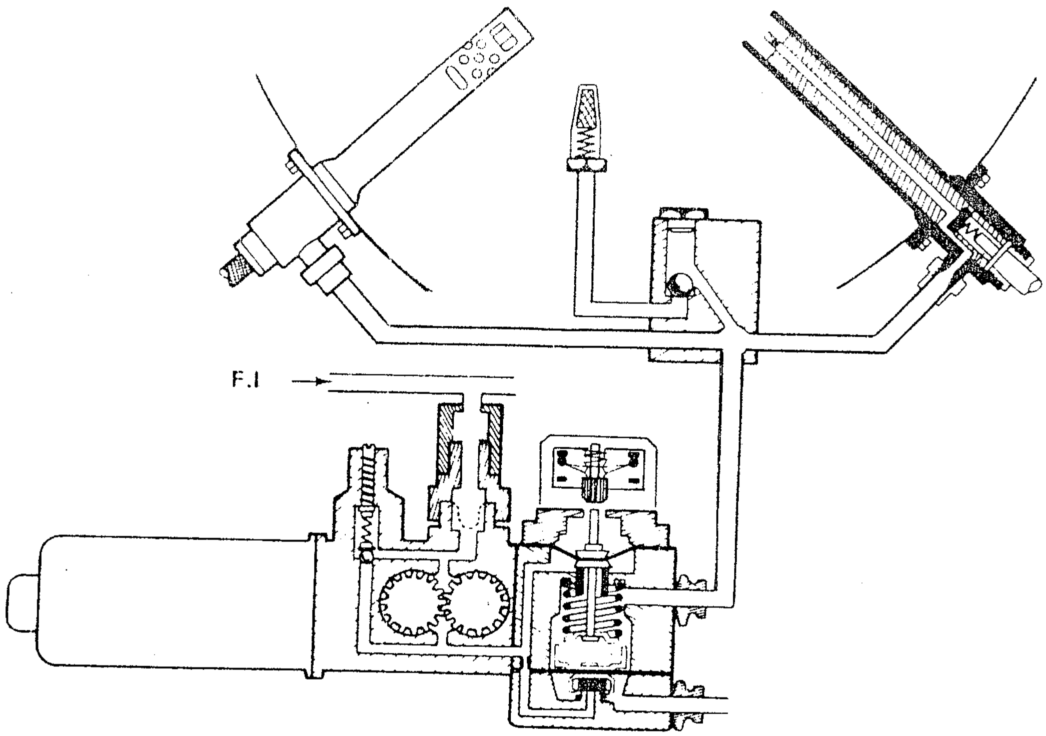
The booster pump pressure acts on the lower face of the injection valve and on the lower face of the drain valve.

This pressure is not sufficient to allow the injection valve opening, but it is sufficient to cause the full opening of the drain valve.

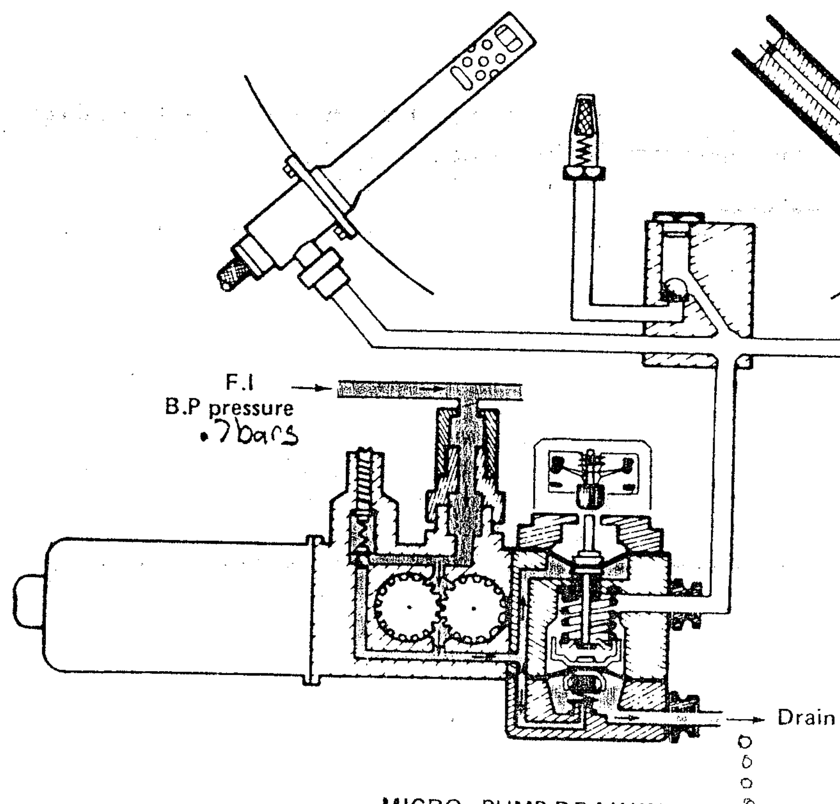
The fuel then flows overboard through the outlet connection and a pipe ; the flow being limited by the calibrated orifice.

The purpose of this phase of operation is to blow out the air which may be present in the system and also to prime the micro-pump.

This draining is necessary for the correct operation of the system, and it is then recommended to actuate the booster pump a certain while before the "starting" selection.



MICRO–PUMP AND ENGINE STOPPED



MICRO–PUMP DRAINING

ground

Fuel injection

The micro-pump being operated, its delivery pressure increases and after about half-a-second it becomes sufficient to cause the injection valve opening.

The fuel then flows between the stem of the valve and its seat, enters the internal chamber, causes the drain valve closing and flows towards the four-way union and the igniters.

Being given that the coil starts operating at the same time as the micro-pump, there are already some sparks and the fuel atomized by the igniters is then ignited. During this phase, the ball of the four-way union prevents the fuel from flowing towards the P2 air tapping.

The injection valve opening causes the action on the microswitch which ensures the supply to the fuel cock and to a warning light. The fuel cock opens and the fuel coming from the main pump flows towards the injection wheel which atomizes it into the chamber. This atomized fuel is then "ignited" by the flame generated by the igniters. There is "ignition" of the flame in the combustion chamber.

When the electric fuel cock is fully open, a "limit-switch" mechanically actuated ensures the supply to a time-delay switch. After a few seconds, this time-delay switch cuts-out the electric supply to the coil, the micro-pump and the warning light. TSA switch

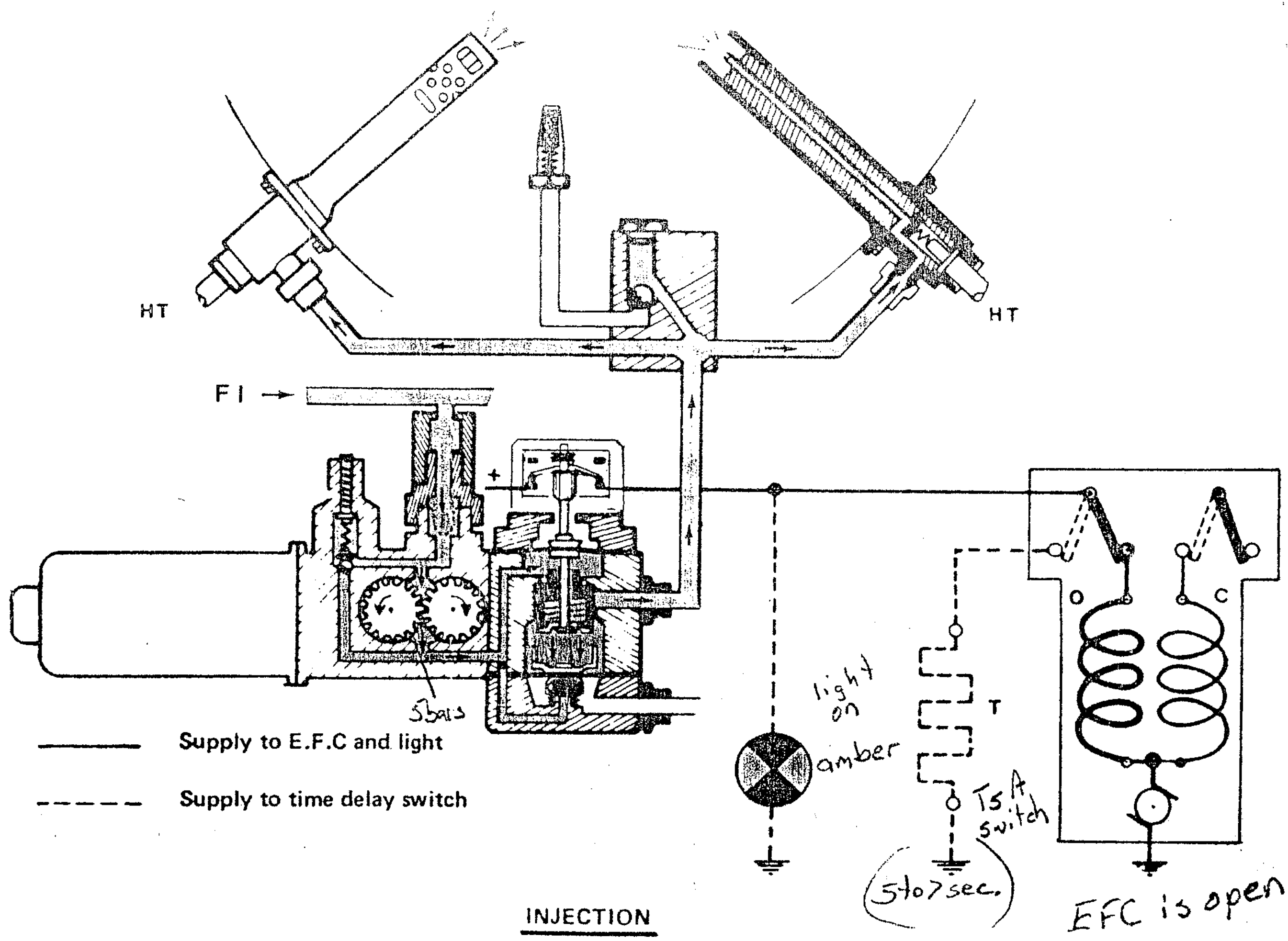
Ventilation

The micro-pump is now stopped and the engine starting continues.

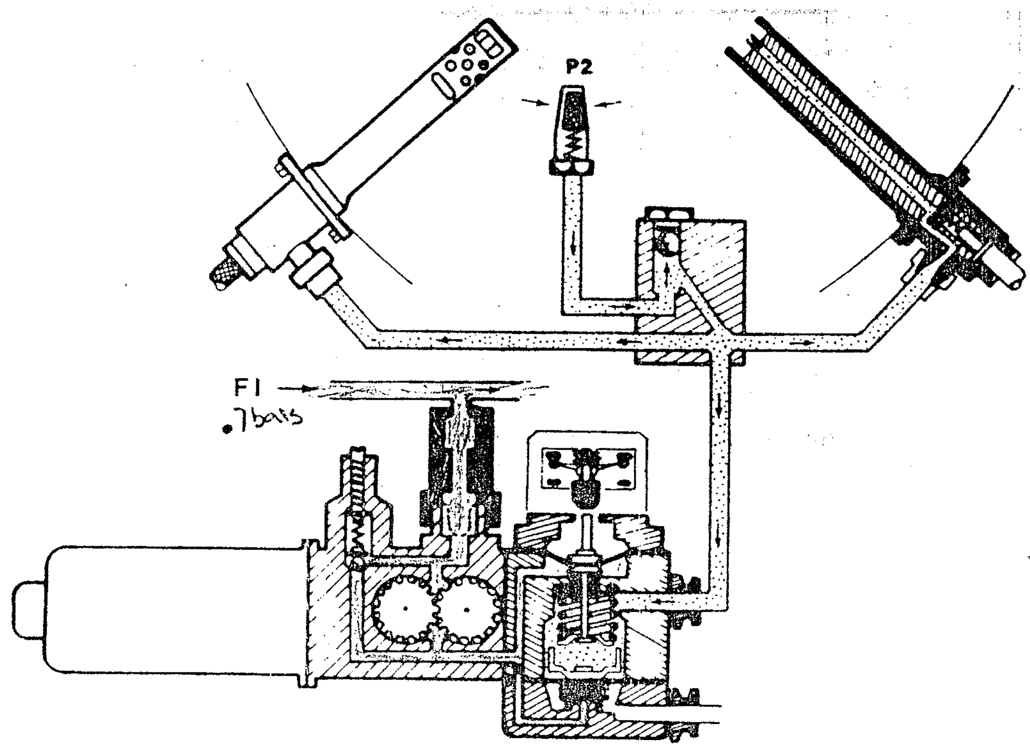
The injection valve closes (under the action of its spring) and there is then no more fuel pressure in the four-way union.

The P2 air pressure then lifts the ball and an air flow is generated towards the igniters (ventilation) and towards the micro-pump (drain valve kept closed).

This phase lasts as long as the engine is running and its main purpose is to prevent the residual fuel carbonization in the igniters.



INJECTION



VENTILATION

MAINTENANCE OF THE IGNITION FUEL SYSTEM

This paragraph deals with the "maintenance" of the system according to the following scheme :

- Characteristics
- Servicing and maintenance
- Check-out procedures and adjustments
- Fault analysis
- Practical works.

Characteristics

- Electrical operating voltage .... 14 to 30 V
- Micro-pump electric motor intensity .... about 5 A
- Micro-pump rotation speed .... about 6,000 RPM
- Max. rotation speed .... 15,000 RPM
- Booster pump pressure .... about 0.5 b
- Micro-pump pressure .... 4 b
- Pressure at microswitch engagement ..... 3 b
- Time to build-up micro-pump pressure ... about 1/2 sec.
- Micro-pump fuel flow .... 80 l/h
- Igniter fuel flow .... 20 l/h
- Ignition coil intensity .... 5 A
- Tension at ignition coil outlet .... 15,000 V
- Time-delay switch operating time .... about 3 sec.

Servicing and maintenance

In service, it is possible to make sure of the correct operation of the system by checking :

- the time to build-up micro-pump pressure,
- the operating time of the ignition accessories,
- the increase in temperature due to the operation of the system.

The periodic maintenance consists in checking the "P2 tapping filter" and the "four-way union ball".

Moreover, there is a method to check the accessories of the ignition fuel system which is described in the chapter "Maintenance" of the manual.

Check-out procedures and adjustments

Micro-pump pressure check

The check-out procedure consists in connecting a pressure gauge at the fuel outlet, in operating the micro-pump and in checking the pressure indicated.

Micro-pump pressure adjustment

Previous to adjust carry out the pressure check-out procedure.

The adjustment is carried out on the adjusting screw of the pressure relief valve ; screw in to increase pressure.

Adjustment of the micro-pump microswitch

Can only be carried out by means of a special installation.

Adjustment of the ignition coil intensity

This adjustment is possible only with a special installation.

Check of the 4-way union ball sealing

Disconnect the P2 inlet connection, operate the micro-pump and check for leaks.

Fault analysis

The fault analysis is carried out for "training purposes" mainly. It consists in searching for the symptoms and effects of a given fault. The following analysis does not intend to be exhaustive, but it considers the most characteristic cases.

Micro-pump electric motor faulty

In this case, there is of course no "pressure building up", no fuel towards the igniters, no fuel cock opening, no rise in t4 temperature, and starting is not possible.

Micro-pump delivery pressure too low.

If the pressure is not sufficient to cause the injection valve opening, same symptoms as for the above case.

If the pressure is sufficient to cause the valve opening, this may give rise to a difficult ignition, which leads to a slow start or to an impossibility to start.

Micro-pump delivery pressure too high

The peak in t4 at starting may be too high.

Microswitch jammed in "resting" position (i.e. not engaged)

There is then a rise in t4 due to the operation of the igniters (although a slight one) but no electrical supply for fuel cock opening. The yellow light does not turn ON and start is not possible.

Microswitch jammed in "working" position (i.e. remains engaged)

The electric fuel cock opens before the proper time, which may lead to a t4 too high during starting.

Faulty sealing of the four-way union ball

During the ignition phase, the fuel flows towards the P2 air tapping point and this excess leads to a t4 too high at the beginning of starting.

Faulty operation of an igniter

Engine starting is "possible" on a single igniter, but the starting "speed" is affected (slower start).

Ignition coil faulty

There is no generation of high tension current, no sparks and consequently no ignition.

A too low tension of the coil may cause an abnormal rise in t4 (insufficient spark in a first phase, then sudden ignition of the fuel accumulated).

Air entering the fuel system through the micro-pump

If the air enters the fuel system, this may cause, according to the quantity of air : false starting, overheating, rotation speed fluctuations.

Practical works

- Locating of accessories and of the system
- Check-out procedures and adjustments
- Removal and installation of the accessories
- P2 filter removal
- Removal of the four-way union ball
- Demonstration on test bench.

INTRODUCTION

The essential purpose of the main fuel system is to ensure the fuel supply and the fuel flow control in all operating conditions.

It consists of the following components :

- The pump assembly including :
  - the gear pump
  - the pressure relief valve
  - the "by-pass" calibrated orifice
  - the fuel control valve
  - the safety microswitch.
- The idling device
- The starting fuel valve
- The electric fuel cock
- The isochronous speed governor
- The starter cut-out switch
- Pipes
- The internal fuel system.

The study of the operation of the system induces to consider the following phases :

- operation during starting
- operation during acceleration
- "normal" operation (fuel flow control)
- operation during stopping.

The operation of the assembly is considered after the detailed study of each component of the system.

The phase of "normal" operation (or fuel flow control) is covered in a special chapter.

GENERAL DESCRIPTION

The fuel pump assembly

It ensures the fuel supply to the engine and it consists of the following components incorporated in a same unit :

The pump itself : it is a "gear type" pump driven by a pinion of the accessory drive lower train.

The fuel pressure relief valve : its purpose is to maintain practically constant the pump delivery pressure.

The "by-pass" calibrated orifice : it limits the pump fuel flow at low rotation speeds (i.e. during starting).

The fuel control valve : it is a progressive valve mechanically controlled by the pilot's lever. It allows the engine acceleration after starting and the return to idling speed before engine stopping.

The safety microswitch : this microswitch is mechanically actuated by the control lever. It prevents starting if the fuel control valve is not fully closed.

The idling device

The purpose of this device is to control the fuel flow required to obtain idling speed.

The starting fuel valve

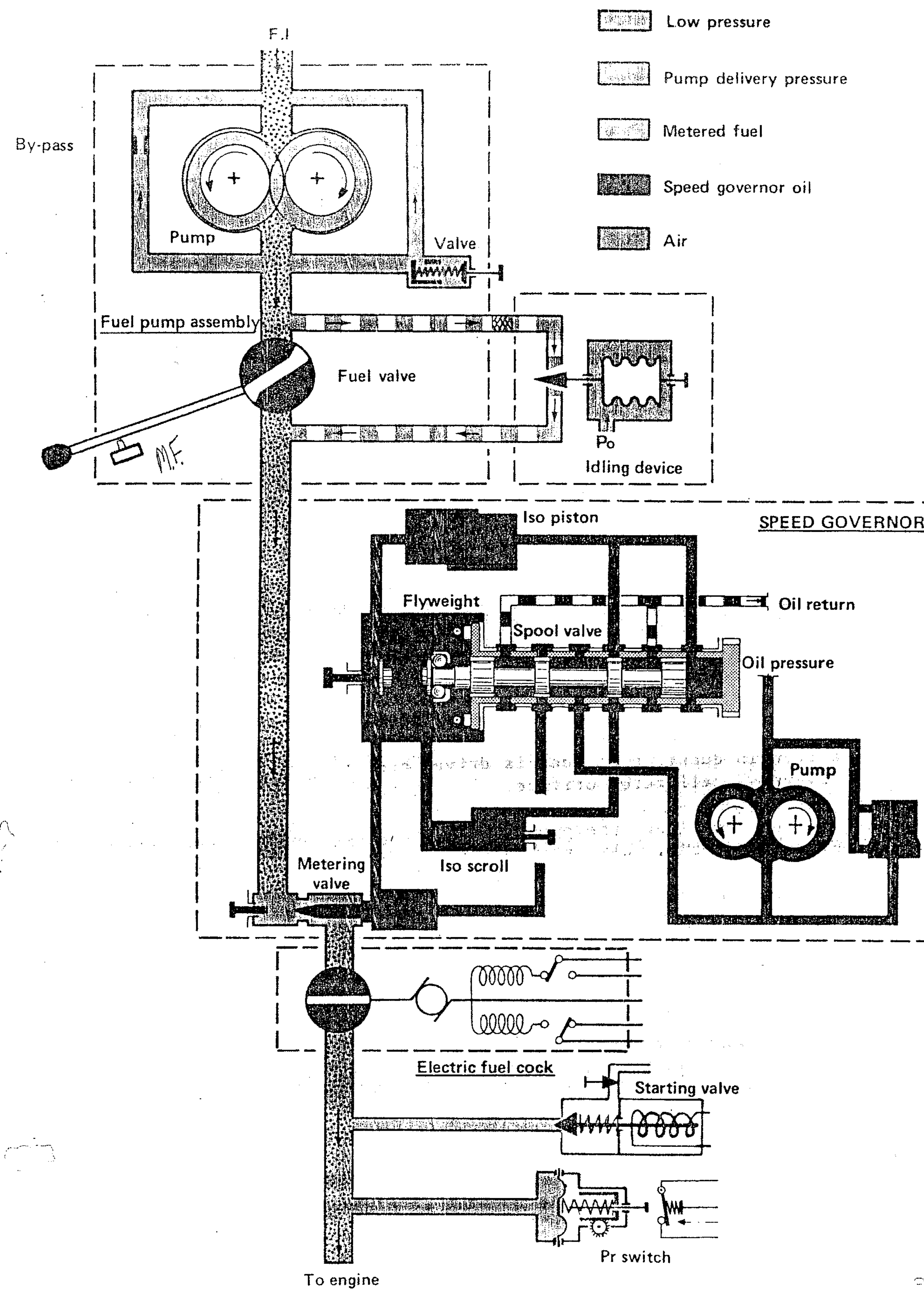
Its purpose is to decrease the fuel flow during the starting initial phase, by creating a fuel escape overboard.

The electric fuel cock

Fuel cut-off valve allowing starting and stopping. It is electrically controlled by means of an electric motor.

The speed governor

The speed governor meters the fuel flow in order to obtain a constant rotation speed.



FUEL SYSTEM SCHEMATIC DIAGRAM

FUEL PUMP ASSEMBLY

INTRODUCTION

The assembly ensures the engine supply with fuel under pressure. It is composed of :

- the gear pump
- the pressure control valve
- the "by-pass" calibrated orifice
- the fuel control valve
- the safety microswitch.

OPERATION

Operation during starting

The control lever is on "start" and the fuel control valve is fully closed.

As soon as the pump is driven by the engine (cranking phase), it begins ensuring a flow and increasing its delivery pressure.

The fuel flows through the idling device and towards the engine as soon as the electric fuel cock is opened.

The delivery pressure being low, the pressure control valve is fully closed. The fuel flow of the pump itself being then too high, a certain quantity of fuel is driven back to pump inlet through the "by-pass" calibrated orifice.

When the pump delivery pressure becomes sufficient, the pressure control valve starts operating, and from that time controls a practically constant pressure. The valve starts operating a short time before the idling speed.

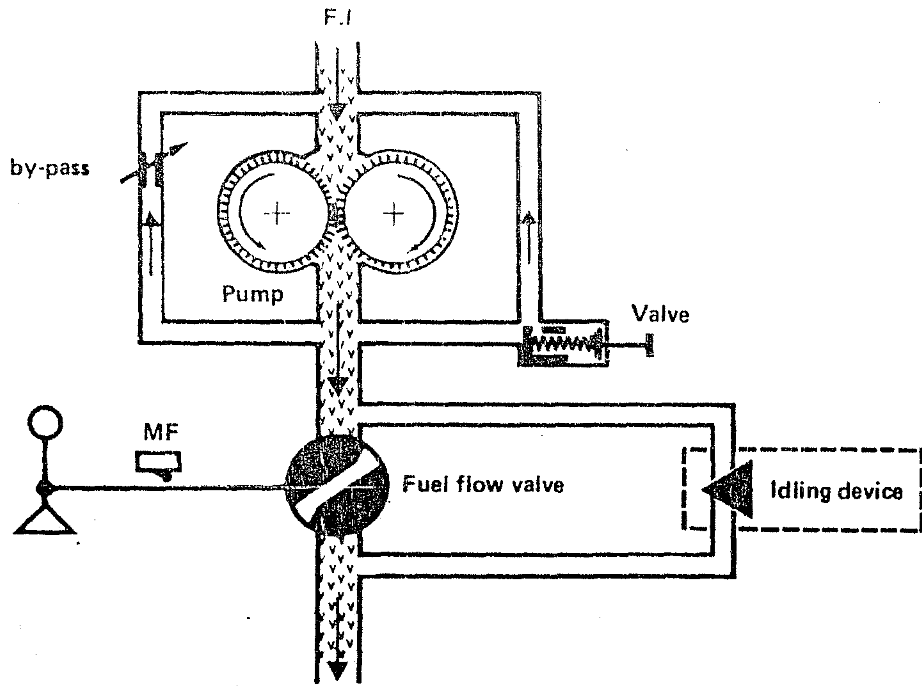
At the end of starting, the speed becomes stabilized at a speed determined by the fuel flow controlled by the idling device.

Acceleration

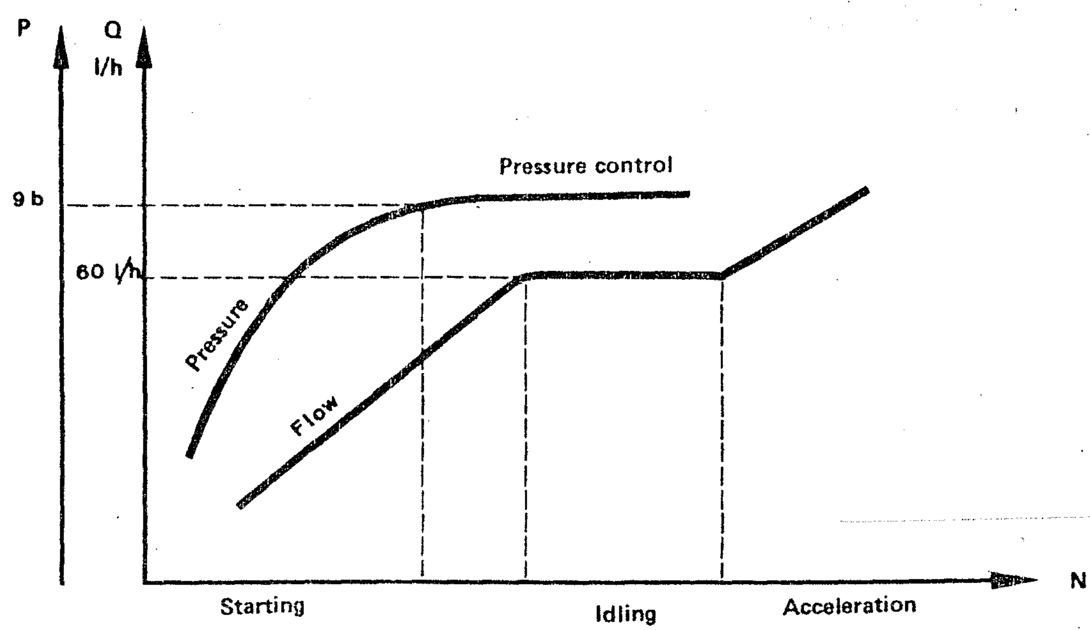
Moving the control lever causes the fuel control valve opening and consequently the increase in fuel flow and the speed acceleration.

Normal operation

The pump rotates at a constant speed and it is able to deliver a flow higher than the one required by the engine ; the excess fuel is driven back to pump inlet by the pressure control valve.



FUEL PUMP ASSEMBLY SCHEMATIC DIAGRAM



PUMP FUEL FLOW AND PRESSURE CURVE

DESCRIPTION OF THE PUMP ASSEMBLY

The pump unit is mounted on the external set of oil pumps by means of four screws. Its driving shaft is connected to the driving shaft of the oil pumps by means of a toothed sleeve.

It incorporates :

- the pump body
- the valve body
- the microswitch.

Pump body

The pump consists of a driving pinion and two driven pinions included in a body of light alloy. The sealing on the driving shaft is carried out by means of a "simrit" type seal.

It is assembled with the pump body, after placing a paper gasket, by means of four screws which secure the assembly on the external set of oil pumps.

The fuel control valve consists of a hollow shaft, an end of which rests against the fuel deviation block forming a diaphragm, and the other end is rotated by the control lever.

The pressure control valve consists of a valve subjected to the fuel pressure on one side, and to the force of a spring with adjustable tension on the other side.

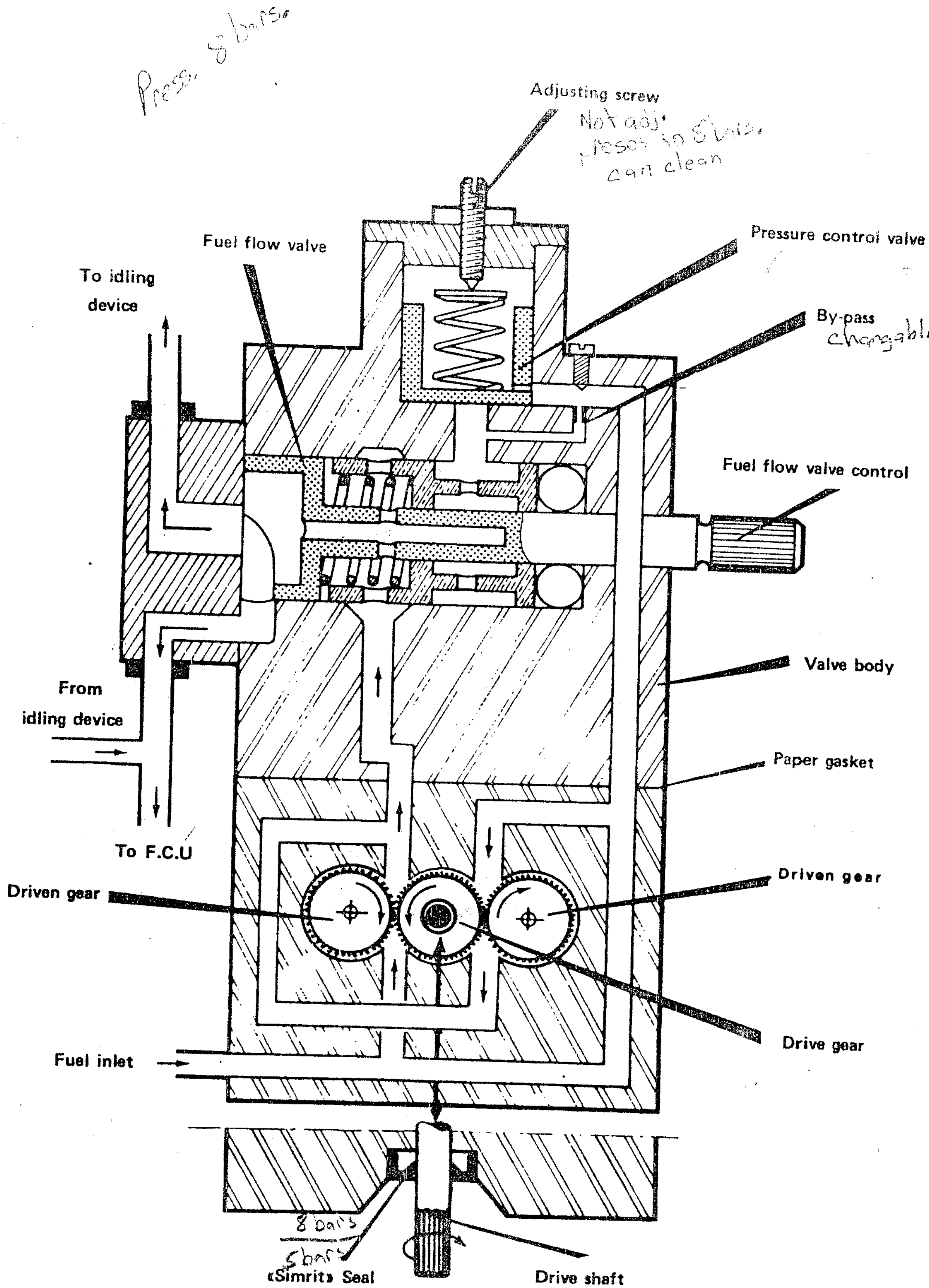
The "by-pass" calibrated orifice is a jet screwed in the valve body. It is accessible through a cap.

Microswitch

The microswitch is located in a box secured by means of a plate on the valve body.

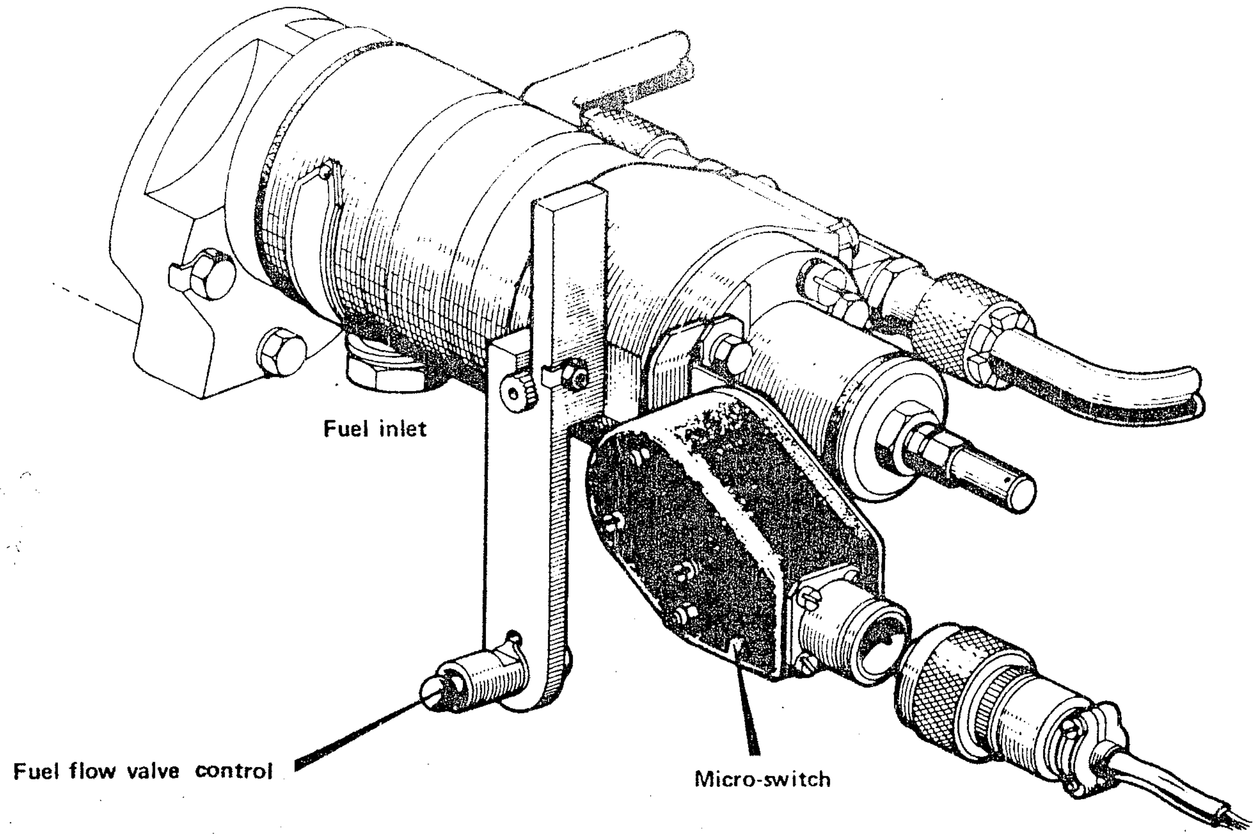
An electric plug with two pins permits the connection of the microswitch to the automatic control box.

The microswitch is controlled by a plunger actuated by the control lever of the fuel control valve.

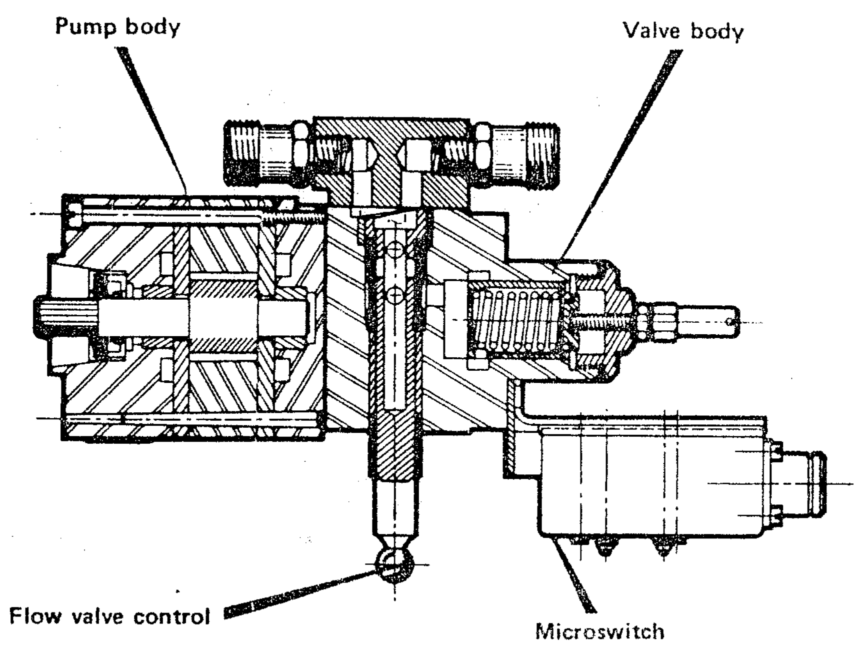


failure of seal will cause oil dilution

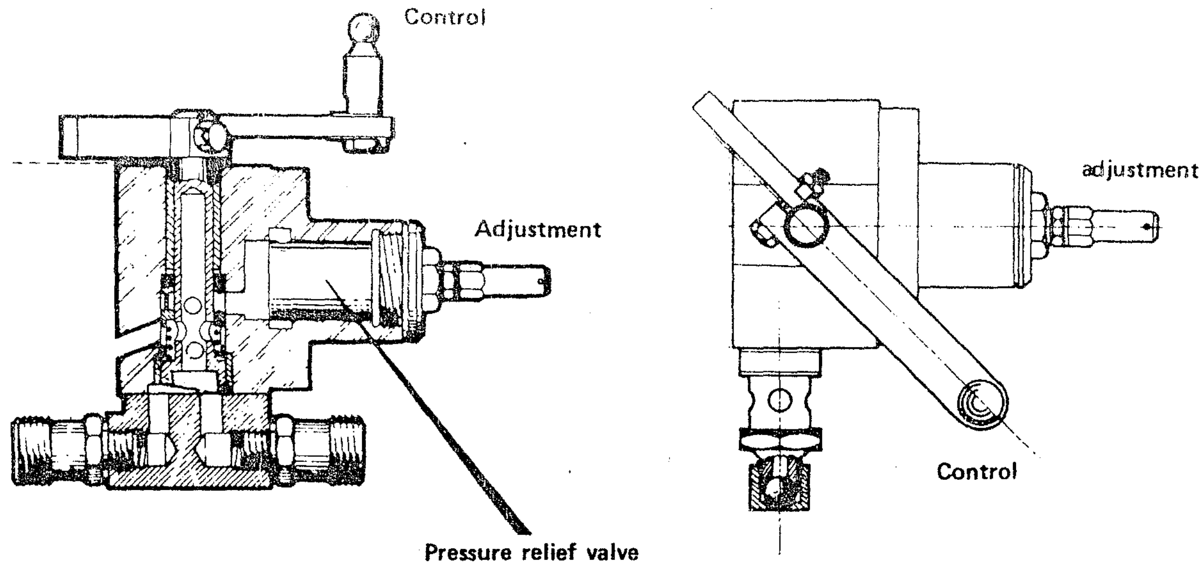
FUEL PUMP SCHEMATIC CUT-AWAY



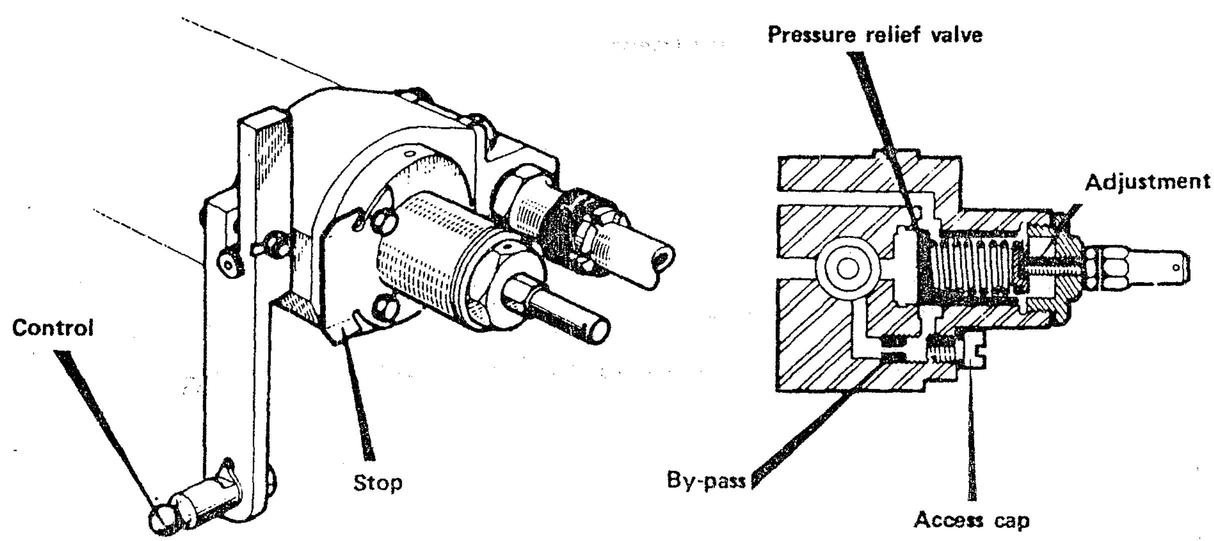
FUEL PUMP EXTERNAL VIEW



FUEL PUMP CUT—AWAY



VALVE BODY—EXTERNAL VIEW AND CUT—AWAY



VALVE BODY— EXTERNAL VIEW AND CUT—AWAY

MAINTENANCE OF THE PUMP ASSEMBLY

Characteristics

- Booster pump pressure .... about 0.5 b
- Engine pump pressure .... 8 b
- Pump rotation speed .... SIH. N/10,370
- "By-pass" flow ....
- Idling fuel flow .... about 60 l/h

Servicing and maintenance

In service, it is possible to make sure of the correct operation of this assembly by checking the engine parameters.

It is recommended to carry out the acceleration by the lever of the fuel control valve quite "slowly".

Check-out procedures and adjustments

Control lever check

This check consists in making sure of the complete free movement of the fuel control valve control lever.

Sealing check

Either during a ground run, or by using the booster pump pressure (refer to "Maintenance" chapter).

Pump pressure adjustment

This adjustment which is carried out on the adjusting screw of the pressure control valve is strictly forbidden in field maintenance. However it is possible to remove the valve without disturbing the adjustment.

Pump "by-pass" adjustment

It is not a properly called adjustment, but the jet may be replaced to adjust the starting t4 temperature. The jet diameter must remain within well determined limits.

Fault analysis

Driving shaft seal faulty

There is passage of fuel into the accessory drive casing ; i.e. passage of fuel into oil. It is possible to replace the seal.

Booster pump pressure

In "normal" operation the booster pump pressure does not affect the engine notably (engine running is of course possible without booster pump).

During starting however, the booster pump pressure has a great influence on the starting "speed" (particularly the t4 temperature). As a rule, starting is not possible without booster pump.

Obstruction of the pump "by-pass"

The pump flow at low rotation speed is too important ; there is a risk of too high a t4 temperature.

Pressure control valve jammed

If the valve is jammed "open", most of the pump flow is driven back to pump inlet and there is not enough flow to ensure engine operation.

If the valve is jammed "closed", there is too high a flow, which risks to cause : too quick an acceleration, surging, overheating.

Fuel control valve faulty sealing (i.e. passage of fuel even when the valve is closed).

There is then an extra fuel flow during starting which risks to cause a high t4.

Note

The main purpose of this fault analysis is to permit a better knowledge of the system and to prepare the trainee for the "reasoning mechanism" ensuring a quick fault finding.

Therefore it must not be assumed that all these faults are likely to occur.

Practical works

- Locating of the components
- Check-out procedures and adjustments
- Removal and installation
- Disassembly of the pump drive shaft seal
- Replacement of the paper gasket
- Removal of the by-pass
- Removal of the pressure control valve.

IDLING DEVICE

INTRODUCTION

The idling (or starting) device permits the engine supply during the starting phase (fuel control valve closed) and the governing of the idling speed.

DESCRIPTION

The device is composed of an aneroid capsule subjected to the Po air pressure and of a fuel metering valve actuated by the distortions of the capsule.

The capsule is provided with a screw which permits the adjustment of the idling fuel flow. A device of "ball locking" type locks the screw every fraction of a turn.

The fuel outlet connection is provided with a filter of "strainer" type.

OPERATION

During the engine starting phase, the fuel control valve is fully closed.

The fuel delivered by the pump then flows towards the engine through the idling device (by-pass of the fuel valve).

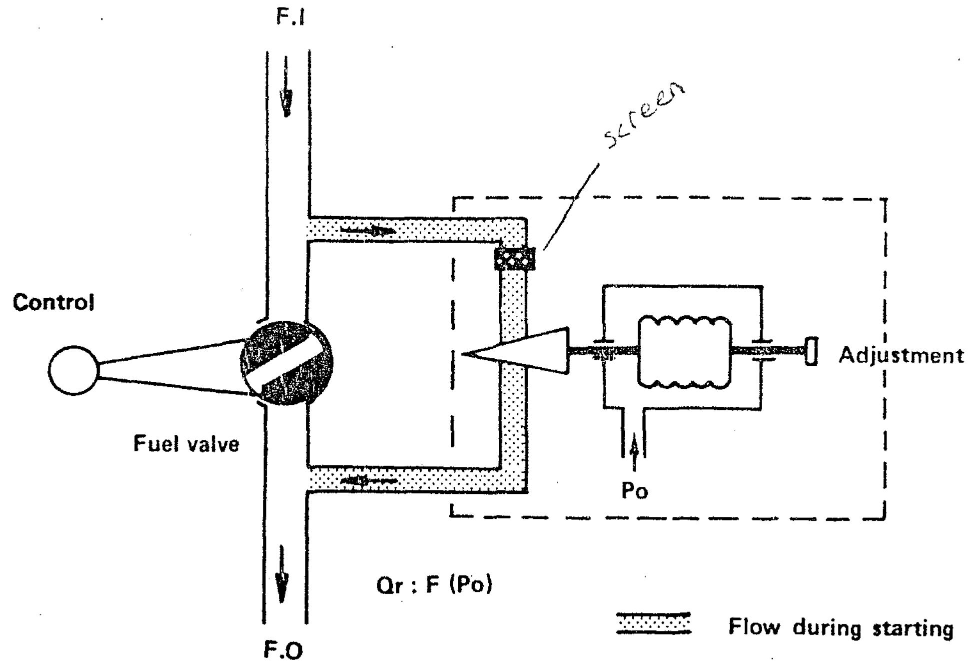
In "normal" operation the fuel control valve is opened and the fuel flows through the fuel control valve without passing through the idling device.

Case of Po variations

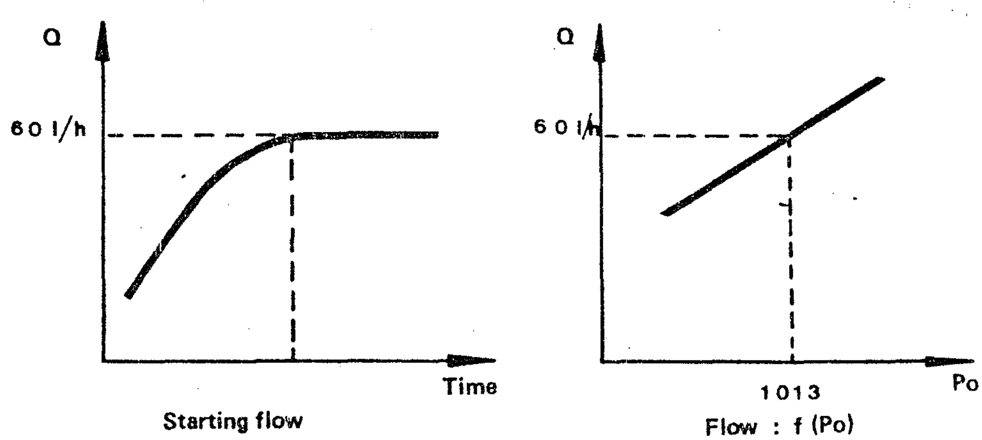
When the atmospheric pressure (Po) increases, the capsule is distorted and it controls the metering valve "opening" and consequently the increase in idling fuel flow.

When the Po pressure decreases, the distortion of the capsule controls the displacement in the metering valve "closing" direction, and consequently the decrease in idling fuel flow.

Thus the idling rotation speed remains practically constant for different atmospheric pressures.



IDLING DEVICE SCHEMATIC DIAGRAM



FUEL FLOW CURVE OF THE DEVICE

MAINTENANCE OF THE IDLING DEVICE

Characteristics

15 l/h.

- Flow in standard atmosphere .... about 60 l/h
- Max. fuel flow limit .... 68 l/h
- Min. fuel flow limit ....
- Idling rotation speed .... 18,500 RPM ± 1,500

16,000 – 19,000 rpm

Servicing

In service, check the gas temperature during starting and the idling rotation speed (check the idling rotation speed with engine "warm").

Adjustment

Idling speed adjustment

Prior to undertake adjustment, inspect the fuel inlet filter.

Act on the adjusting screw of the capsule by fraction of turn ; screw in to decrease the fuel flow.

If the adjustment is required by a difficulty to start, begin the procedure by increasing the fuel flow (do not forget that the idling fuel flow metering also affects the starting "speed").

The adjustment may be carried out with engine in operation ; the idling speed check must be carried out with engine "warm".

Fault analysis

Capsule rupture

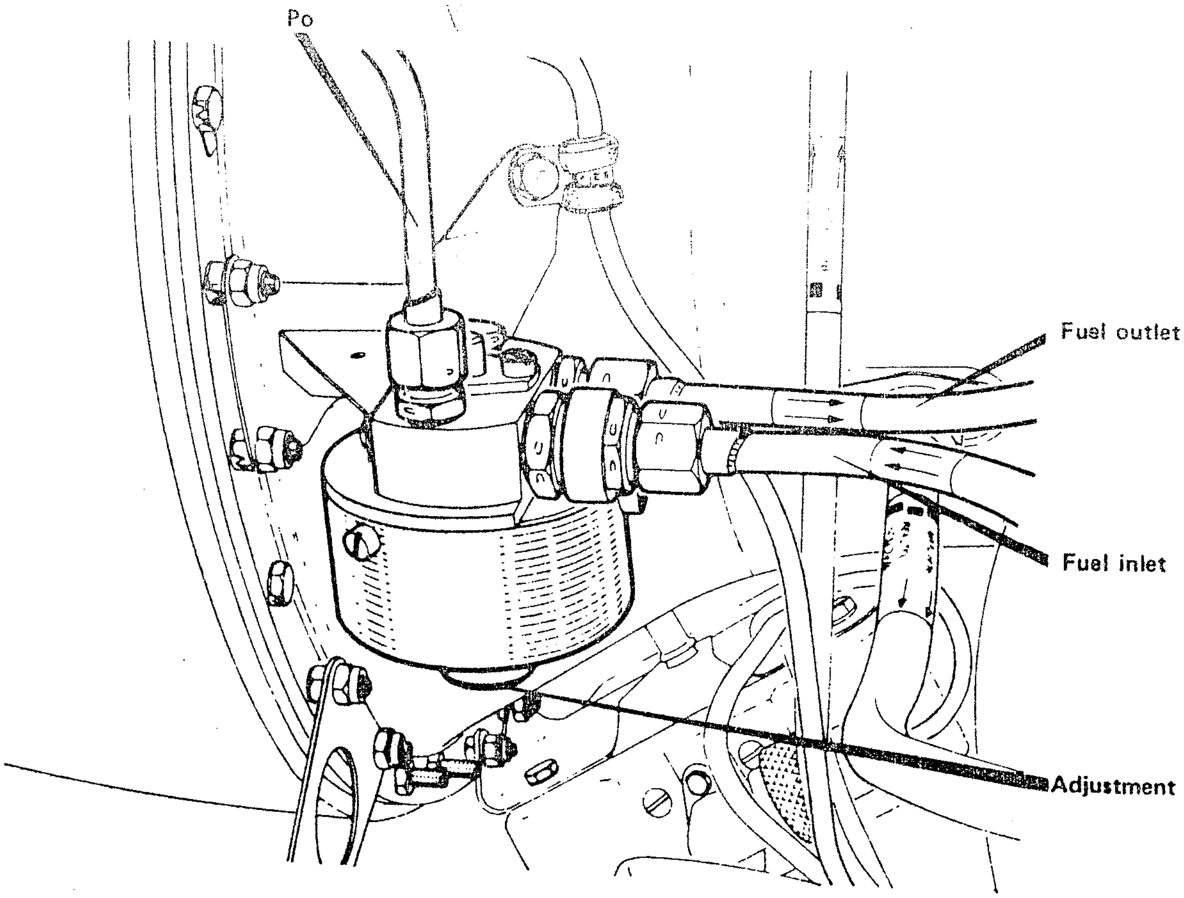
The metering valve takes the position fully closed, the fuel flow is not sufficient to perform starting.

Obstruction of the metering valve (or of the filter)

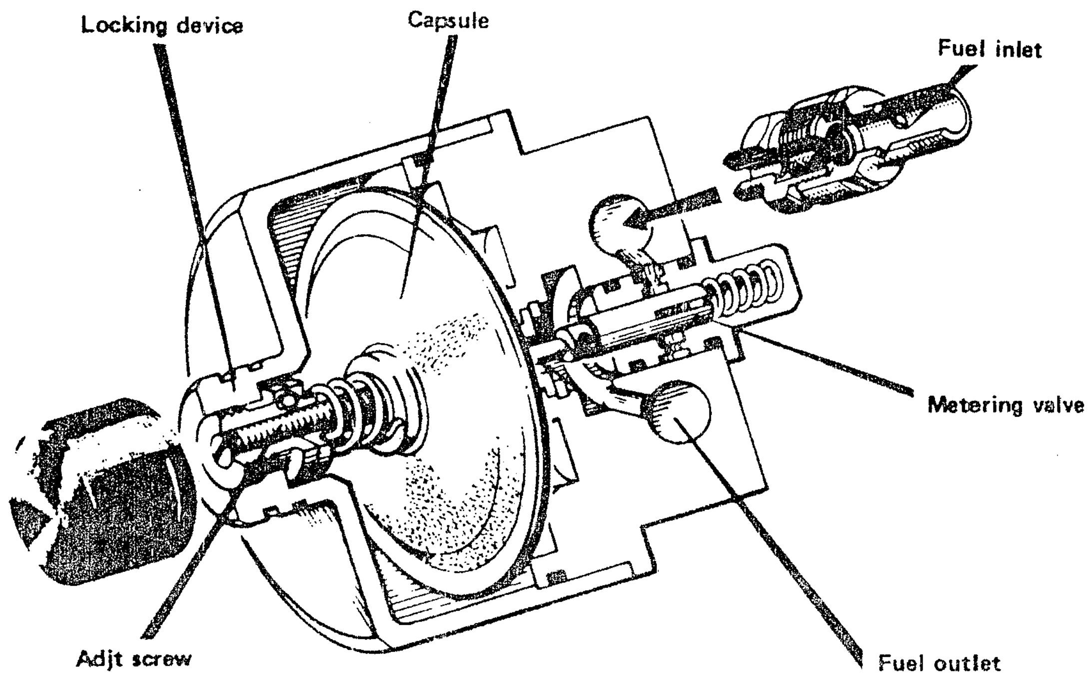
Insufficient fuel flow ; slow starting or even impossible starting (according to the amount of clogging).

Maintenance works

- Locating
- Adjustment
- Removal and installation
- Fuel filter inspection.



IDLING DEVICE–EXTERNAL VIEW



IDLING DEVICE – PERSPECTIVE CUT AWAY

STARTING VALVE

INTRODUCTION

The purpose of the starting fuel valve is to limit the gas temperature during starting.

It ensures this function by draining overboard a determined quantity of fuel.

DESCRIPTION

It consists of an electro-magnet which controls the fuel "spill valve".

An adjusting screw located on valve downstream allows the modification of the amount of draining.

OPERATION

On "starting" selection, the electro-magnet is electrically supplied together with the ignition coil and the micro-pump.

The electro-magnet controls the valve opening and a part of the fuel supplying the engine is drained overboard.

When the ignition phase is over, the electro-magnet is no longer supplied and the valve closes, and then cancels the draining.

MAINTENANCE

Characteristics

The time of electro-magnet electrical supply is the same as that of the ignition coil and of the micro-pump. The required intensity is low.

Check-out procedure, adjustment

It is possible to check the correct operation by watching the draining during a start.

The adjusting screw allows the modification of the amount of spillage, i.e. the t4 gas temperature during the ignition phase ; screw down to ~~decrease~~ increase temperature.

Fault analysis

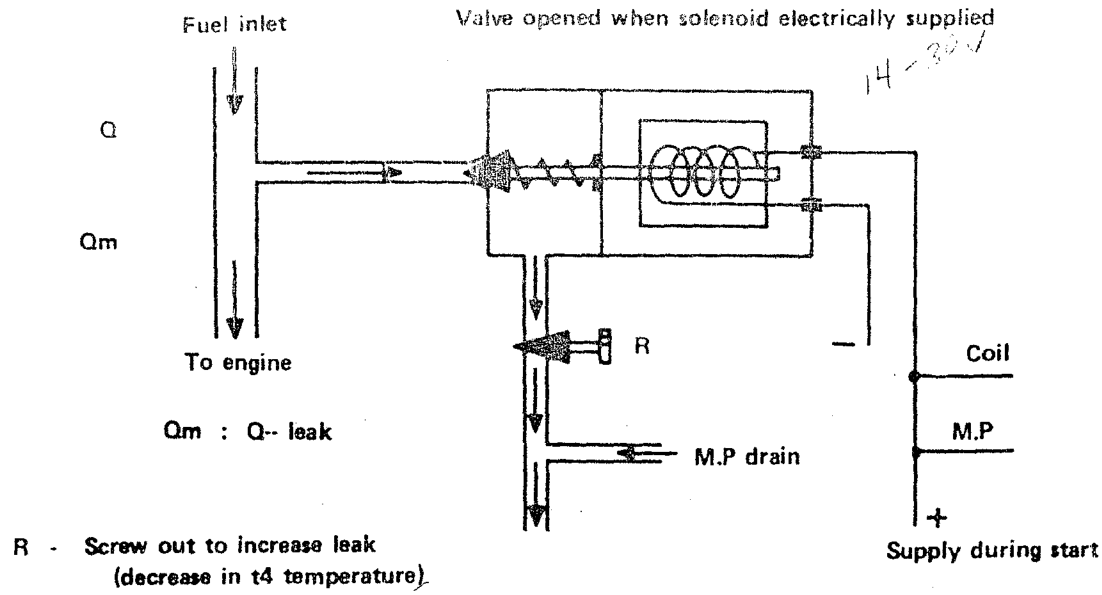
Faulty operation of the electro-magnet

There is no draining, then a risk of too high a t4.

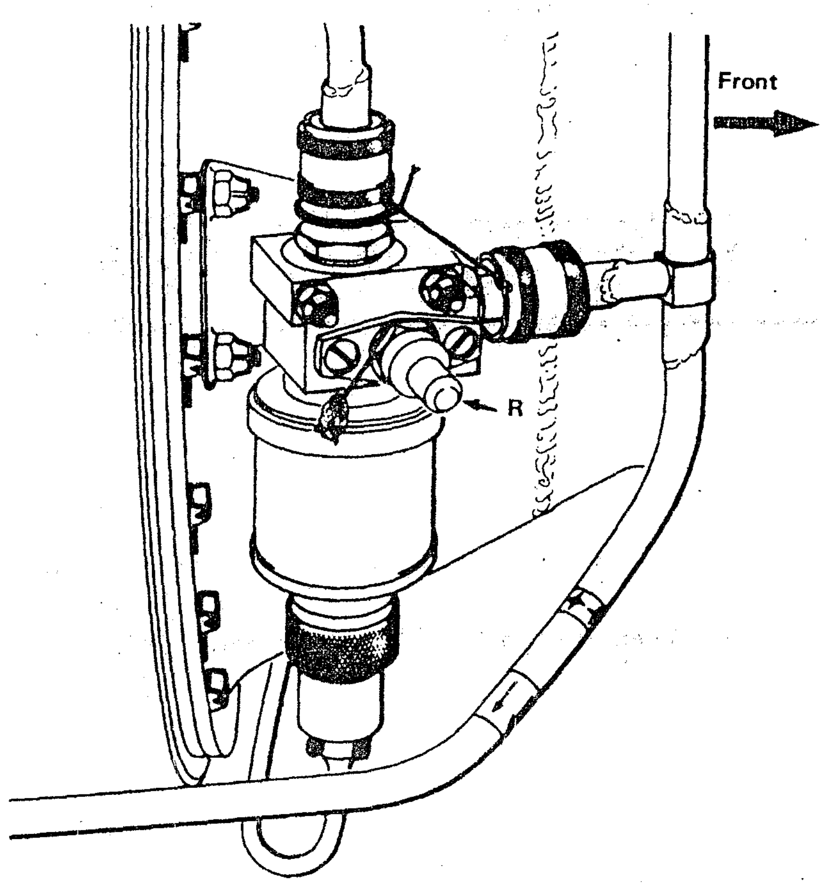
Valve out of adjustment

Insufficient or too important draining, i.e. difficult start or too warm start.

Practical works :
- Locating
- Adjustment
- Check
- Removal and installation.



STARTING VALVE SCHEMATIC DIAGRAM



VALVE EXTERNAL VIEW

ELECTRIC FUEL COCK

INTRODUCTION

The purpose of the electric fuel cock is to ensure the fuel opening or closing for engine starting and stopping.

DESCRIPTION

The electric fuel cock assembly consists of an "open-close" valve and of an electric actuator.

The actuator incorporates : an electric motor with two windings, a reduction gear, a visual indicator, two "limit-switches" and an electric plug with 5 pins.

The cock itself is a rotating valve driven by the actuator. The rotating valve sealing in its body is made by means of "O'rings".

OPERATION

Engine starting

Before starting, the fuel cock is in position "closed" (starting is not possible when the cock is opened).

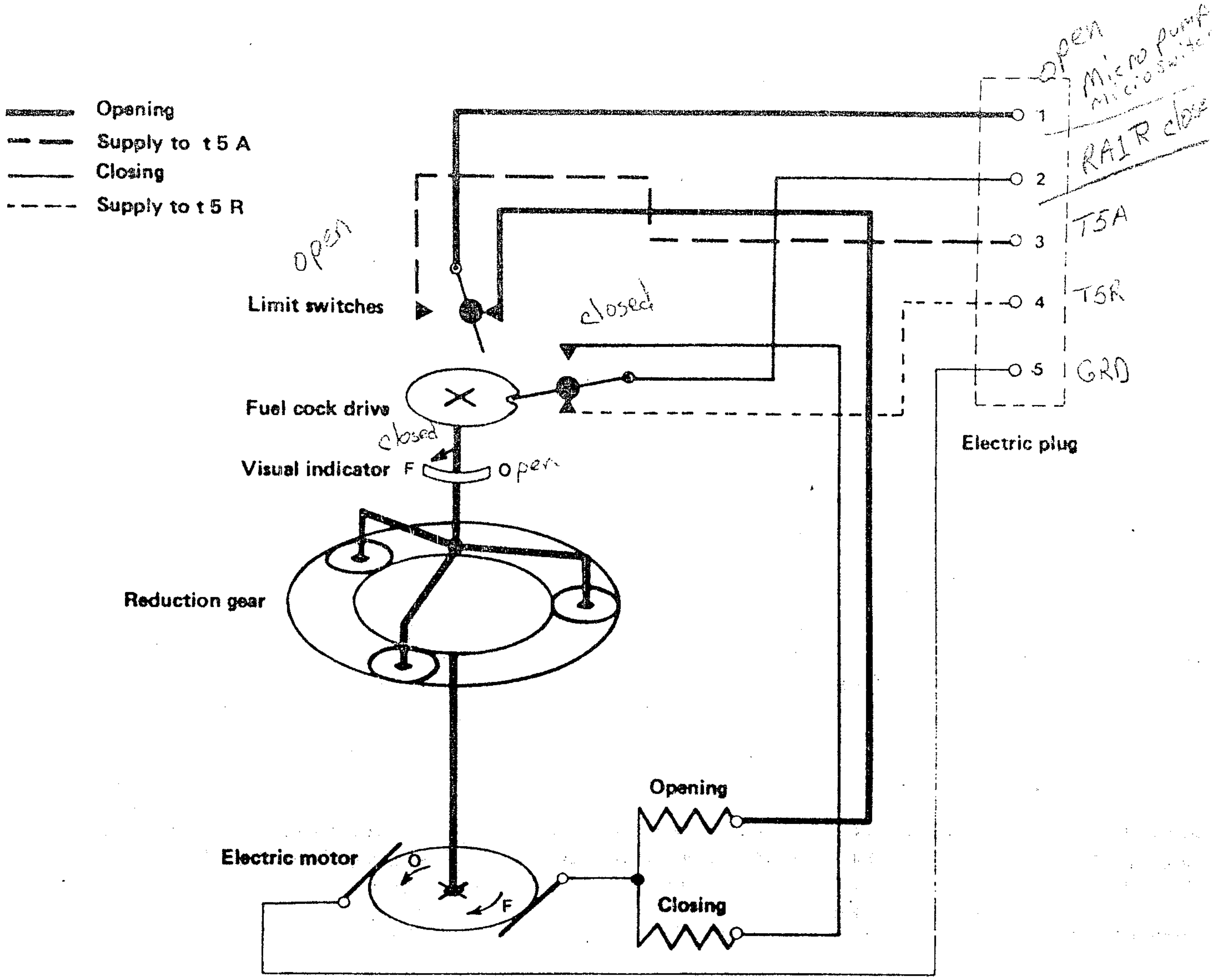
When the micro-pump builds-up, its microswitch allows the supply to the actuator "opening" coil. The electric motor drives the control cam by means of the reduction gear, and the cam controls the valve opening and the tripping of the "limit-switches".

When the cock is fully opened, the "opening limit-switch" cuts-out the supply to the actuator and ensures the supply to a time-delay switch located in the "automatic control box". The purpose of the time-delay switch is to cut-out the supply to the ignition accessories after a few seconds.

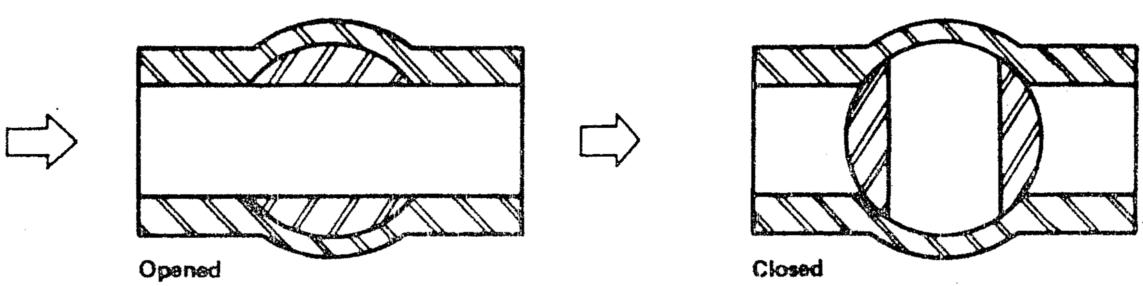
Engine stopping

The selection "stop" of engine causes the supply to the actuator closing coil. The electric motor starts operating (reverse rotating direction), and causes the closing of the valve and the tripping of the contacts by means of the reduction gear and of the cam.

When the cock is fully "closed", the closing limit-switch cuts-out the supply to the coil of the actuator and ensures the supply to another time-delay switch whose purpose is to "reset" the electric circuit.



ACTUATOR SCHEMATIC DIAGRAM



FUEL VALVE SCHEMATIC DIAGRAM

MAINTENANCE OF THE ELECTRIC FUEL COCK

Characteristics

- Supply voltage of the actuator .... 14 to 30 V
- Intensity taken .... 5 A
- Opening (or closing) time .... about 1/2 sec.

Servicing and maintenance

In service, the operation is indicated by the panel warning lights (fuel cock light : yellow). The check can also be made by the visual indicator located on the side of the fuel cock.

Fault analysis

No operation in the opening direction

Of course, the starting is not possible ; the fault is indicated by the engine indicating instruments (yellow light).

No operation in the closing direction

The normal stop of the engine is not possible ; it is then necessary to stop the engine by means of the fuel shut-off valve of the aircraft system.

Internal leaks

In this case, there is passage of fuel even when the cock is closed. The fault leads to a risk of overheating during starting and to a risk of impossibility to stop the engine normally.

Air entering the system through the valve

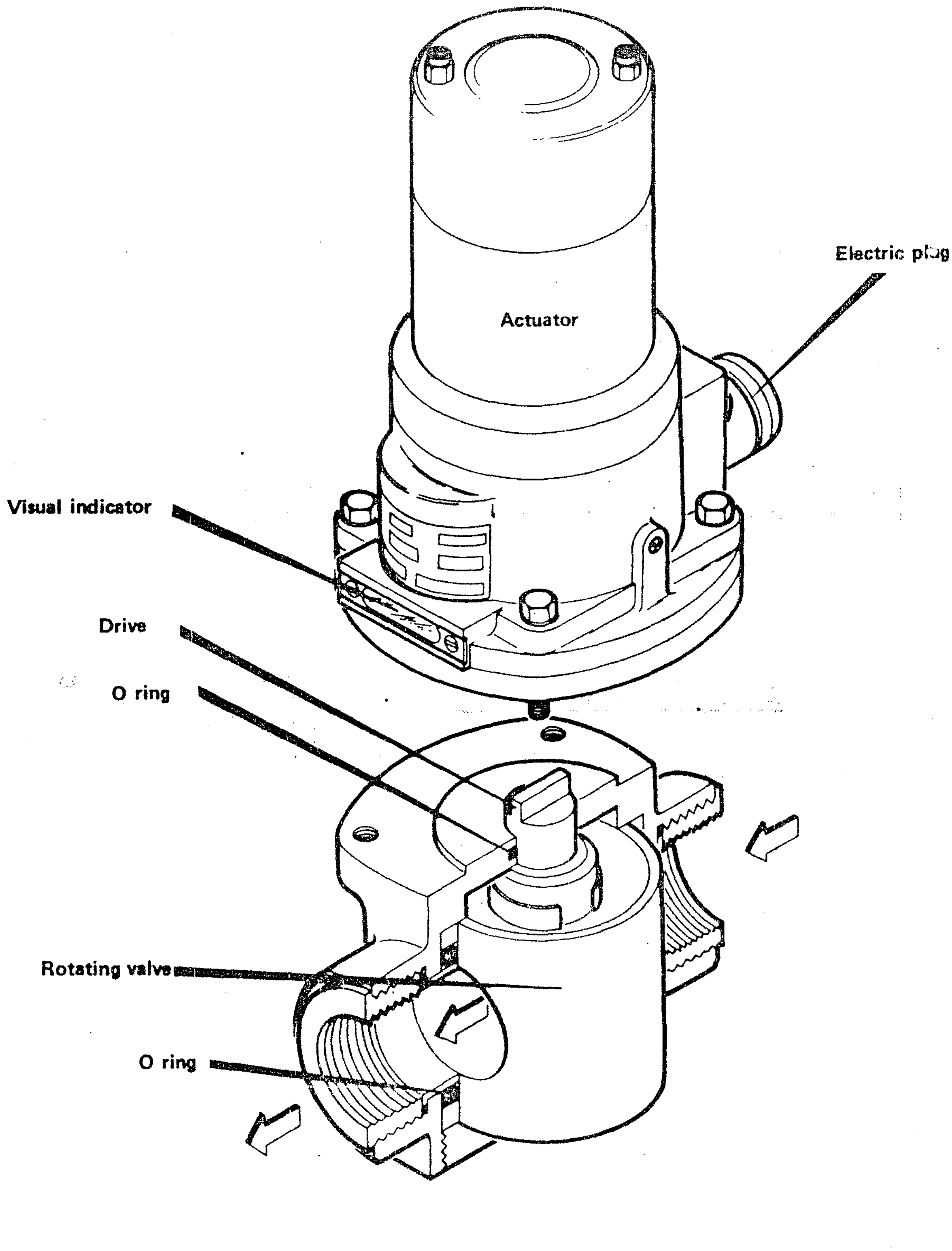
Difficulties in starting, rotation speed fluctuation (the "difficulties" in starting may be intermittent).

Note

The detail of the faults due to "limit-switches" is covered in chapter "Electric system" of the manual.

Practical works

- Locating
- Tests and check-out procedures
- Removal and installation
- Replacement of the valve
- Complete disassembly.



ELECTRIC FUEL COCK

STARTER CUT-OUT PRESSURE SWITCH

INTRODUCTION

The purpose of the "starter cut-out switch" is to cut-out the electric supply to the starter circuit when the engine reaches self-sustaining speed.

DESCRIPTION

It consists of a diaphragm subjected to the fuel inlet pressure on one side, and to the strength of a spring with adjustable tension on the other side. The diaphragm is integral with a plunger which actuates a microswitch.

OPERATION

At the beginning of starting, the fuel pressure is lower than the spring tension, and the microswitch ensures the supply to the electric system of the starter.

When the engine reaches the speed called "self-sustaining", the pressure becomes sufficient to cause engagement of the microswitch which cuts-out the supply to the starter and to a warning light (green light).

MAINTENANCE

Characteristics

- Setting of the pressure switch .... 0.39 b
- Rotation speed at starter cut-out .... 14,000 RPM.

Servicing and maintenance

In service, it is possible to make sure of the correct operation of the pressure switch by observing the starting indicating instruments.

There is no special periodic maintenance.

Adjustment

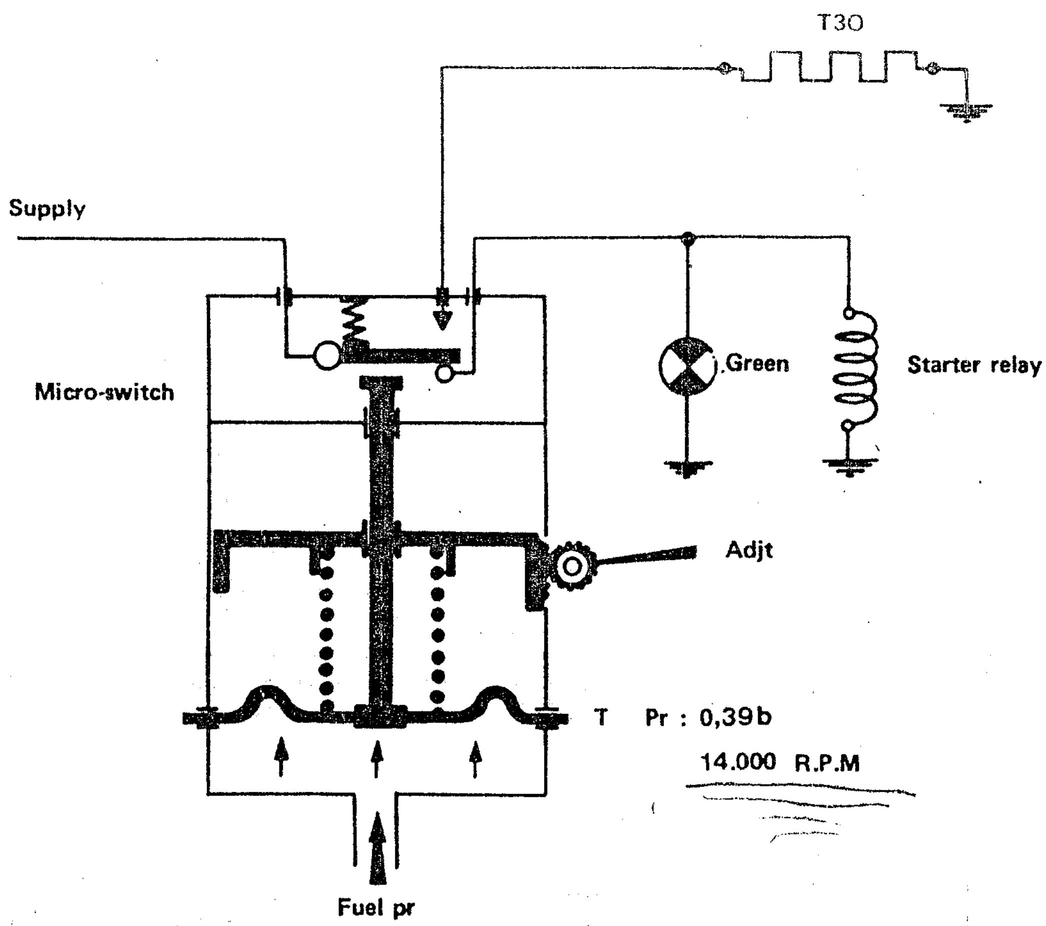
The switch is provided with a screw allowing the setting adjustment ; screw in to increase the setting .

Fault analysis

Any defect of the switch is expressed by a faulty operation of the starting electric system ; the fault analysis is therefore considered in the chapter "Electric system".

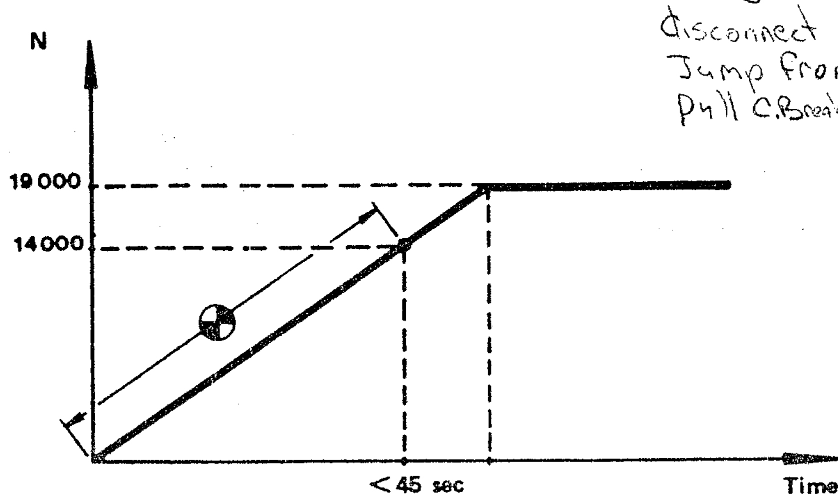
Practical works

- Locating
- Adjustment
- Removal and installation.



PRESSURE SWITCH SCHEMATIC DIAGRAM

if eng won't start;
disconnect cannon plug and
Jump from B to C. then
Pull C.Breaker to disengage



INTRODUCTION

In addition to the various accessories which have just been considered, the fuel system lay-out incorporates a line of pipes and an engine internal circuit.

PIPES

Supply

The supply is carried out from a pipe located on the engine right front section ; the aircraft fuel system is connected to this pipe. A three-way union ensures the supply to the ignition fuel system and to the main fuel system.

Ignition fuel system

The system comprises the following pipes :

- micro-pump supply pipe
- pipe from micro-pump to four-way union
- pipe from four-way union to igniters (2)
- ventilation pipe
- micro-pump air vent pipe.

Main fuel system

The system comprises the following pipes :

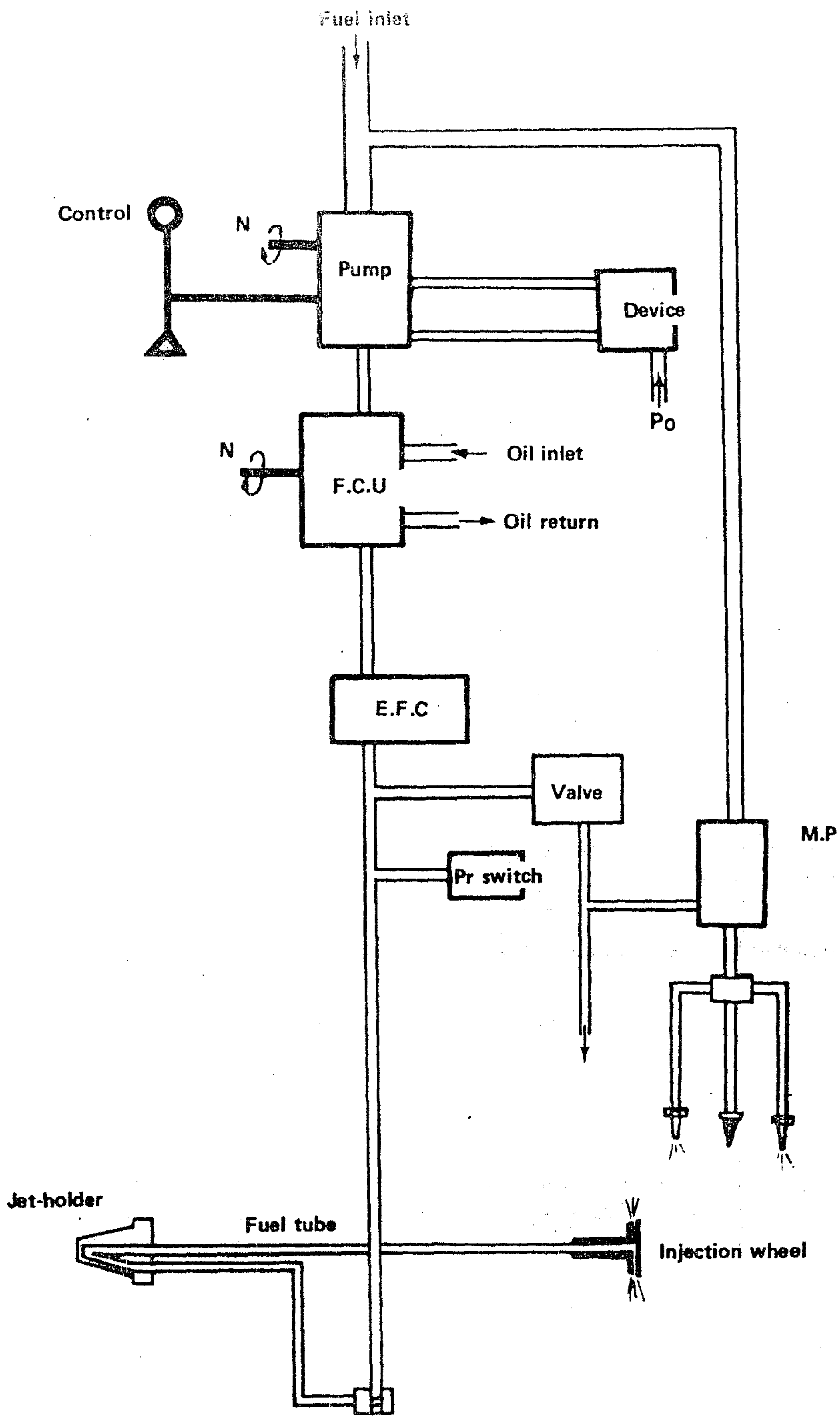
- supply pipe to the fuel pump
- supply and return pipe of the idling device (2)
- pipe from pump to speed governor
- pipe from speed governor to fuel cock
- pipe from fuel cock to starting fuel valve
- draining pipe of the starting fuel valve
- supply pipe to the pressure switch
- pipe from fuel cock to engine inlet
- draining pipe of the combustion chamber.

Note

Refer to maintenance manual at chapter "Standard practices" for unions and pipes.

INTERNAL FUEL SYSTEM

It incorporates : the fuel inlet internal channel, the jet-holder, the fuel tube and the centrifugal injection wheel (for details, refer to chapter "Engine description").



FUEL SYSTEM LAY OUT

OPERATION DURING STARTING

Engine starting is entirely automatic. It is carried out according to sequences which involve, not only the fuel system, but also other components which will be subsequently dealt with. Nevertheless, it is of interest to consider here and now the operation of the assembly.

Sequences

A - "Starting"selection

- the "green" light goes ON
- the starter operates ; the rotation speed increases
- the coil operates ; sparks to igniters
- the micro-pump operates.

B - Micro-pump pressure building-up

- fuel towards igniters ; flame, rise in t4
- microswitch engagement ; supply to electric fuel cock and light.

C - Electric fuel cock opening

- fuel cock fully opened ; fuel towards injection wheel, flame ignition in the chamber, rise in t4.
- supply to a time-delay switch (T5A).

D - Action of the time-delay switch

- ignition coil cut-out
- starting fuel valve cut-out
- micro-pump cut-out ; igniter ventilation
- yellow light goes OUT.

E - Action of the starter cut-out switch

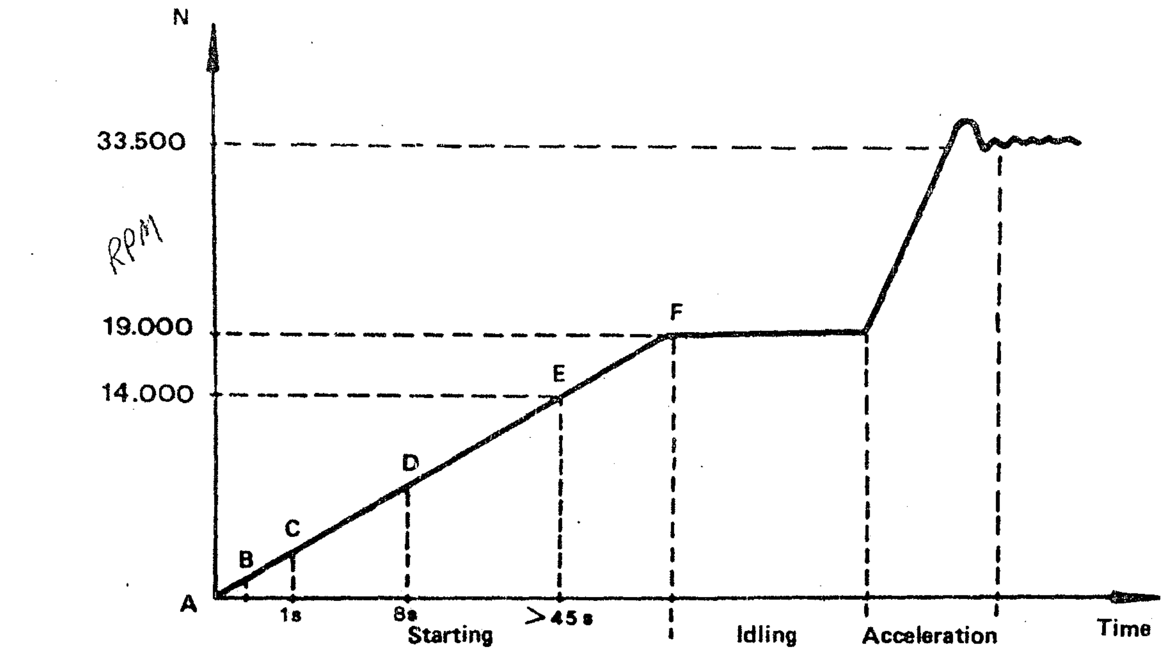
- starter cut-out
- green light goes OUT.

F - Idling

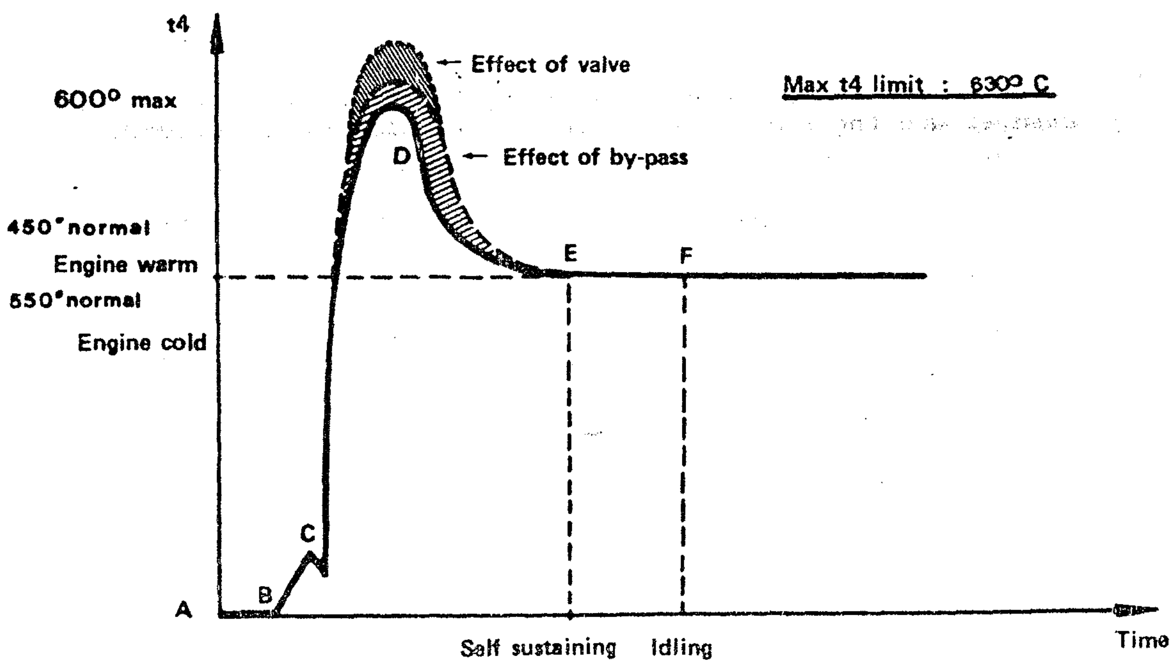
- starting is over
- the pump supplies the engine under controlled pressure
- the idling device meters the fuel flow.

Note

The curves illustrate the various operating phases as well as the variation of the rotation speed and of the t4 gas temperature in time.



N–TIME CURVE



T4 – TIME STARTING CURVE

OPERATION DURING ACCELERATION

The acceleration consists in increasing the engine rotation speed from idling speed to nominal speed. The acceleration is achieved by moving the control lever of the fuel control valve towards its position "fully opened".

The action on the lever causes the fuel control valve opening and the increase in rotation speed.

When the maximum rotation speed (or nominal speed) is reached, the speed governor meters the fuel. Nevertheless, it is important to open the control lever completely prior to regard the acceleration as being over.

"NORMAL" OPERATION (OR FUEL FLOW CONTROL)

The engine rotates at a practically constant rotation speed, and the output shaft delivers the power required to drive the receiver.

The engine fuel pump ensures the supply with fuel under controlled pressure (practically constant pressure).

The isochronous speed governor (refer to chapter "Fuel flow control") meters the fuel flow required to maintain the rotation speed.

The injection wheel atomizes the fuel into the combustion chamber and the flow injected determines the "operating point" of the engine.

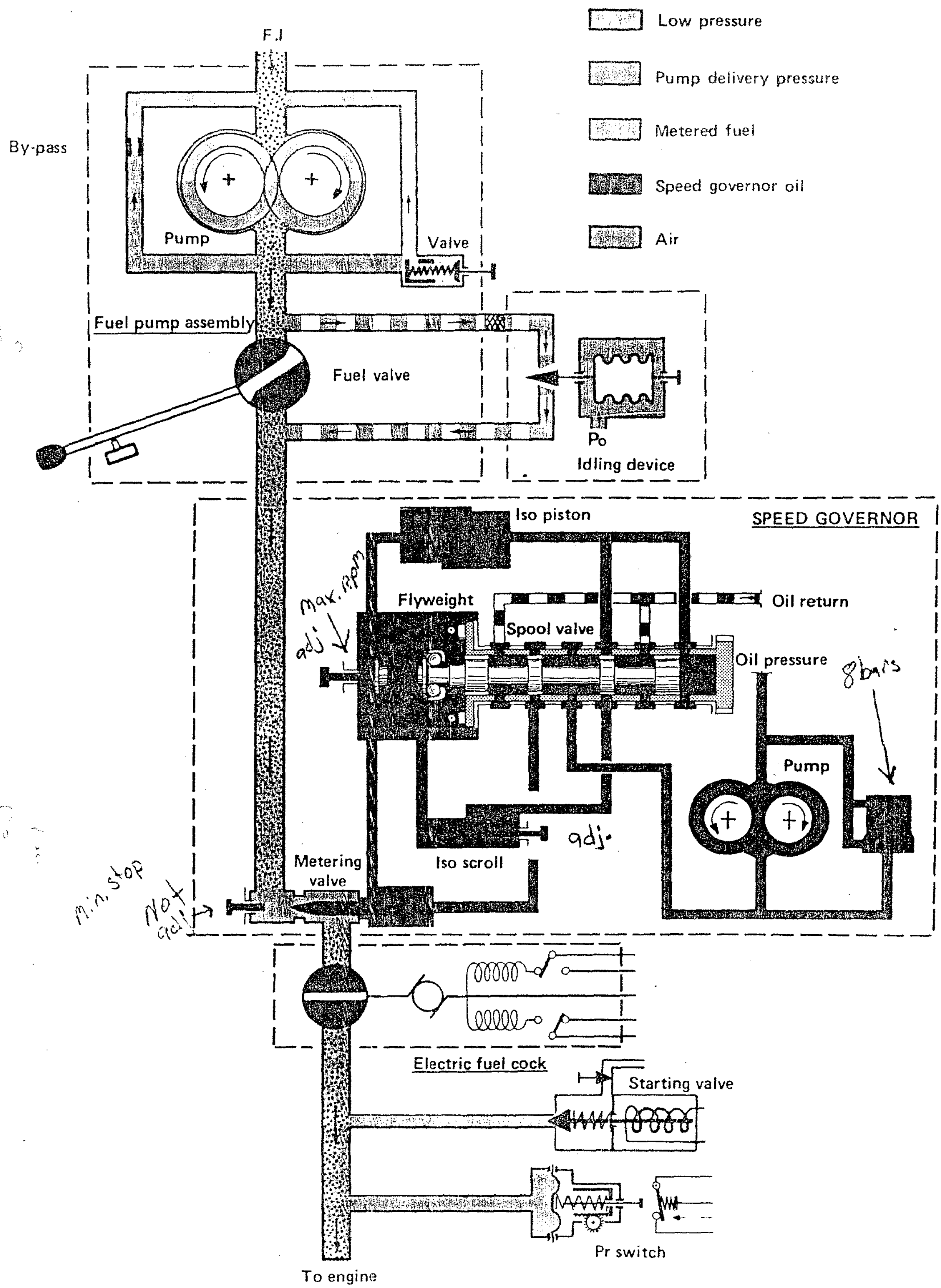
There is no engine direct manual control. The fuel flow corrections according to the variations of operating conditions are automatically carried out.

The operation is indicated by watching : the rotation speed and the t4 gas temperature.

OPERATION DURING ENGINE STOPPING

The control of "engine stopping" ("stop" selection of the switch) causes the electric fuel cock closing and the establishment of the electrical stop sequences.

The fuel cock cuts-off the fuel supply and the engine stops.



FUEL SYSTEM SCHEMATIC DIAGRAM

CHAPTER 6

AIR SYSTEM

- INTRODUCTION
- TORCH–IGNITERS VENTILATION CIRCUIT
- STARTER CUT–OUT SWITCH CIRCUIT
- AIR TAPPING AT THE AIRCRAFT MANUFACTURER DISPOSAL
- AIR SUPPLY TO IDLING DEVICE
- DRAINING CIRCUITS

INTRODUCTION

This chapter deals with the air circuits of the turbo-shaft.

The following circuits are to be considered :

TORCH-IGNITER VENTILATION CIRCUIT

It is a P2 air circuit ensuring the ventilation of the igniters during engine operation.

This circuit is considered again in the chapter "Fuel system", in the paragraph "Ignition fuel system".

STARTER CUT-OUT SWITCH CIRCUIT

The pressure switch ensures the electric supply to the starter and cuts-out this supply when, during the starting phase, the engine reaches "self-sustaining speed". It is supplied with P2 air by means of a tapping located on the turbine casing and of a pipe.

Note There are two types of starter cut-out switch : one actuated by the P2 air pressure, the other actuated by the fuel pressure. The P2 pressure switch is dealt with in the present chapter, whereas the fuel pressure switch is dealt with in the chapter "Fuel system".

AIR PRESSURE TAPPING AT AIRCRAFT MANUFACTURER'S DISPOSAL

The turbo-shaft is provided with a P2 air tapping which can be used for various purposes by the aircraft manufacturer.

AIR SUPPLY TO IDLING DEVICE

The barostatic idling device is subjected to the atmospheric pressure Po.

The Po tapping is ensured by a static tapping and a pipe.

DRAINING CIRCUITS

Their purpose is to drain out the leaks from various engine components.

TORCH-IGNITERS VENTILATION CIRCUIT

INTRODUCTION

The circuit ensures the ventilation of the igniters as soon as the ignition phase is over.

The purpose of the ventilation is to avoid clogging of the igniters by carbonization of the residual fuel.

DESCRIPTION

The circuit consists of a P2 air tapping on the turbine casing, and of a pipe connecting the air tapping to the four-way union.

The P2 air tapping incorporates a filter composed of a wire gauze mounted inside a housing provided with the air tapping orifice.

OPERATION

The igniter ventilation starts as soon as the micro-pump has stopped and lasts during the whole operating time of the engine.

The operation is also dealt with in full details in the chapter "Fuel system".

MAINTENANCE

Characteristics

- ventilation air flow .... very low
- beginning of operation .... micro-pump stop

Servicing and maintenance

Inspection and cleaning of the filter in periodic inspection.

Fault analysis

Obstruction of the P2 tapping

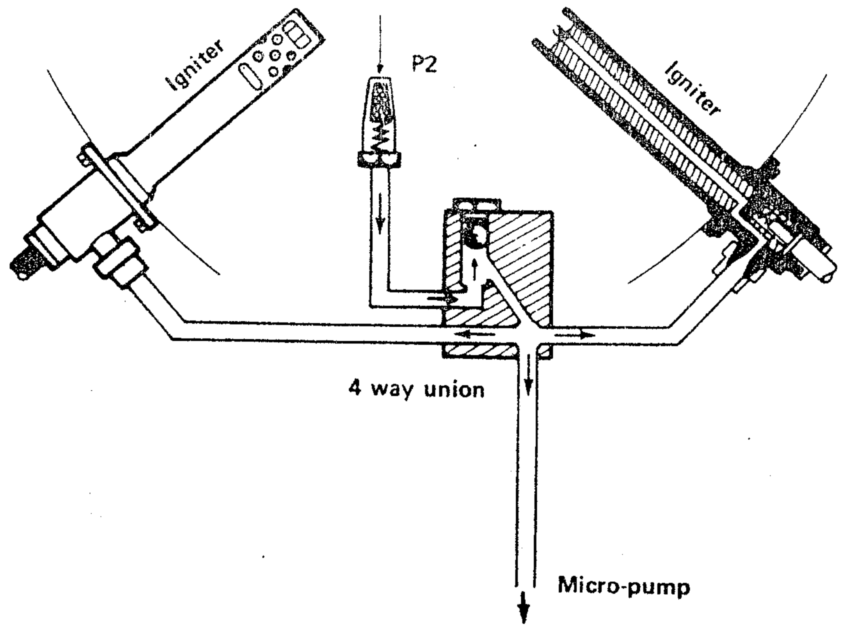
Faulty ventilation leading to igniter clogging after a certain operating time.

Faulty sealing of the four-way union ball

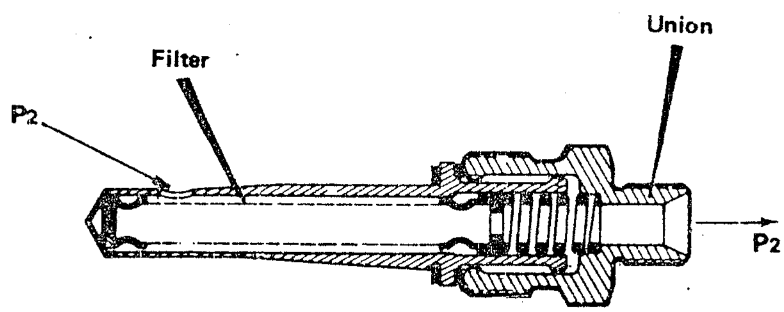
See Fuel system.

Practical works

- Locating
- Filter disassembly
- Four-way union removal.



VENTILATION SYSTEM SCHEMATIC DIAGRAM



P2 AIR TAPPING

STARTER CUT-OUT SWITCH CIRCUIT

INTRODUCTION

The circuit consists of a P2 pressure tapping on the turbine casing and of a pipe connecting the air tapping to the pressure switch.

The purpose of the pressure switch is to cut-out the starter when the self-sustaining speed is reached during starting.

DESCRIPTION

The P2 pressure tapping of the pressure switch is also used for igniter ventilation.

The pressure switch incorporates a diaphragm subjected to the P2 air pressure on one side, and to the strength of a spring on the other side. A stem integral with the diaphragm actuates a microswitch mounted at the upper part of the pressure switch.

OPERATION

As long as the air pressure is lower than the spring tension, there is no action on the microswitch, and it allows the electric supply to the starter.

When the air pressure reaches a certain value (value obtained at self-sustaining speed), the diaphragm compresses the spring and the plunger causes the tripping of the microswitch contacts. The microswitch then cuts-out the supply to the starter and, by its working contact, ensures another supply (see electric system).

MAINTENANCE

Characteristics

- Setting of the pressure switch .... 0.4 b
- Self-sustaining rotation speed .... 14,000 RPM $\pm$ 1,000

Servicing, maintenance, check-out procedures

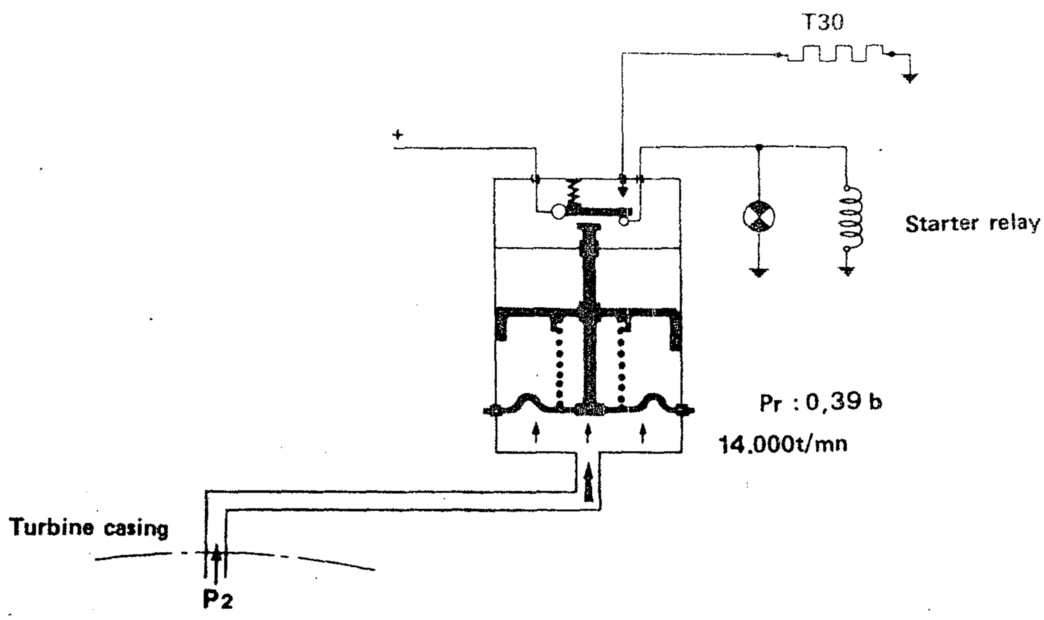
Let us merely note the procedure which consists in - by cold weather - admitting a de-icing fluid into the pipe.

Fault analysis

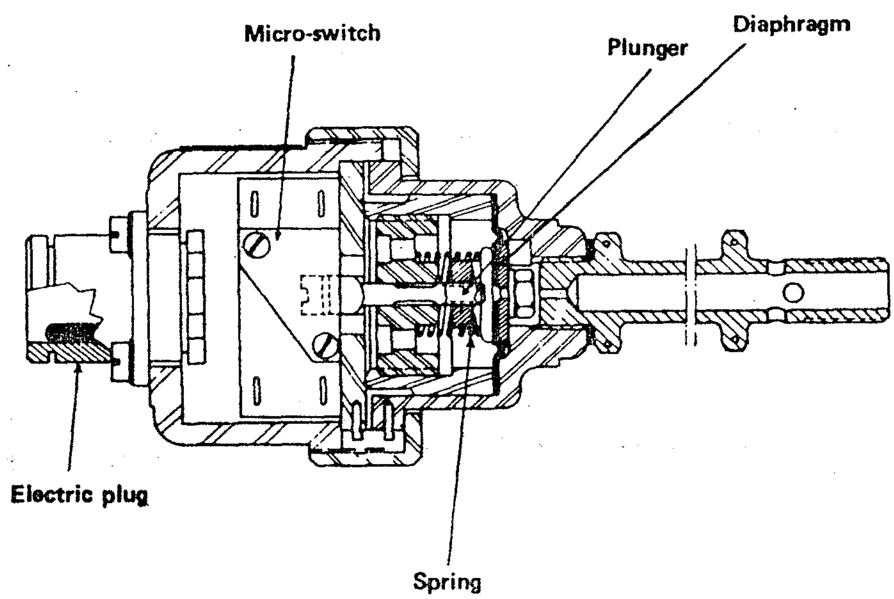
(see electric system)

Practical works

- Locating
- Check
- Installation and removal.



P2 PRESSURE SWITCH SCHEMATIC DIAGRAM



P2 PRESSURE SWITCH CUT–AWAY

AIR TAPPING AT AIRCRAFT MANUFACTURER DISPOSAL

The turbine casing incorporates, at its upper part, a boss allowing the installation of a P2 air tapping point.

The tapping point is at aircraft manufacturer's disposal who can use it for various purposes (see aircraft manufacturer's manual).

The characteristics of the air which can be taken are as follows :

- pressure 5.2
- air flow .... about 80 gr/sec.
- temperature .... 250° C
- loss of power .... about 0.45 kw/gr/sec.

Any quantity of extra air taken affects the performances of the power plant.

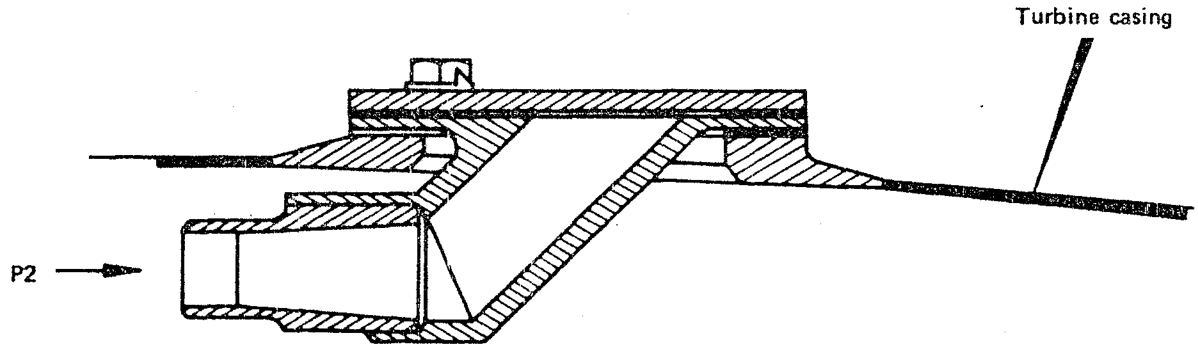
IDLING DEVICE AIR SUPPLY CIRCUIT

The idling device is a barostatic device subjected to the atmospheric pressure Po.

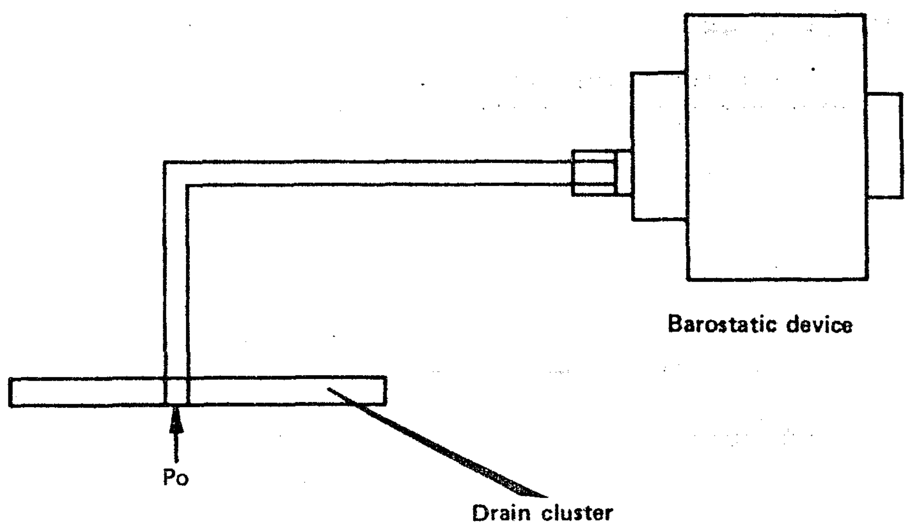
The Po tapping is a static pressure tapping which consists in a pipe emerging in open air and connected to the barostatic device box.

The pressure tapping is mounted on the collector-ring of the drains at the lower section of the engine.

Obstruction of the tapping may cause a faulty operation of the idling device, and consequently an incorrect idling speed. A fuel leak through the Po tapping indicates a faulty sealing between the idling metering valve and the barostatic device box.



AIR TAPPING AT AIRCRAFT MANUFACTURER DISPOSAL



AIR SUPPLY TO IDLING DEVICE–SCHEMATIC DIAGRAM

DRAINING CIRCUITS

INTRODUCTION

The purpose of the draining circuits is to drain overboard the possible or functional leaks from the various engine components.

The various drainings are also dealt with in the various chapters to which they belong, but the assembly of all the drainings is covered by this paragraph.

The following circuits are to be considered :

COMBUSTION CHAMBER DRAINING

The purpose of this draining is to expell the fuel accumulated in the combustion chamber during engine starting (particularly after a false start).

It consists of a boss located at the lower section of the turbine casing, of a union and of a drain pipe.

The only maintenance practice consists in checking the drain non-obstruction ; this check may be carried out by admitting compressed air into the pipe or by merely putting a finger at the tip of the pipe during engine operation. The removal, cleaning and installation are covered in practical works.

MICRO-PUMP DRAINING

It is a functional draining, the purpose of which is to expell the fuel when the micro-pump starts operating.

It is worthy of note that the drain pipe is connected by a T-union to the starting fuel valve pipe.

STARTING FUEL VALVE DRAIN

It is a functional draining which consists of a pipe connecting the starting valve to the micro-pump drain.

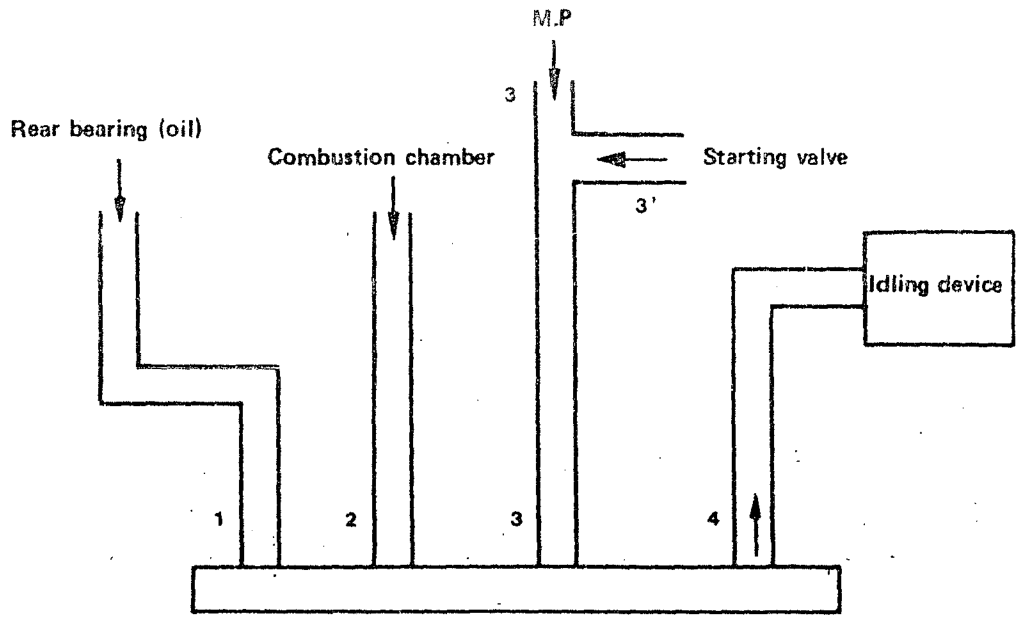
JET-HOLDER DRAINING

At the moment, this drain is obturated by a cap, but the removal and the check for leaks can give an interesting indication about the jet-holder sealing (fuel and oil sealing).

REAR BEARING AIR VENT

The rear bearing breathering is effected by means of an air vent pipe.

Note - It is also worthy of note the jet pipe drain and the oil tank air vent, provided by the aircraft manufacturer.



Drain cluster (engine lower section)

1- Functional drain

2- Functional drain

3- Functional drain before and at the beginning of starting only

3'- Functional drain during ignition

4- PO tapping (no leak)

DRAINING CIRCUITS SCHEMATIC DIAGRAM

NOTES

CHAPTER 7

ENGINE CONTROL

- INTRODUCTION
- FUEL FLOW VALVE CONTROL
- CONTROL SWITCHES
- ENGINE CONTROL PROCEDURE

INTRODUCTION

ENGINE CONTROL : FUNCTIONS

The control of the turbo-shaft ARTOUSTE III enables to ensure the following functions :

- control of engine starting
- control of engine stopping
- control of engine ventilation
- control of engine acceleration.

In "normal operation", the control is entirely automatic and does not require any direct action on the engine.

CONTROL COMPONENTS

The various control functions of the power-plant are ensured by means of the following components :

- control lever of the shut-off valve (aircraft fuel system)
- control lever of the fuel control valve
- circuit-breakers and components meant to set the electric circuits under power
- "start-stop-ventilate" switch
- "booster pump" switch.

CHAPTER LAY-OUT

This chapter deals with :

- the fuel control lever
- the switches
- the main engine control procedure.

Note

These components are also considered in the chapters corresponding to their function.

FUEL FLOW VALVE CONTROL

INTRODUCTION

The purpose of the fuel control lever is to ensure the engine acceleration after starting and the return to idling speed before stopping.

DESCRIPTION

The pilot's control lever as well as the transmission are provided by the aircraft manufacturer.

The control actuates :

- the fuel control valve of the fuel pump assembly
- safety microswitches (a microswitch located on the pump assembly and two microswitches located on the control lever box).

On engine side, the control transmission is connected to the end of the fuel control valve shaft by means of splines and of a locking system.

It rotates the fuel control valve shaft and its movement is limited between stops.

OPERATION

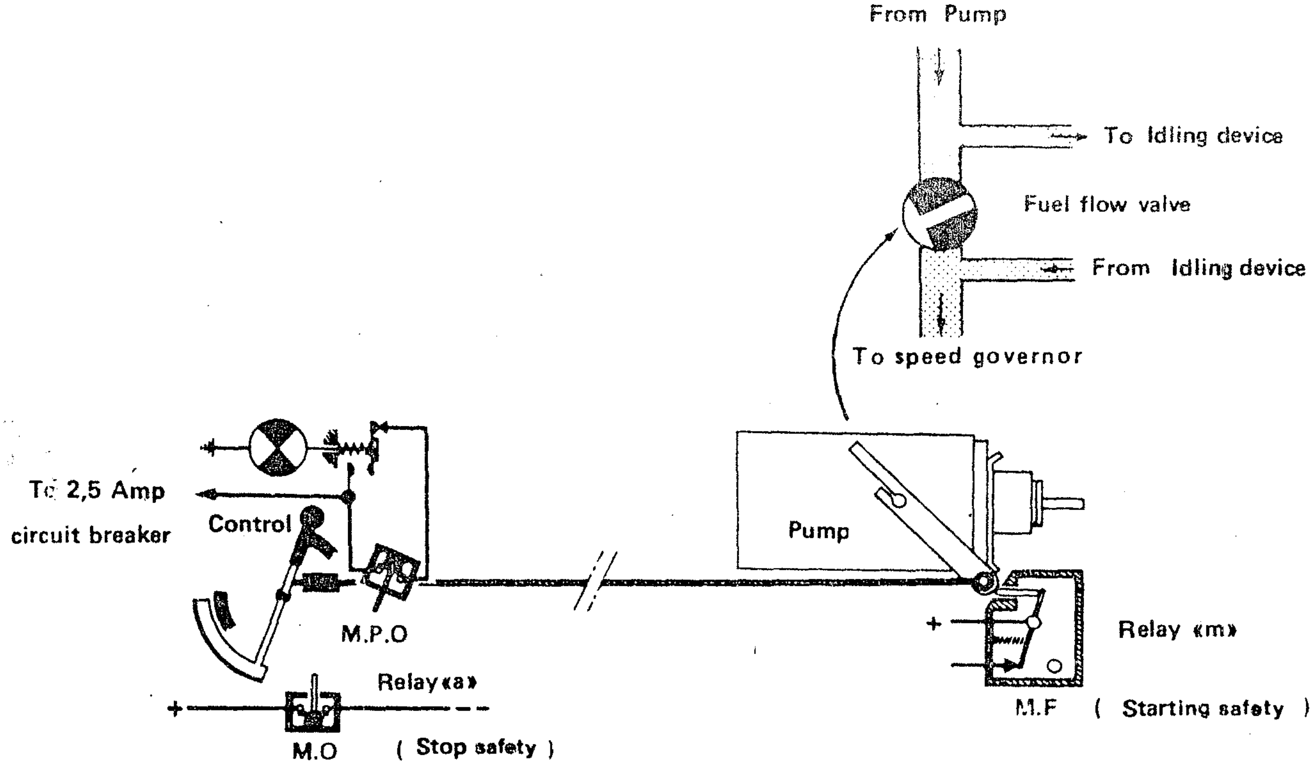
Moving the lever forward causes the fuel control valve opening, and the action of the microswitches ; the following "main positions" can be noted :

- "stop-start" position : control at 0°, fuel control valve closed, MF microswitch engaged.
- "flight" position : control at max., fuel control valve fully opened, action of the lever block microswitches.
- the intermediate positions are only temporary positions during acceleration and deceleration ; nevertheless it is worthy of note the opening position at about 2/3 of the control lever, this position corresponds to the nominal speed, the remaining range being only meant to the full opening of the fuel control valve.

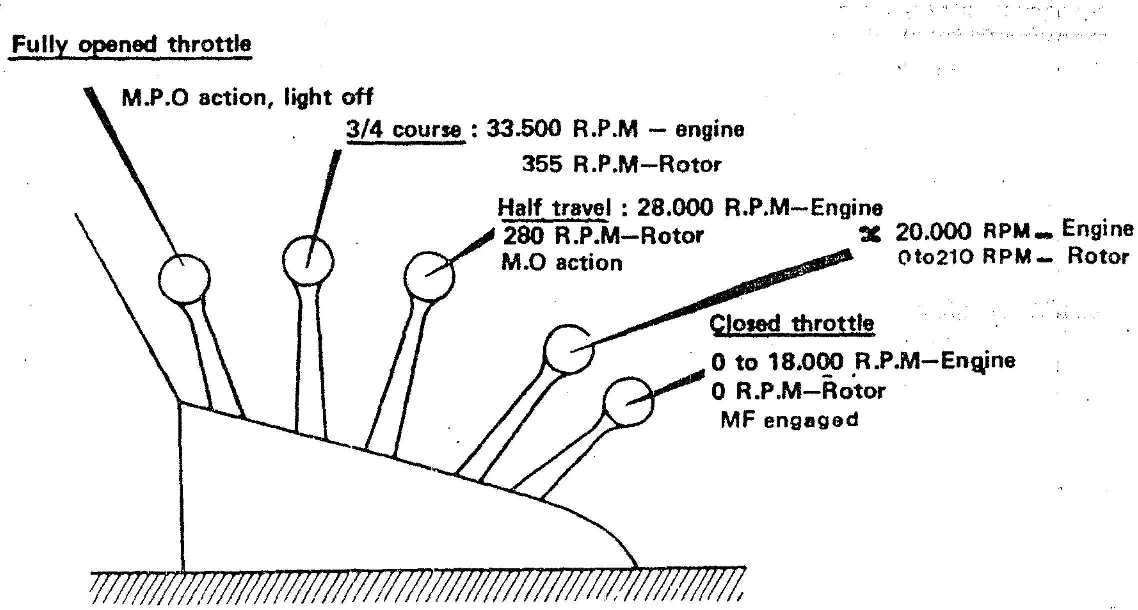
MAINTENANCE

Let us note only :
- displacement check and adjustment
- safety check.

In practical works :
- Locating
- Assembly
- Checks, adjustments.



FUEL FLOW VALVE CONTROL



CONTROL POSITIONS

CONTROL SWITCHES

INTRODUCTION

In a general way, it can be said that the switches permit to control the engine starting, stopping and ventilation.

They are supplied by the aircraft manufacturer but nevertheless, it is of interest to consider their functions in the outline of the engine control procedures.

CIRCUIT-BREAKERS AND SWITCHES

These components are used to apply power on the electric systems necessary for engine operation. They consist of :

- The supply switch

  A switch ensuring the supply with current to the electric system.

- The "starting" circuit-breaker

  A "10 A" circuit-breaker located on the supply circuit of the starting electric system.

- The "indicating system" circuit-breaker

  A "2.5 A" circuit-breaker located on the supply circuit of the engine indicating system electric circuit.

BOOSTER PUMP SWITCH

This switch controls the "start" and the stop sequences of the aircraft fuel system booster pump. It is provided with two positions :

- a position "ON", direct supply to the booster pump,
- a position "OFF", automatic supply to the booster pump during engine starting and stopping after starting.

"START" SWITCH (OR "START-STOP-VENTILATE")

It is a bipolar switch with three positions :

- the position "start"
- the position "stop" (centre position)
- the position "ventilate" (with release spring to neutral).

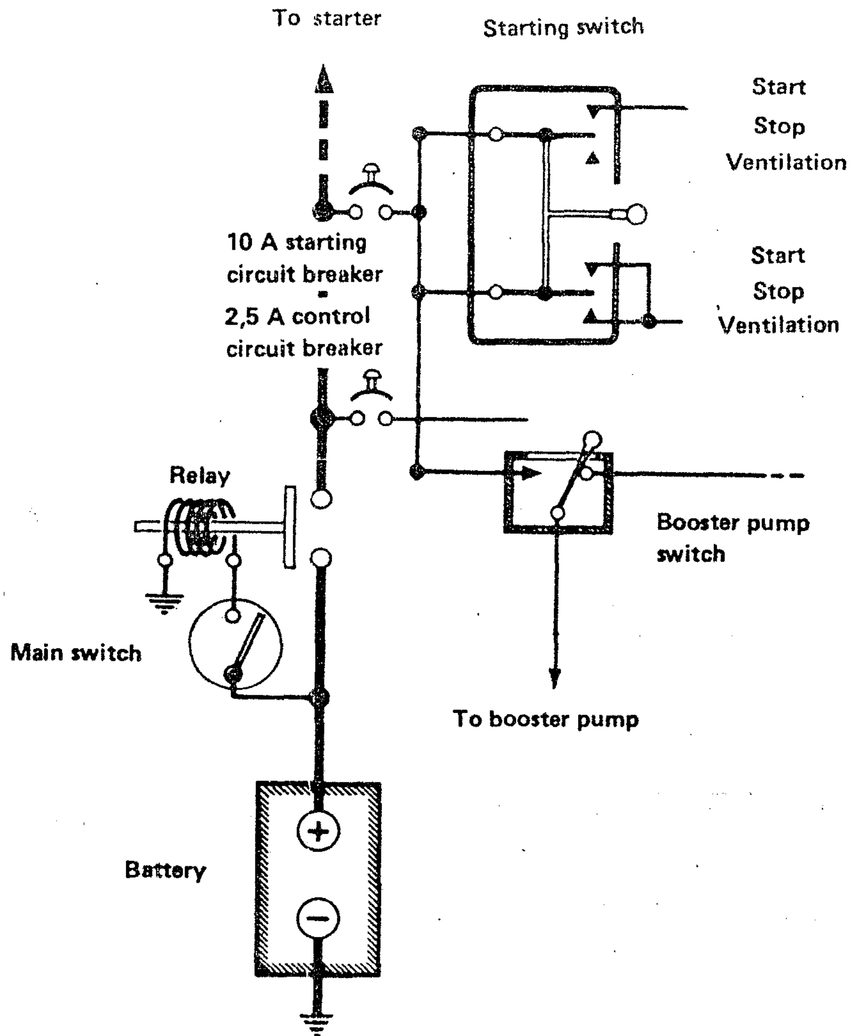


DIAGRAM OF THE CONTROL SWITCHES

ENGINE CONTROL PROCEDURE

INTRODUCTION

This paragraph is only a schematic statement about the engine control and operating procedures. Moreover, it is used (particularly during a training course) to perform a synthesis of the general operation of all the systems.

ENGINE STARTING

- Fuel control lever "closed"
- Power on the electric system
- Booster pump switch "ON"
- Start switch to "start"

During starting , check : indicating lights, t4 gas temperature, rotation speed, battery tension, oil pressure, oil temperature.

ACCELERATION

- Slowly move forward the fuel control lever
- Make sure of the rotor clutching (case of helicopter)
- Control the full opening of the lever.

During acceleration, check : indicating lights, temperature, rotation speed, oil pressure and temperature.

"NORMAL" OPERATION (FLIGHT)

- No direct control
- Respect "flight envelope and limitations"
- Check : temperature, rotation speed, oil pressure.

ENGINE STOPPING

- Move the lever "backwards"
- Switch to "stop".

During stopping, check : indicating lights, rotation speed, acceleration time.

NOTES

CHAPTER 8

ENGINE INSTRUMENTATION

- INTRODUCTION
- T4 TEMPERATURE INDICATING SYSTEM
- ROTATION SPEED INDICATING SYSTEM
- OIL PRESSURE INDICATING SYSTEM
- OIL TEMPERATURE INDICATING SYSTEM
- WARNING AND INDICATING LIGHTS

INTRODUCTION

The purpose of the indicating system of the turbo-shaft is to :

- make sure that the operating limitations are not exceeded ;
- detect a defective operation or a variation of the performances ;
- indicate certain operating phases.

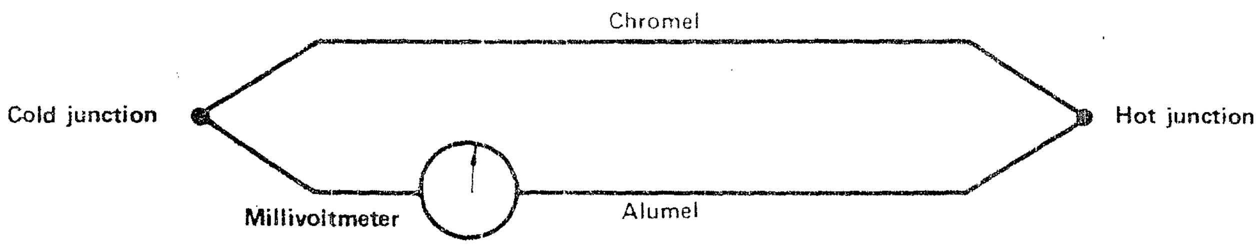
The operating indications of the ARTOUSTE III turbo-shaft are carried out by means of instruments which give the following indications to the operator :

- Gas temperature (t4) indication
- Engine rotation speed indication
- Oil pressure indication
- Oil temperature indication.

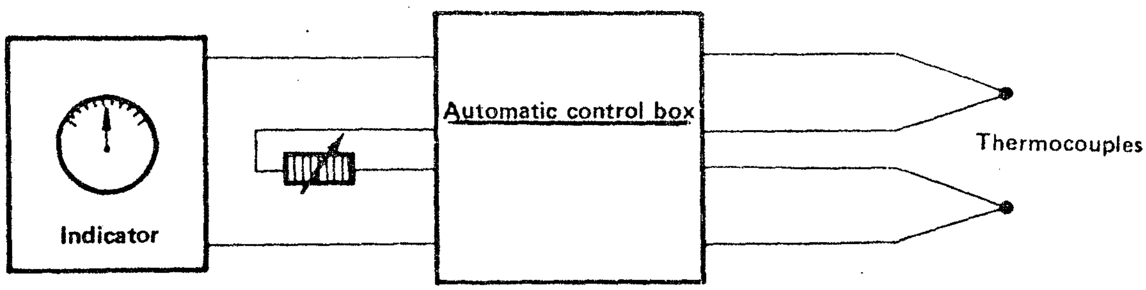
Moreover, various indicating and warning lights give some indications about the engine operation.

- A starting "green" light
- A fuel cock "yellow" light
- A "red" blockage light
- A booster pump pressure light
- A fuel filter clogging light (aircraft system filter).

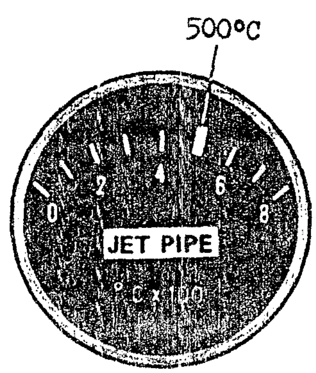
An indicating system for special tests is possible in order to measure certain parameters (vibrations, fuel flow, P2 air pressure).



THERMOCOUPLE PRINCIPLE



INSTALLATION DIAGRAM



T4 indicator

GAS TEMPERATURE INDICATING SYSTEM

ROTATION SPEED INDICATING SYSTEM

DESCRIPTION

The transmitter is a three-phase generator (AMA 220 type), the rotor of which is a four-pole permanent magnet driven by the engine (lower train of the accessory drive).

OPERATION

The tachometer transmitter supplies the motor of the indicator on the aircraft panel, with a three-phase alternative tension whose frequence is proportional to the rotation speed.

MAINTENANCE

Characteristics

Rotation direction	SIH
Rotation speed	N/10

Field maintenance

Check the attachment of the transmitter

Check the attachment of the electric plug

Check for leaks at the mating surface and on the shaft.

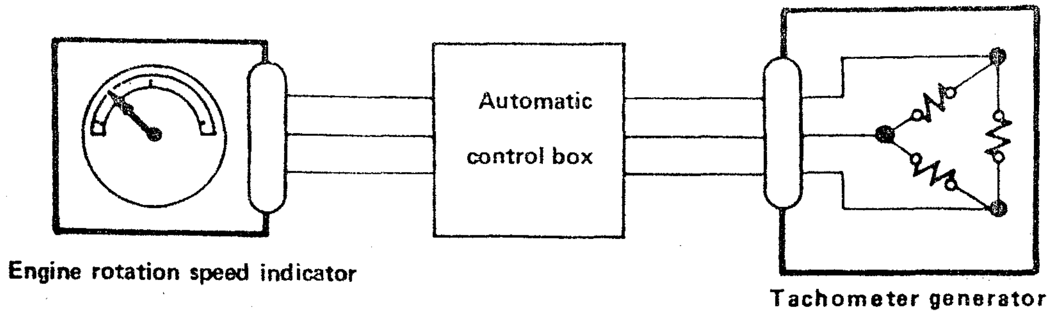
Fault analysis

A faulty indication comes either from the transmitter or from the receiver. Proceed by analysis or by elimination to repair.

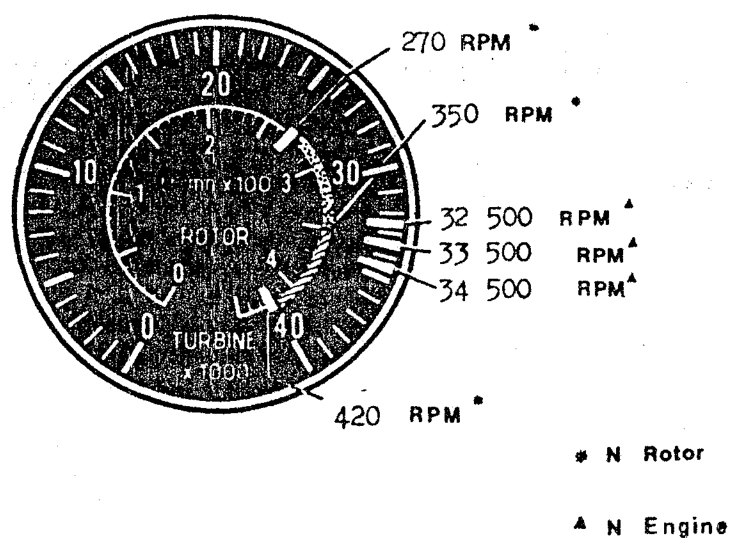
It is possible to check the rotation speed indication by using a mechanical tachometer connected to the accessory spare drive. The tachometer ensures an accurate indication which may be compared with that of the indicating system (see chapters "fuel flow control" and "maintenance").

Practical works

- Locating
- Check-out procedure
- Installation and removal.



SCHEMATIC DIAGRAM OF THE ROTATION SPEED INDICATING SYSTEM



ROTATION SPEED INDICATING

ROTATION SPEED INDICATING SYSTEM

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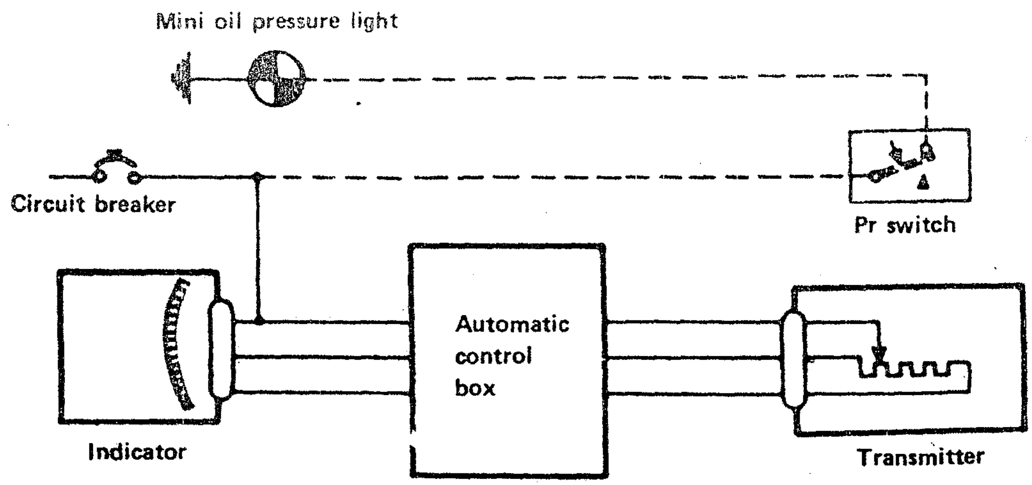
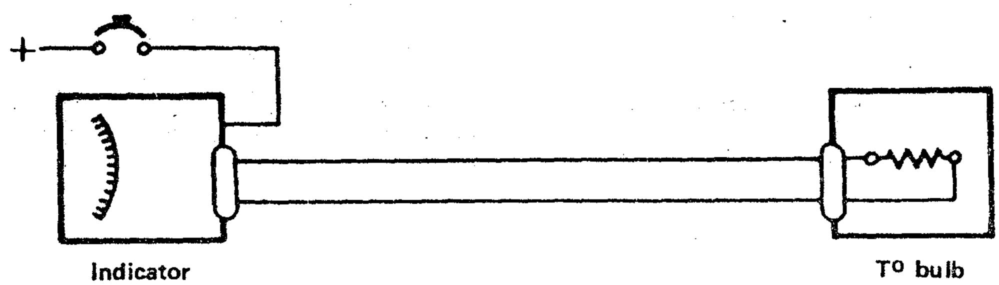
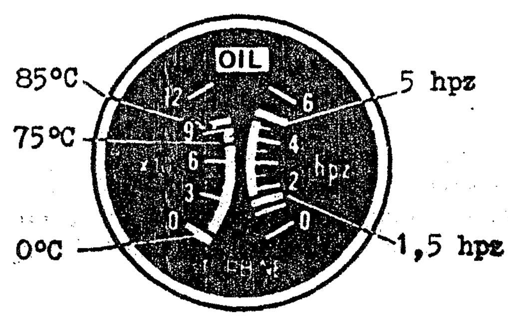


SCHEMATIC DIAGRAM OF THE OIL PRESSURE INDICATING SYSTEM



SCHEMATIC DIAGRAM OF THE OIL TEMPERATURE INDICATING SYSTEM



INDICATOR (Oil t°.Oil pr.)

WARNING AND INDICATING LIGHTS

STARTING LIGHT

It is a "green" light which ensures the indication during the starting phase and during engine ventilation.

It goes "on" as soon as the "start" selection has been made, and thus indicates the beginning of the starting phase (supply to starter relay).

When it goes "out", a short time before idling speed, this indicates the starter cut-out.

ELECTRIC FUEL COCK LIGHT

It is a "yellow" light which ensures the indication of the ignition phase.

It goes "on" about half-a-second after start selection and indicates the micro-pump pressure building-up (beginning of ignition).

When it goes "out" after a few seconds, this indicates the electric fuel cock opening and the operation of the T5A time-delay switch (end of ignition, micro-pump and coil cut-out).

At engine stopping, it goes "on" a fraction of second and thus indicates the fuel cock closing.

BLOCKAGE LIGHT

It is a "red" light which ensures the indication of engine stopping.

It goes "on" as soon as the stop selection (after the fuel cock light flash) and thus indicates the fuel cock closing.

When it goes "out" a few seconds (about 20 seconds) later, this indicates the resetting of the electric system (T5R).

When it goes "on" during starting, this indicates a fault in the starting electric system.

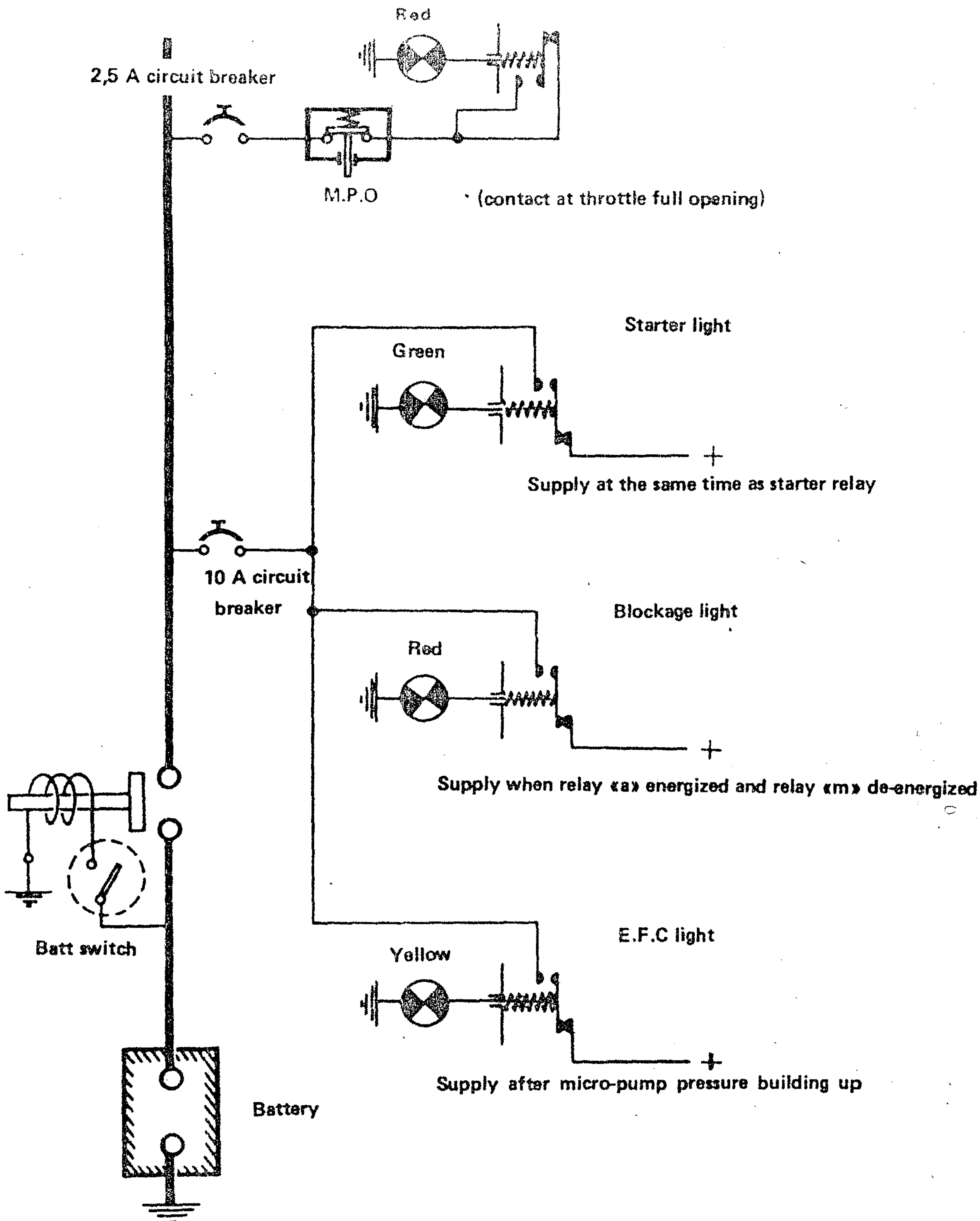
FUEL CONTROL LEVER LIGHT

It is a "red" light which indicates , when it goes "out", the control lever full opening.

OTHER LIGHTS

It is of value to note in addition :

- <u>the booster pump light</u>
- <u>the filter clogging light</u>.



WARNING AND INDICATING LIGHTS

NOTES

CHAPTER 9

FUEL FLOW CONTROL

- INTRODUCTION
- TURBO–SHAFT CONTROL – GENERAL
- ARTOUSTE III FUEL FLOW CONTROL – PRINCIPLE
- ROTATION SPEED CONTROL
  - Purpose and principle
  - Mechanical speed governor
  - Hydro-mechanical speed governor
- ARTOUSTE III ISOCHRONOUS SPEED GOVERNOR
  - Purpose
  - Description
  - Operation
  - Maintenance

INTRODUCTION

The operating point of a gas turbine engine is essentially characterized by the following parameters :

- the thrust (T) in the case of a turbo-jet engine
- the power (W) in the case of a turbo-shaft engine
- the turbine rotation speed (N)
- the turbine inlet temperature (T3).

These parameters being all in close connection, diagrams showing the changes in each of them in terms of a single one taken as a reference, can be represented.

The reference parameters are generally the rotation speed (N) and the turbine inlet temperature (T3). That choice may be explained by reason of the limitation laid down by the resistance to "creeping" of the turbine blades.

These parameters are "mainly" depending upon the air/fuel ratio, the temperature and the combustion efficiency. In most of engines, the sole "physical" parameter available is the fuel flow. This action on the fuel flow is called the "fuel flow control".

The fuel flow control is then entrusted with (as a general rule) :

- the setting of an "operating point",
- the holding of N and T3 within prescribed limits.

The various functions of a fuel flow control are obviously depending upon the engine considered. The above statement must only be regarded as a brief and incomplete introduction to the fuel flow control function.

As a general rule, two main types of fuel flow control are to be considered : the fuel flow controls of "programme type", and the self-controlling devices (loop type control).

An operating rate (or operating point) is called <u>stabilized</u> when the main parameters do not change in the course of time ; it is called <u>transient</u> when one of the parameters changes in a consistent way in the course of time.

TURBO-SHAFT CONTROL – GENERAL

INTRODUCTION

A turbo-shaft is a "gas turbine" type engine designed to supply a receiver with a power energy.

The receiver has its operating point mainly characterized by :

- the resisting torque
- the rotation speed.

The turbo-shaft (or power generator) has its operation mainly characterized by :

- the engine torque
- the rotation speed
- the turbine gas temperature.

The purpose of the fuel flow control is to hold these parameters within prescribed limits. The following functions can be considered : rotation speed control, temperature control, limitations, operating procedures.

ROTATION SPEED CONTROL

In most of cases, an attempt is made to keep a constant rotation speed.

To obtain operation at constant rotation speed, it is necessary to achieve balance between the torque produced by the engine, and the resisting torque of the receiver. To this purpose, it is possible, either to control the receiver or to control the power generator.

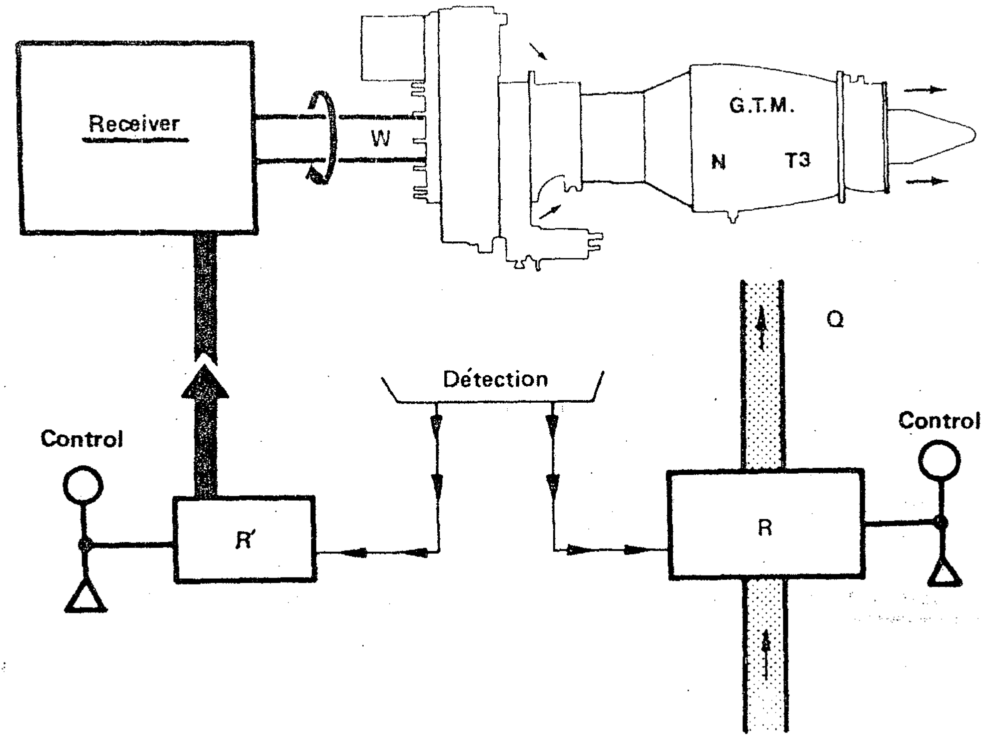
TEMPERATURE CONTROL, TORQUE CONTROL

In order to maintain the engine within the temperature limits and within the torque limits, it is possible to act on the receiver, or on the generator when these limits are reached.

In some cases, the temperature control (as well as the torque control) is not necessary, being given that the parameters are considered to remain within the limits as regards the receiver operation.

ENGINE POWER SELECTION

The choice (and the variation) of the operating point can be made either by controlling the receiver, or the generator, and sometimes, even by acting on both at the same time.



Receiver

Torque...C

Speed ---N

Generator

Speed ---N

Temperature T3

Handling

Receiver control

Generator control

Automatic

Fuel flow control

Parameters detection — Correction

TURBO–SHAFT FUEL FLOW CONTROL GENERAL

ARTOUSTE III FUEL FLOW CONTROL – PRINCIPLE

INTRODUCTION

To adapt engine and receiver, it is required to keep a constant rotation speed.

It is then necessary to achieve balance between the energy taken by the receiver and the energy produced by the engine.

The automatic control is achieved by continuously adapting the engine torque to the resisting torque.

The engine torque being essentially function of the fuel flow, this fuel flow is metered in order to achieve this adaptation.

This function is carried out by a speed governor which measures the rotation speed and meters the fuel in function of the rotation speed detection.

OPERATION

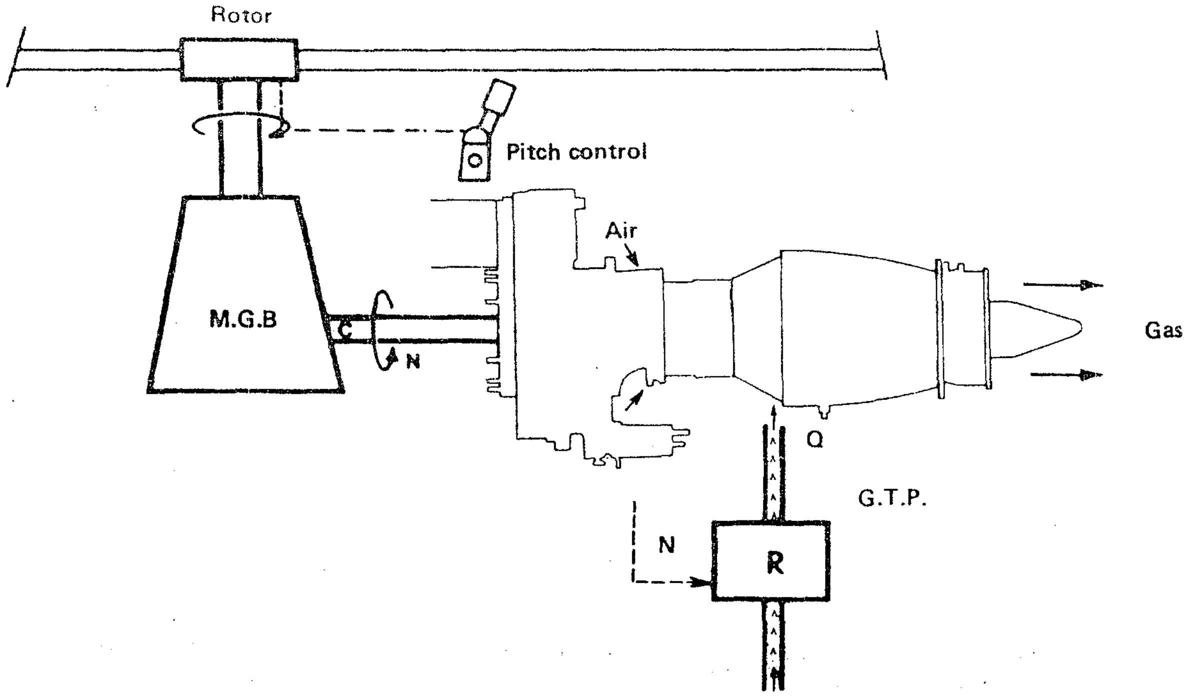
In stabilized condition, the engine torque balances the resisting torque and the assembly operates at a constant rotation speed.

In transient condition (essentially variation of the resisting torque), the balance is broken and the rotation speed "tends" to vary.

The speed governor detects the "tendency to speed variation" and meters the fuel flow in order to adapt again the engine torque to the resisting torque and to restore the nominal rotation speed.

The rotation speed is thus kept practically constant in every operating condition.

The turbine inlet temperature varies, but it is considered (as well as the torque) that it remains within the limits as regards the receiver operation.



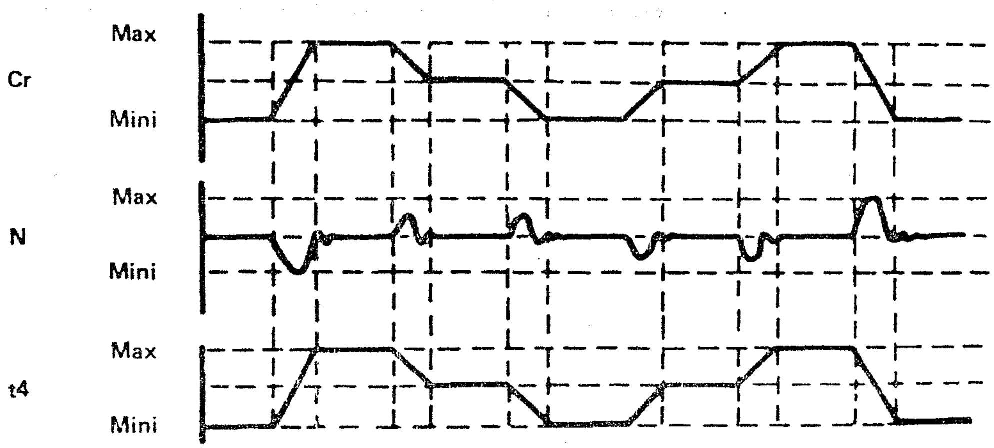
Receiver

Resisting torque : f(pitch and flight)

Generator

Engine torque : f (Q/G , c)

Fuel flow control – Engine torque adapted to resisting torque
N detection , Q correction



GENERAL OPERATION (Helicopter operation)

ROTATION SPEED CONTROL

PURPOSE OF A SPEED GOVERNOR

The purpose of the speed governor is to keep constant the rotation speed in all operating conditions.

In more distinct terms, it can be said that it must ensure :

At a stabilized working speed : the operation at the prescribed rotation speed without fluctuation.

In transient condition :

- the lowest possible variation of the rotation speed,
- the fastest possible return to the nominal stabilized speed.

And these characteristics must be ensured in all operating conditions (even if the variation of the receiver load is "extreme", i.e. sudden and important).

PRINCIPLE OF OPERATION

The speed governor must permit to ensure the following functions :

Speed detection

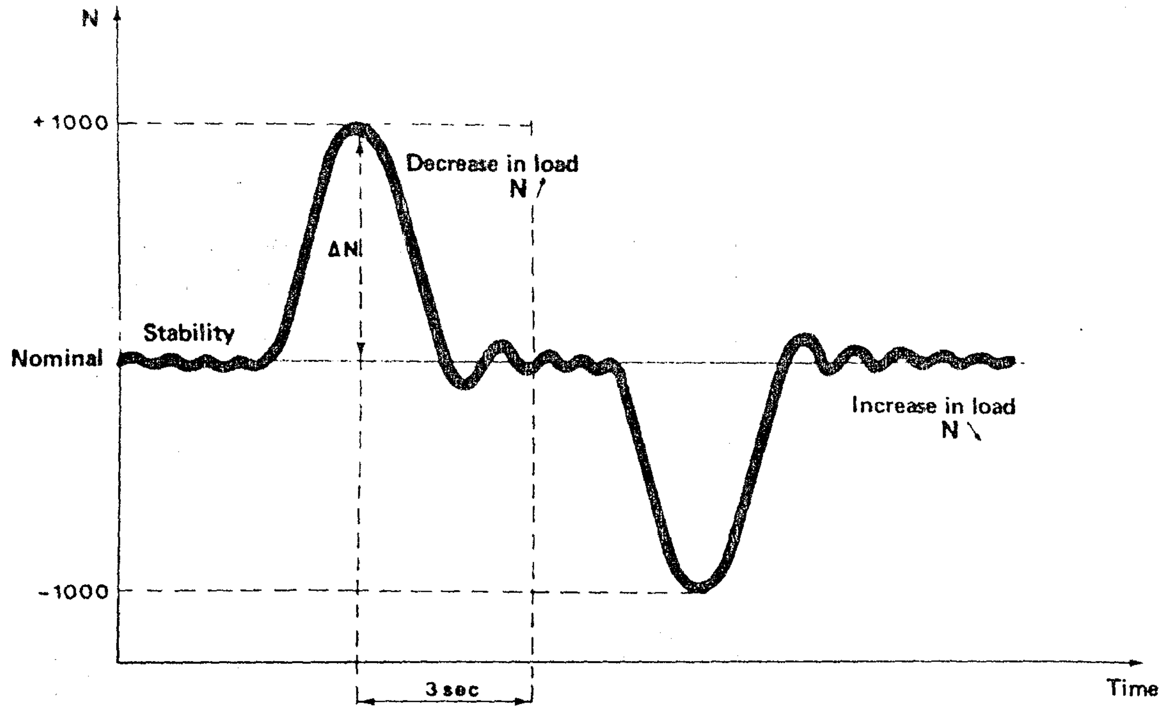
It must be very sensitive. To ensure this function, an engine driven flyweight device is generally used.

Correction of the fuel flow

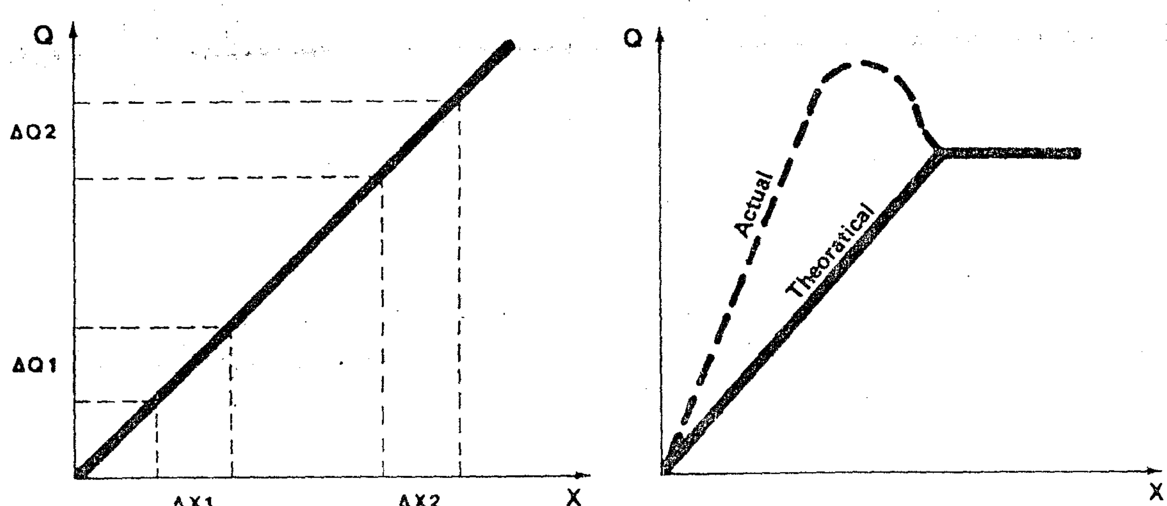
The correction of fuel flow must be proportional to the detection, swift and accurate. It is generally carried out by means of a fuel metering valve. The position of this fuel metering valve determines the fuel flow, and a certain displacement must correspond to a certain variation of fuel flow.

TYPES OF SPEED GOVERNOR

Prior to study the ARTOUSTE III speed governor, the following pages deal with : the mechanical speed governor, the hydromechanical speed governor.



CURVE ILLUSTRATING RPM VARIATIONS



X : Metering valve displacement
Q : Fuel flow

FUEL FLOW CURVES

MECHANICAL SPEED GOVERNOR

Description

The rotation speed detection is ensured by means of a "flyweight device" driven by the engine.

The correction of fuel flow is ensured by means of a fuel metering valve actuated by the flyweight device.

A spring called "opposing" stands against the centrifugal force of the flyweight device.

A control system acting on the spring tension enables to choose a governed rotation speed.

Operation

In "stabilized" condition, the centrifugal force of the flyweight device is balanced by the spring strength. The metering valve stands in a position which meters the fuel flow.

In "transient" condition, the balance between the centrifugal force and the spring strength is broken. The metering valve moves to ensure the change in fuel flow allowing the return to the rotation speed determined by the setting of the speed governor.

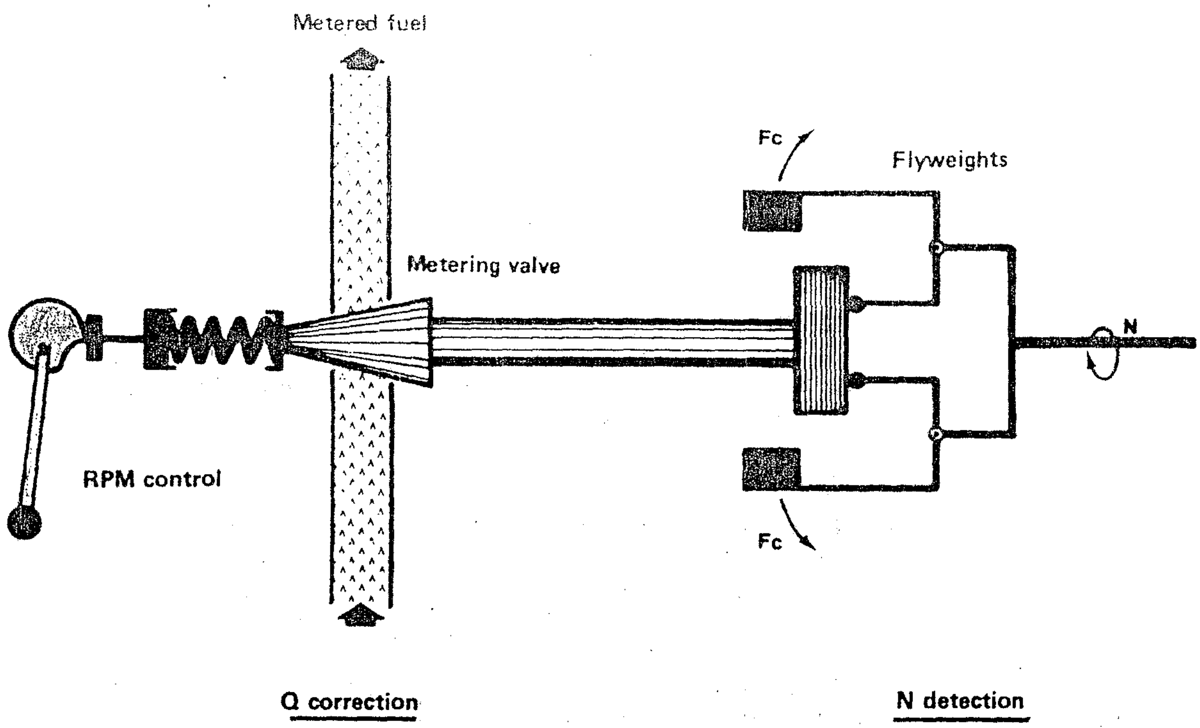
The passage in "transient condition" can be initiated either by acting on the control system or by a variation of the rotation speed (resulting from a variation of the "engine load" for instance).

By variation of rotation speed, it must be distinguished between dynamic variation (variation in transient condition) and the static variation (variation from an operating point to another).

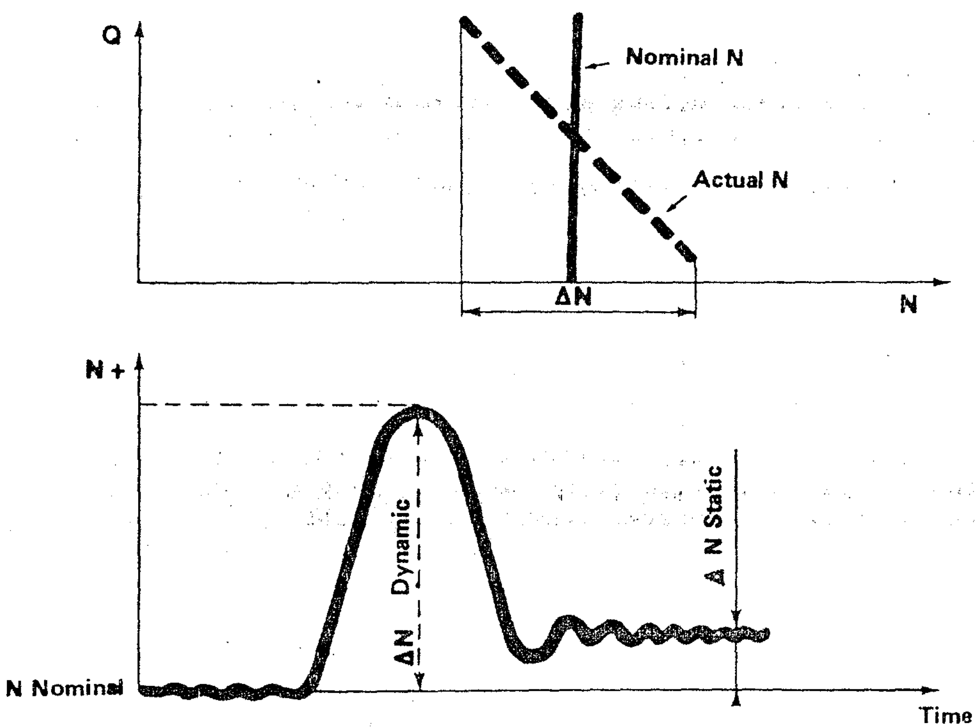
Drawbacks of this type of speed governor

This type of speed governor (proportional) has a static variation of the nominal rotation speed.

Moreover, the direct control of the fuel metering valve may introduce fluctuations.



SCHEMATIC DIAGRAM OF A MECHANICAL SPEED GOVERNOR



CURVES ILLUSTRATING N VARIATIONS

HYDROMECHANICAL SPEED GOVERNOR

Description

It is a speed governor hydraulically assisted.

The rotation speed detection is ensured by a flyweight device driven by the engine.

The control of the fuel metering valve is ensured by means of a hydraulic system including :

- a supply pump
- a distributing spool valve
- a working piston integral with the metering valve
- various channels.

Operation

In stabilized condition the centrifugal force of the flyweight device balances the strength of the opposing spring.

The distributing spool valve is in "neutral" position, and the orifices for oil passage are blanked.

The supply pump operates in "closed" circuit (return to suction through the valve).

The metering valve is in a position determining the fuel flow required to obtain the nominal speed.

In transient condition the balance between the centrifugal force and the spring is broken.

The distributing spool valve moves and opens the orifices allowing the pressure delivery to control the metering valve.

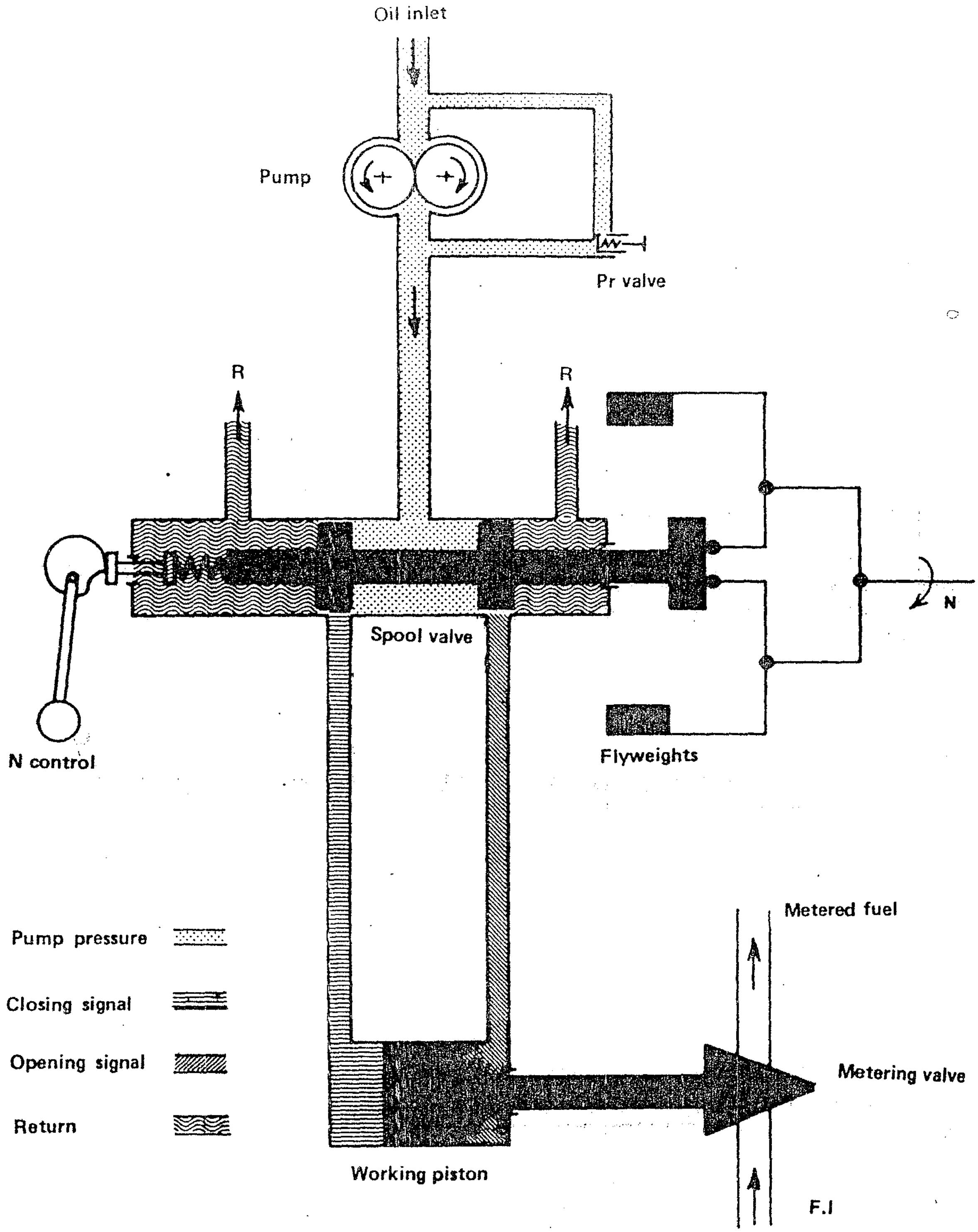
The metering valve moves and ensures the fuel flow correction allowing the return to the nominal speed.

When the nominal speed is restored, the distributing spool valve comes back to neutral position and the metering valve stops its displacement.

Drawbacks of this type of speed governor

The hydraulic control of the metering valve is much more supple than in case of a simple mechanical speed governor, but nevertheless certain drawbacks remain (particularly oscillations and very long return to stabilized condition after a variation).

To improve the operating characteristics, it is necessary to provide such a speed governor with a damping device.



SHEMATIC DIAGRAM OF A HYDRAULICALLY ASSISTED SPEED GOVERNEOR

ARTOUSTE III ISOCHRONOUS SPEED GOVERNOR

...ODUCTION

The ARTOUSTE III fuel control unit is a speed governor hydraulically assisted and provided with a damping device ; it is properly called isochronous governor (isochronous = equal time).

Its purpose is to keep a sole rotation speed practically constant in all operating conditions by metering the engine fuel flow. It must ensure :

- during stabilized condition the operation at the prescribed rotation speed without fluctuation.

- during transient condition
  - the lowest possible speed variation,
  - a fast return to stabilized nominal speed.

GENERAL DESCRIPTION

The speed governor is installed on the support casing at the right lower section and it is driven by the lower train of accessory drive at a speed of : N/8.69.

Its hydraulic supply is ensured by the oil of the lubricating system taken at the oil pump outlet.

It consists of the following components :

- a speed detection system composed of two flyweights standing against an opposing spring.

- an oil pump of gear type which delivers the pressure required for the hydraulic system ; it is provided with a pressure relief valve.

- an oil distributing device which consists of a distributing spool valve and of a sleeve.

- a working piston integral with the fuel metering valve.

- some pipes ensuring the oil and fuel circulation.

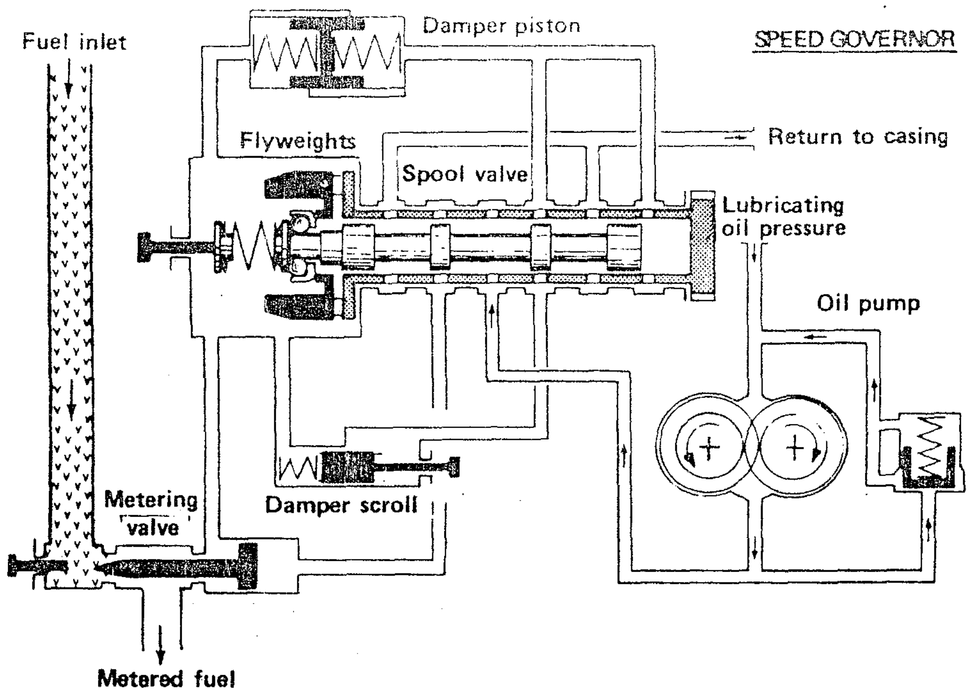
- damping components consisting of a damping piston and of an isochronous scroll.

- a fuel metering device which consists of a metering needle integral with the working piston.

- adjusting devices

- a casing assembly made of light alloy and assembled by means of screws.

SPEED GOVERNOR



SPEED GOVERNOR SCHEMATIC DIAGRAM

Pressure

Closing

Opening

Return

Fuel (pump pressure)

Metered fuel

Speed detection system

The rotation speed detection is carried out by means of a pair of flyweights. The flyweights are rotated by the speed governor shaft, the oil pump and the sleeve of the oil distributing device.

The centrifugal force of the flyweights stands against a spring (called opposing spring) with adjustable tension.

The forces (spring on one side and centrifugal on the other side) determine the position of the oil distributing spool valve.

Oil pump

The oil pump of the speed governor delivers the pressure required to operate the hydraulic system. It is a gear type pump supplied with lubricating oil and whose delivery pressure is controlled by a pressure relief valve.

It is driven by a "shear shaft" and its driven pinion drives in its turn the oil distributing sleeve and the flyweights.

Oil distributing system

The purpose of the system is to ensure the distribution of the oil under pressure delivered by the pump.

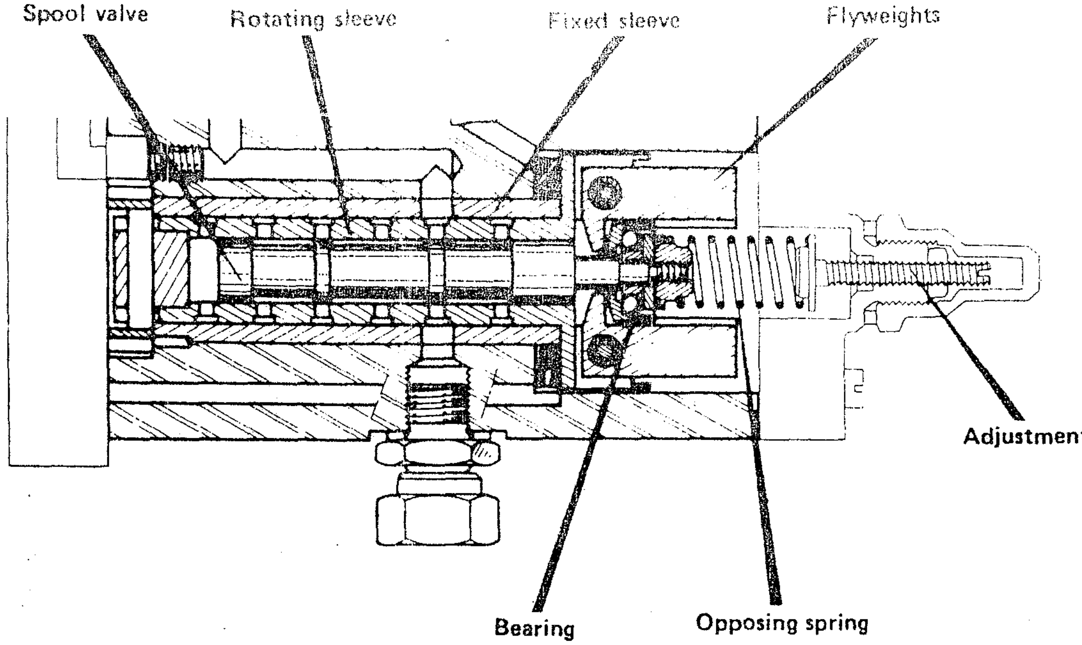
It incorporates a distributing spool valve provided with shoulders sliding inside a sleeve fitted with oil passage orifices. The spool valve moves axially under the action of the centrifugal force of the flyweights and the sleeve is rotated by the driven pinion of the oil pump.

Working piston

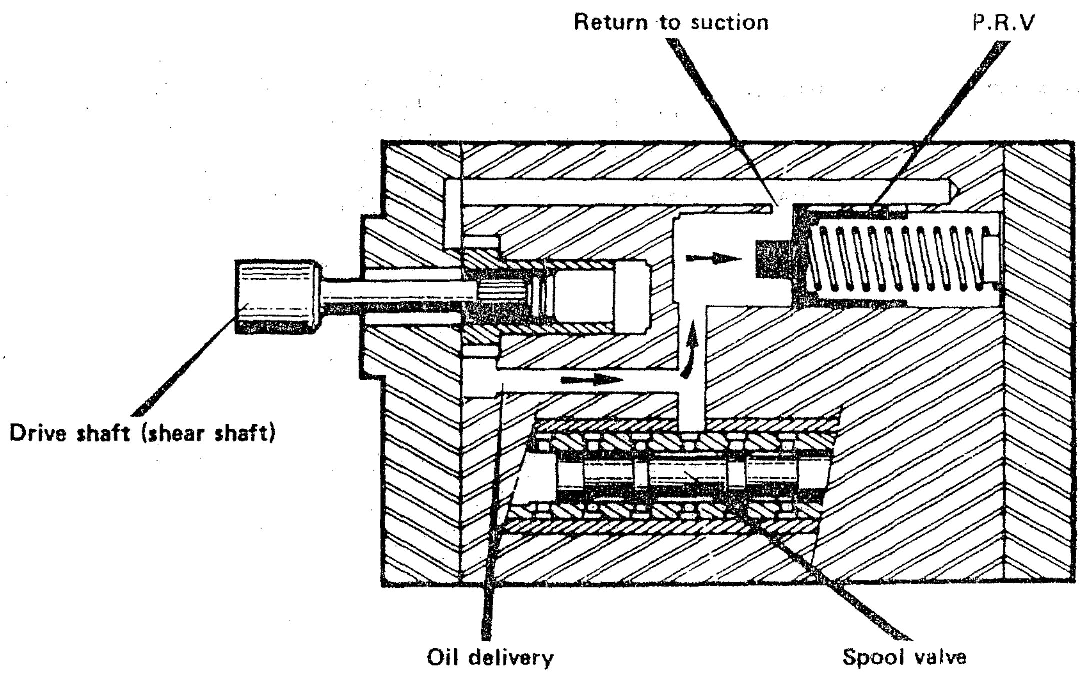
Actuated by oil pressures on each side of its faces, it controls the metering valve which is integral with it.

Channels

The body of the speed governor includes many lines allowing oil and fuel passage. Moreover, the body is provided, on its external section, with : the fuel inlet union, the fuel outlet union and, on its front flange, the orifices for oil inlet and outlet.



ROTATION SPEED DETECTION SYSTEM – OIL DISTRIBUTING SYSTEM



OIL PUMP DRIVE – VALVE

Damping components

The purpose of the damping components is to damp the displacements in order to ensure the characteristics of the isochronous speed governor. They consist of :

- the damping piston

It is a piston, each face of which is subjected to springs of same tension. It slides in a cylinder provided with ports for oil passage.

When the oil pressures are identical on each side of the piston, the latter is in neutral position and the ports are closed.

When the oil pressure becomes greater in one of the two chambers, the piston moves and opens one of the ports, thus allowing the oil passage from one chamber into the other.

In this configuration, the force of the released spring decreases and the force of the compressed spring increases ; in addition, and due to the flow, the pressures tend to counterbalance themselves.

By reason of these two facts, the piston has then a tendency to come back to neutral position and thus to stop the oil flow.

This action, possible in both directions, is progressively carried out. It allows the damping of the displacements of the working piston, i.e. the metering valve (see operation of the isochronous speed governor).

- the isochronous scroll

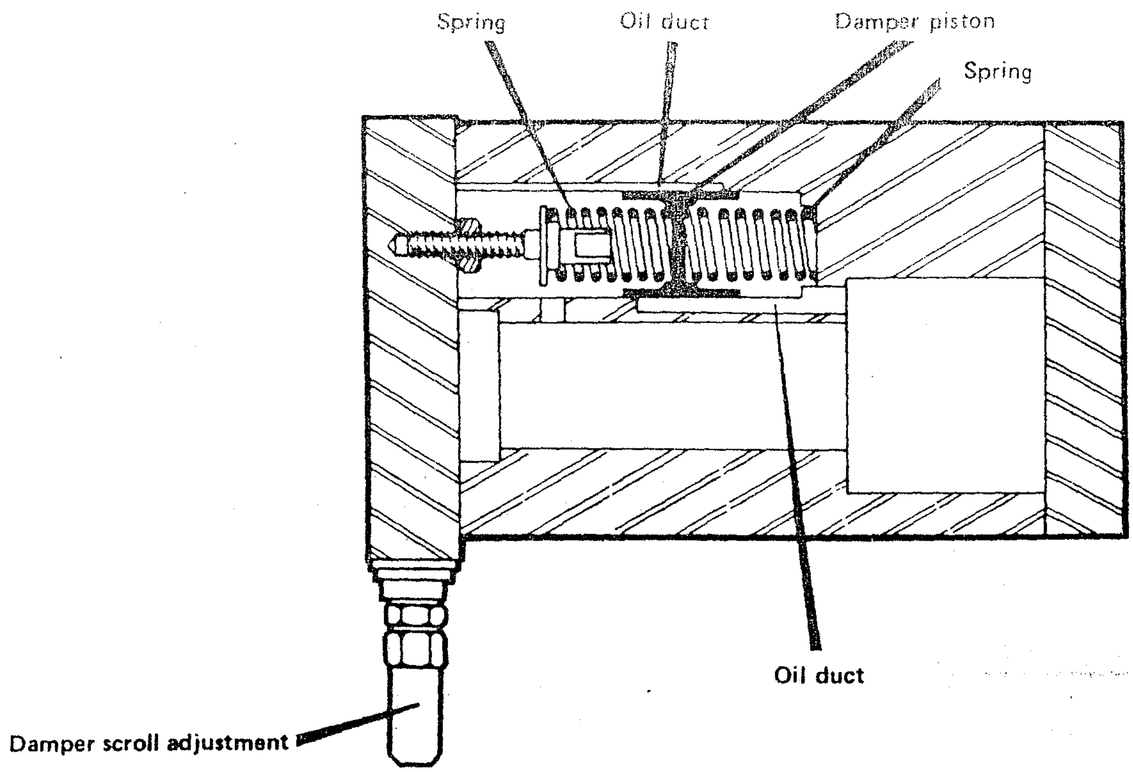
The purpose of the scroll is to equalize the oil pressures of the oil system.

It forms a restriction in the oil flow which controls the working piston.

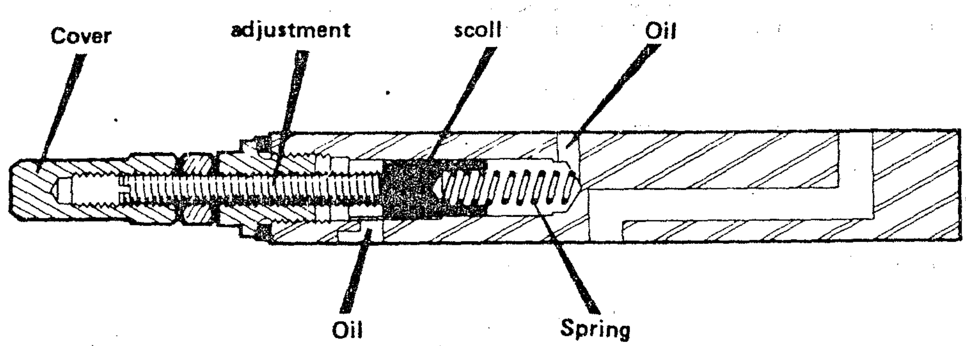
It consists of a threaded cylinder maintained in the body between a spring and an adjusting screw.

The oil flows between the body and the cylinder, and the number of splines in which the oil passes, determines the time required to equalize the pressures.

The adjusting screw emerges outside the speed governor body ; it is protected by a cap.



DAMPER PISTON



DAMPER SCROLL

Fuel metering device

The fuel metering device consists essentially of a metering needle which determines a fuel passage section in a diaphragm.

The metering valve is integral with the working piston sliding in a cylinder and subjected to oil pressures of control.

The displacements of the metering valve are limited in the opening direction by an internal mechanical stop, and in the closing direction by an adjusting stop.

The fuel enters through an external union located on the front flange of the speed governor, it flows into the orifice between the diaphragm and the metering valve and then goes through an internal channel towards the outlet union located on the side of the speed governor body.

Adjusting devices

The speed governor is provided with the following adjusting devices :

- rotation speed adjustment

  It consists of a screw allowing the modification of the flyweight opposing spring calibration.

- isochronous scroll adjustment

  It consists of a screw allowing the modification of the restriction formed by the scroll.

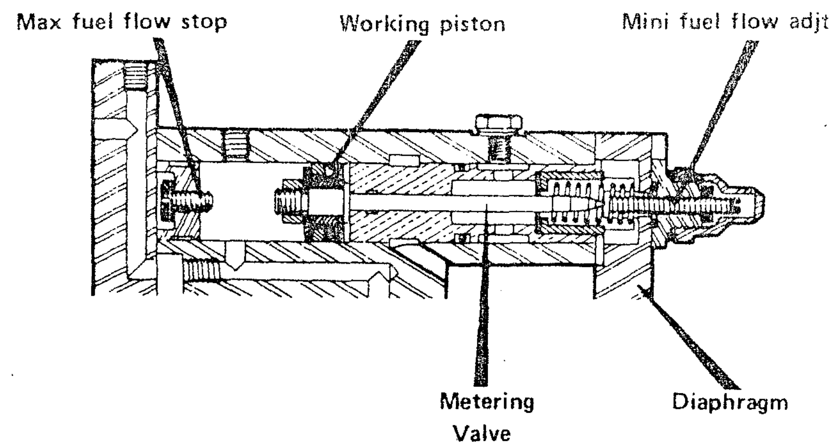
- adjustment of the metering valve min. stop

  It is a screw with adjusting stop which limits the displacement in the closing direction of the fuel metering valve.

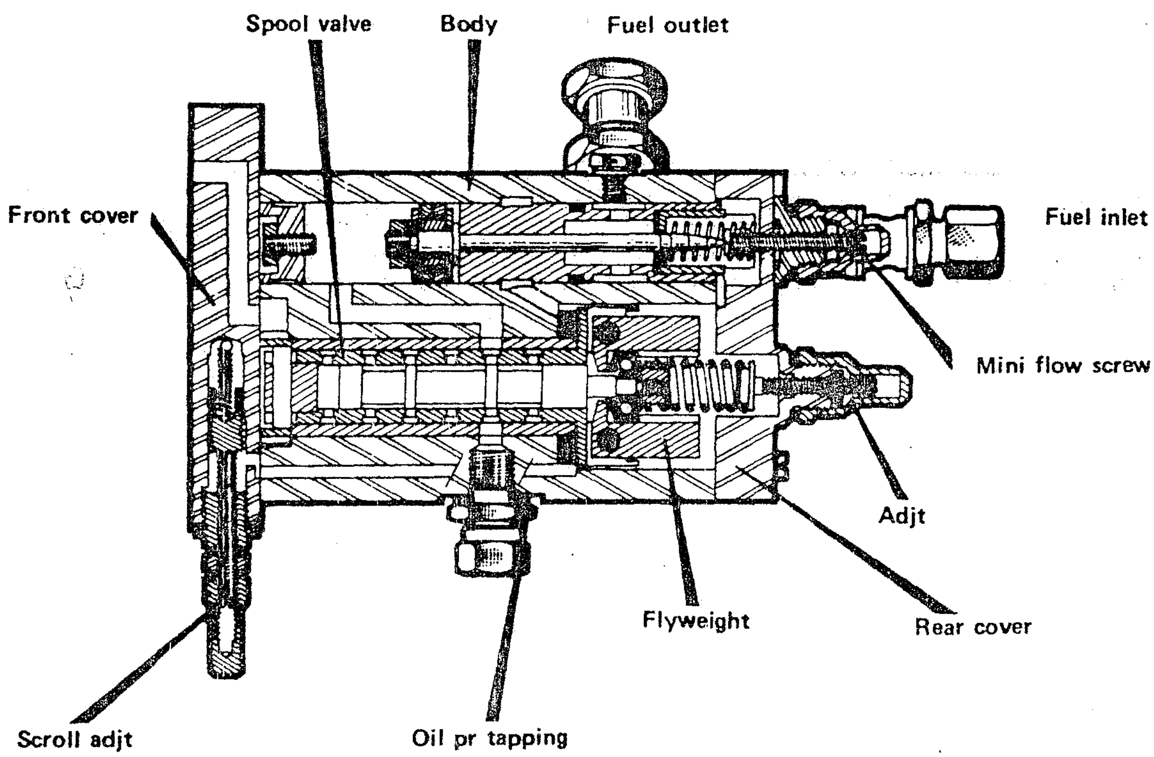
Casing assembly

The assembly is composed of a front flange, a main body and a rear flange.

These three assemblies are made of light alloy and they are assembled by means of screws.



FUEL METERING SYSTEM



SPEED GOVERNOR CUT–AWAY

OPERATION OF THE ISOCHRONOUS SPEED GOVERNOR

Introduction

The operation of the speed governor is covered through the following conditions :

- position of the speed governor during engine starting
- speed governor entering into operation (taking over)
- stabilized condition
- transient condition
- operating limitations.

Position of the speed governor during engine starting

The rotation speed is "low" and consequently the strength of the opposing spring is greater than the centrifugal force of the flyweights.

The oil distributing spool valve allows oil supply to metering valve opening as soon as the pump delivers pressure.

During starting, the metering valve is then in a position of "full opening".

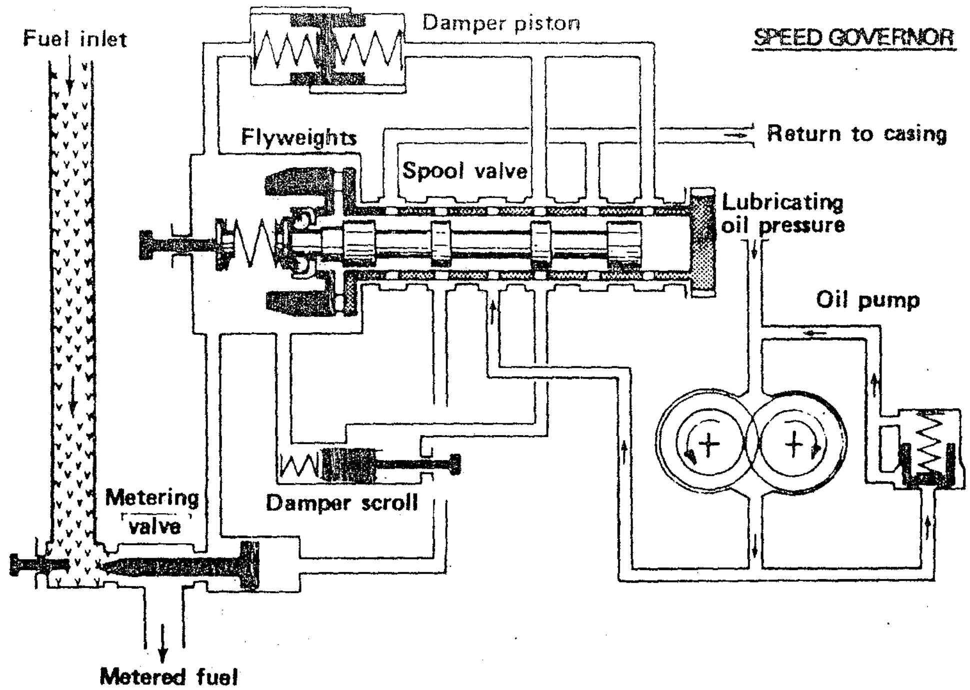
Entering into operation (taking over)

When (after starting has been carried out and during acceleration) the engine reaches the value of nominal rotation speed, the centrifugal force of the flyweights comes and balance the spring strength, and the spool valve moves towards the "neutral" position. At this very moment (theoretically) the metering valve is still fully opened.

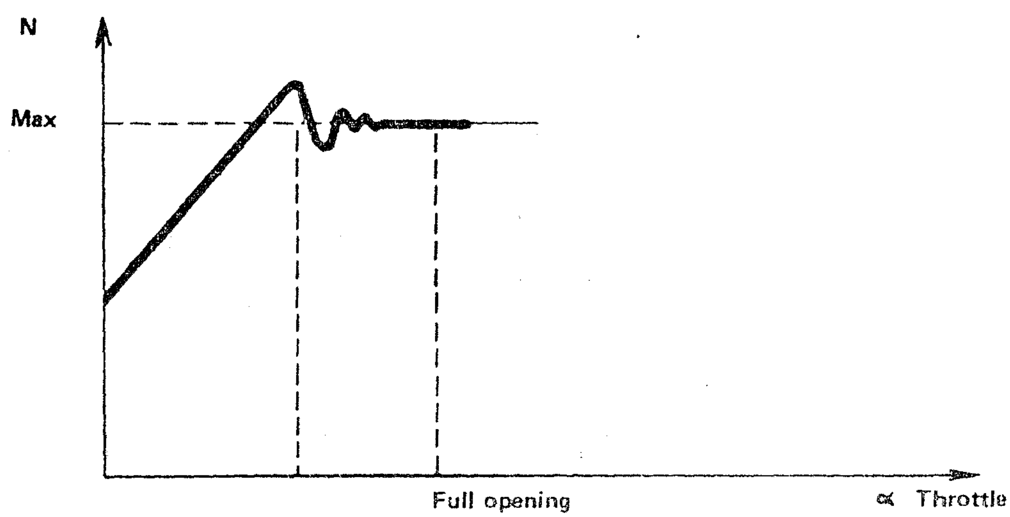
Nevertheless, during acceleration, the increase in flow causes an override of the nominal speed. The balance is then broken (the centrifugal force becoming greater than spring strength), and the distributing spool valve is displaced. The oil pressure enters the metering valve closing system in order to decrease the fuel flow, and to restore the nominal rotation speed.

From this moment, the speed governor "takes over" the "fuel flow control".

This phase of operation is indicated by a very clear and characteristic fluctuation of the tachometer indicator.



SPEED GOVERNOR SCHEMATIC DIAGRAM



FUEL FLOW CONTROL – PRINCIPLE

Stabilized condition

In this case, the engine torque balances the resisting torque, and the engine runs at a constant rotation speed.

The centrifugal force of the flyweights balances the strength of the opposing spring and the oil distributing spool valve is in neutral position.

The pressures on each side of the working piston are equalized and the metering valve is in fixed position which determines the fuel flow required to balance the torques.

Transient condition - general

Variation of very low magnitude

The slightest speed variation is detected. The distributing spool valve moves very slightly. The oil pressure delivered is very low and it is not sufficient to cause the metering valve displacement (this is due to the damping device). Thus it is possible to avoid too frequent fuel flow corrections leading to speed fluctuations.

More important variation

A more important variation of rotation speed occurs in case of breaking of the balance between the engine torque and the resisting torque.

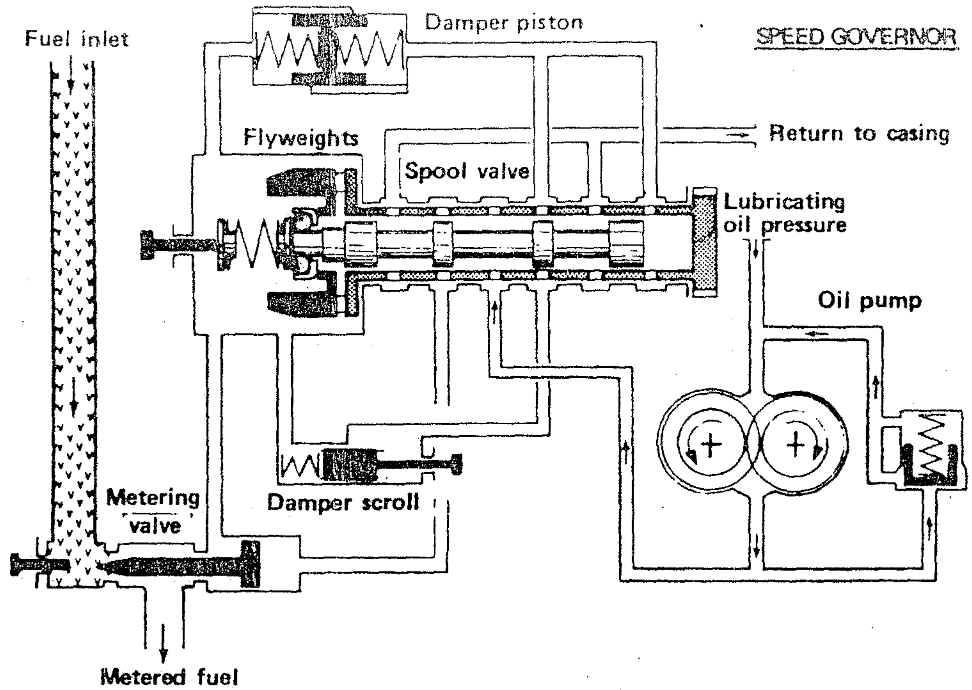
The fuel flow control must operate in order to prevent too important a variation of rotation speed and to restore the nominal rotation speed as soon as possible.

It is clearly obvious that the speed variation will depend upon the importance and the rapidity of the load variation.

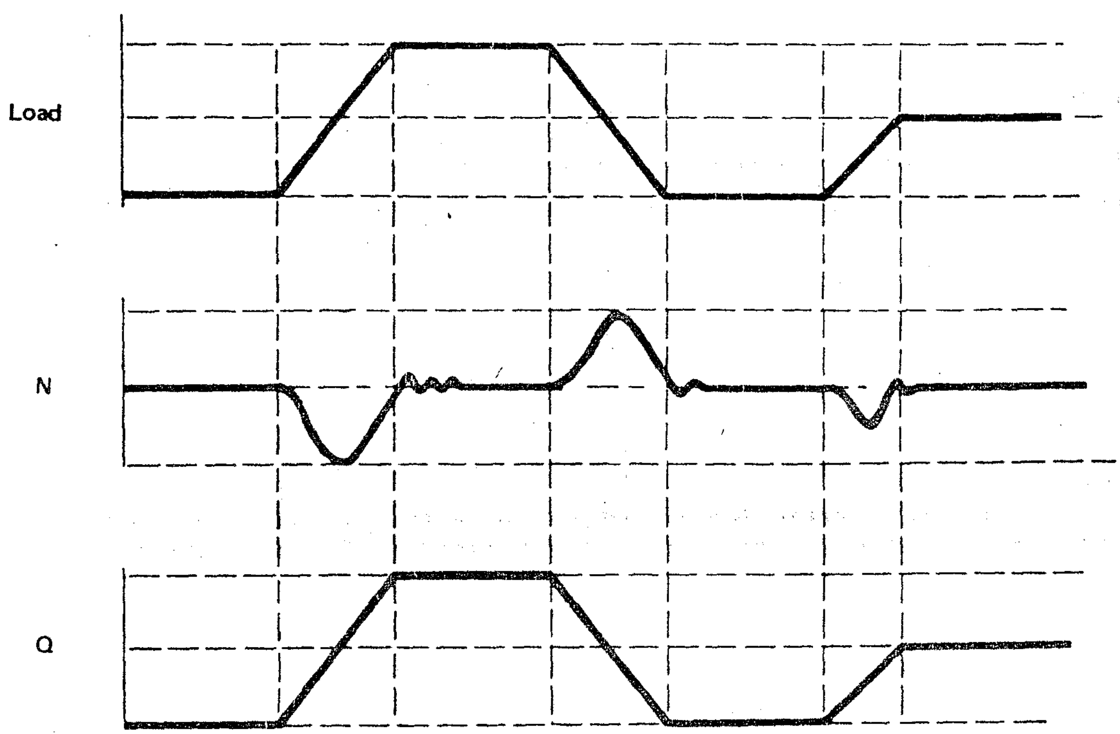
Nevertheless the speed governor must "respond" correctly in all operating cases of the receiver.

Two cases of transient condition are to be considered :

- loading condition (decrease in rotation speed)
- unloading condition (increase in rotation speed).



SPEED GOVERNOR SCHEMATIC DIAGRAM



FUEL FLOW CONTROL – PRINCIPLE (Stabilized and transient conditions)

Transient condition - increase in rotation speed

The centrifugal force of the flyweights becomes greater than the opposing spring strength.

The distributing spool valve moves and opens the oil passage ports in the sleeve.

The pump oil pressure is delivered to the metering valve closing system (direct supply to the working piston).

The oil being in the opening system returns to suction through the isochronous piston and through the isochronous scroll.

The fuel metering valve moves in the closing direction.

The fuel flow decreases, the engine torque decreases and balances the resisting torque.

The rotation speed stops increasing and comes back to its nominal value.

The oil pressures become progressively equal by reason of the isochronous piston action, the isochronous scroll action and of the return to neutral of the distributing spool valve.

The isochronous piston comes progressively back to its neutral position (by reason of the pressure equalization and the effect of the springs).

The isochronous scroll allows, in a determined time, the pressure equalization.

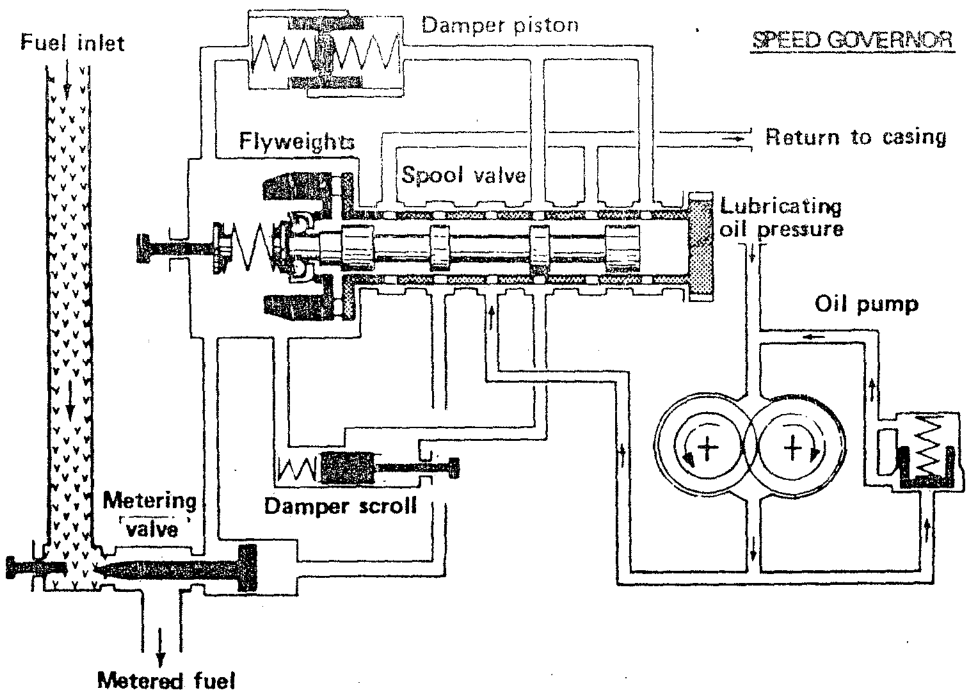
Thus the metering valve displacement is first slowed down and finally stopped before the return to the balance position. This "damping" permits a quick return to stabilized nominal speed.

In short

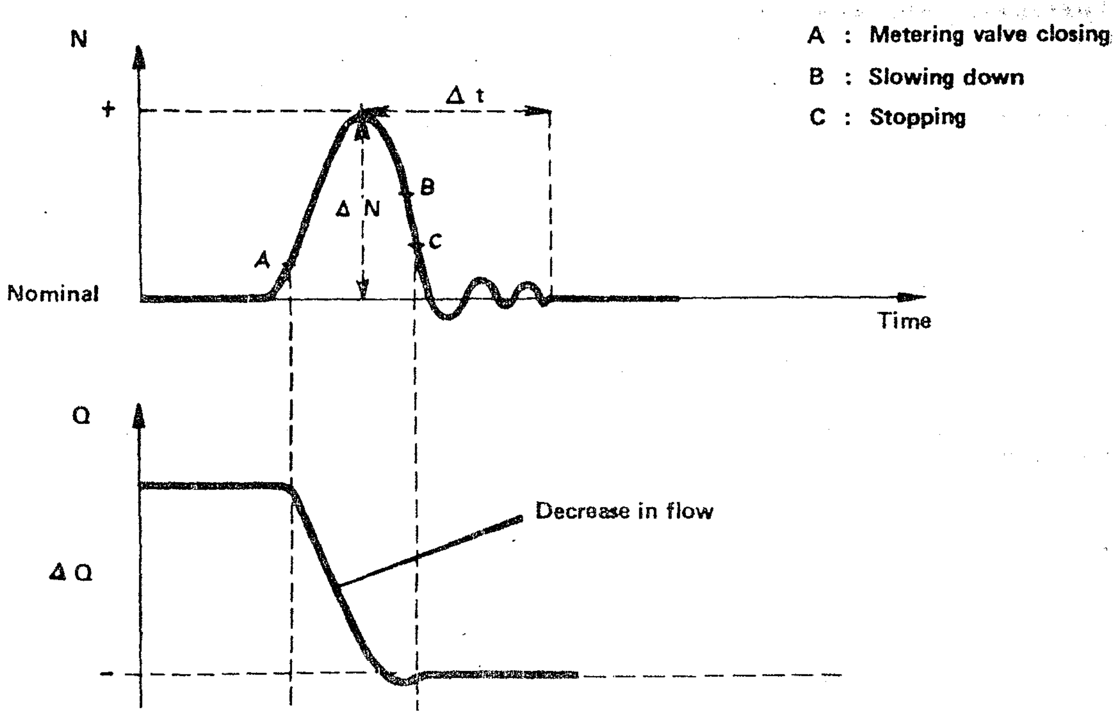
There is first, an action of quick correction of the fuel metering valve (in order to avoid too important a speed variation).

Then a "slowing down" of the fuel metering valve displacement.

The metering valve stop before the return to the balance position (return to stabilized nominal speed).



SPEED GOVERNOR SCHEMATIC DIAGRAM



FUEL FLOW CONTROL – PRINCIPLE – Increase in rotation speed

Transient condition - decrease in rotation speed

The centrifugal force of the flyweights becomes greater than the strength of the opposing spring.

The distributing spool valve moves and opens the oil passage ports in the sleeve.

The pump oil pressure is delivered in the metering valve opening system (supply through the isochronous piston and the isochronous scroll).

The oil being in the closing system is returned to pump inlet directly through the orifice opened in the sleeve.

The fuel metering valve moves in the opening direction.

The fuel flow increases, the engine torque increases and comes and balance again the resisting torque.

The rotation speed stops decreasing and comes back to its nominal value.

The oil pressures become progressively equal by reason of the action of the isochronous piston, of the isochronous scroll and of the return to the neutral position of the oil distributing spool valve.

The isochronous piston comes progressively back to its neutral position (by reason of the pressure equalization and the effect of the springs).

The isochronous scroll allows, in a determined time, the oil pressure equalization.

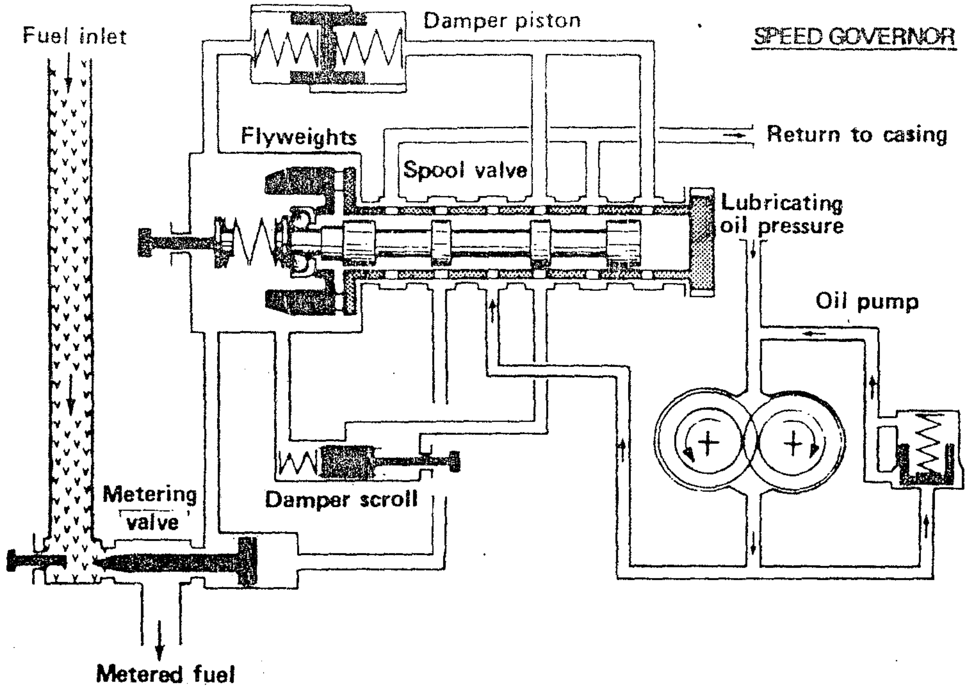
Thus the metering valve displacement is first slowed down and finally stopped before the return to the balance position. This damping permits a quick return to stabilized nominal speed.

In short

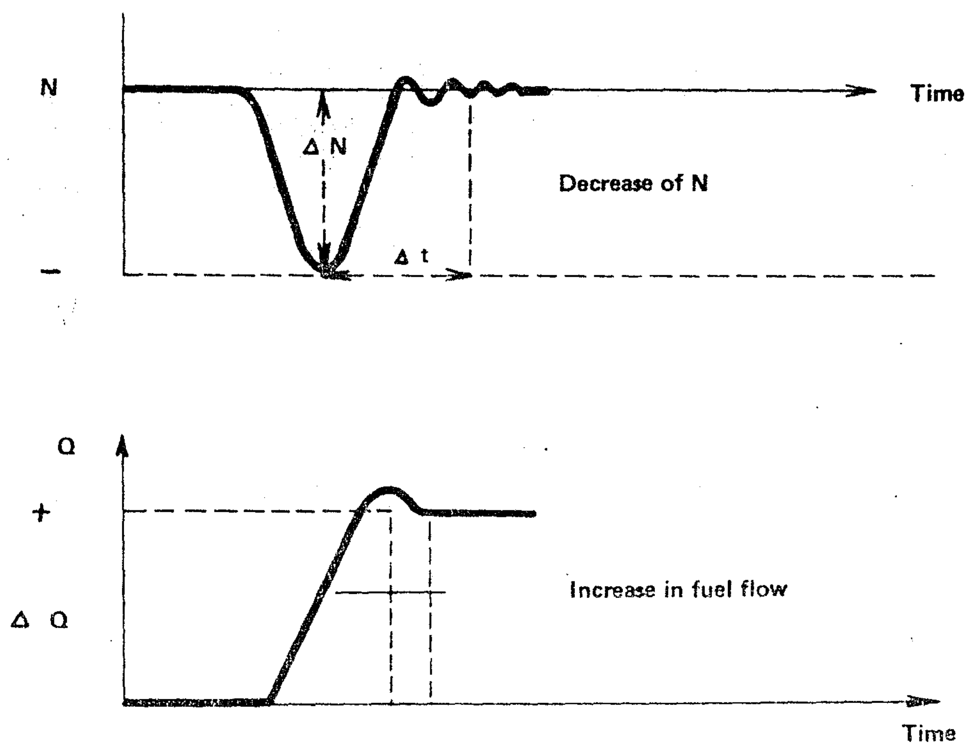
There is first an action of quick correction of the fuel metering valve (in order to avoid too important a speed variation).

Then a "slowing down" of the metering valve displacement.

The metering valve stop before the return to the balance position (quick return to the stabilized nominal speed).



SPEED GOVERNOR SCHEMATIC DIAGRAM



PRINCIPLE OF FUEL FLOW CONTROL – DECREASE OF N

Operating limitations

The speed governor must be able to ensure the engine operation within specified limits.

Rotation speed

The rotation speed in stabilized condition (called nominal speed) must be steady and its value must be : 33,500 RPM $\pm$ 200.

The rotation speed variation in transient condition must not exceed 1,000 RPM (i.e. more or less 1,000 RPM around the nominal speed whatever be the case of transient condition).

The restoration of the stabilized nominal speed after a transient condition must be made within less than 4 seconds.

Minimum fuel flow limitation

This limitation corresponds to the full closing of the fuel metering valve. It is determined by an adjustable stop screw and required by the risk of flame out in the combustion chamber with too low a fuel flow.

The limit can be reached only in cases of extreme condition of operation (overspeed, operation at very high altitude).

Maximum fuel flow limitation

This limitation corresponds to the full opening of the fuel metering valve. Then it represents the maximum power which can be produced by the engine. It is determined by an internal stop which limits the fuel metering valve displacement in the opening direction.

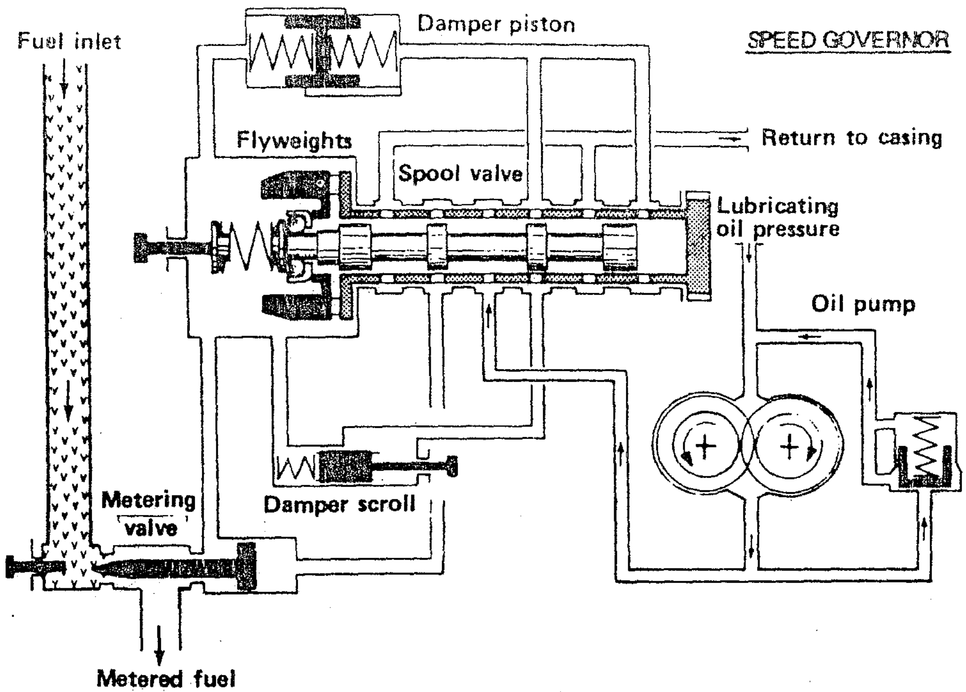
The limitation is required by the maximum load of engine and it can be reached only in a case of extreme operating condition. Beyond this limit, the engine can no longer adapt itself to the receiver and there is a risk of drop in rotation speed and surging.

Oil temperature limitation

The characteristics of the oil affect the operation of the speed governor.

It is particularly necessary to make sure of an oil temperature higher than 10° C before applying power.

It is also necessary to carry out the characteristic checks with an oil temperature which is high enough. Do not forget that the temperature affects the characteristics and particularly the governed rotation speed (the speed decreases when the temperature increases).



SPEED GOVERNOR SCHEMATIC DIAGRAM

- Pressure
- Closing
- Opening
- Return
- Fuel (pump pressure)
- Metered fuel

MAINTENANCE OF THE ISOCHRONOUS SPEED GOVERNOR

Characteristics

- Nominal rotation speed .... 33,500 RPM $\pm$ 200
- Max. variation in transient condition.. $\pm$ 1,000 RPM
- Time for return to stabilized condition:4 sec. max.
- Min. oil temperature (to apply power).. 0° C
- Oil temperature for check .... 40° C to 60° C
- Speed governor driving speed N/8.89
- Max. fuel flow (limit) ....
- Min. fuel flow (limit) ....
- Speed governor pump oil pressure ...... about 8 b

Servicing and maintenance

In service, check the operating characteristics of the speed governor (i.e. nominal speed, speed variation and time for speed restoration in transient condition).

Respect the oil temperature limitation and the operating envelope of the receiver. Take due note of the possible "overrides" and take the necessary steps.

No periodic and field maintenance except for the usual visual inspections.

Check-out procedures

In service (especially during an inspection), check the characteristics by watching the engine parameters.

For an accurate check of the rotation speed value, it is possible to install a mechanical tachometer on the drive provided on the accessory drive upper train.

Of course, check the rotation speed during a ground run test, and take all the usual precautions.

Take into consideration the reduction ratio of the spare drive and that of the adaptor for reading. With the tachometer drive ref. 99990639, reduction ratio 1/4.206, the speed must be within 7,917 RPM and 8012 RPM.

Adjustments

Rotation speed adjustment

Make sure of an accurate rotation speed indication (see check with hand tachometer).

Carry out speed check (and adjustment) with engine running and with an oil temperature high enough.

The adjustment is carried out on the adjusting screw at the end of the speed governor after the lock-nut of the screw has been unscrewed.

Warning - When the lock-nut has been unscrewed, never pull the screw-driver out of the screw slot, because the screw might be pushed out by the opposing spring (overspeed then possible).

Act on the screw in order to obtain the nominal rotation speed, screw in to increase the speed.

Isochronous scroll adjustment

It allows the adjustment of the fluctuations and of the speed governor operating characteristics.

Make sure that the fluctuations are not due to another cause that the scroll misadjustment.

Make sure of an accurate rotation speed indication (it is possible to measure the P2 air pressure by means of a pressure gauge connected to a tapping of the turbine casing).

Carry out the check with engine running by slowly acting on the adjusting screw. It is advisable to first unscrew the adjusting screw until fluctuations appear and then to screw in up to a better stability.

Note - If need be (e.g. for cleaning), it is possible to remove the isochronous scroll without disturbing the adjustment.

Minimum fuel flow adjustment

It is the adjustment of the fuel metering valve full closing stop.

It is strictly forbidden in field maintenance.

Fault analysis

Oil supply to the speed governor

A faulty oil supply to the speed governor may cause an unstable operation.(N fluctuations, overspeed, underspeed).

Do not forget the influence of oil temperature on the characteristics.

Clogging of the isochronous scroll

The obstruction leads to rotation speed fluctuations and to speed governor characteristics beyond limits. It is possible to remove and to clean the scroll without disturbing the adjustment.

Faulty sealing of the fuel metering valve

This fault causes "unstabilities" of fuel flow control and passage of fuel into oil (very rare case).

Faulty sealing of the rear cover

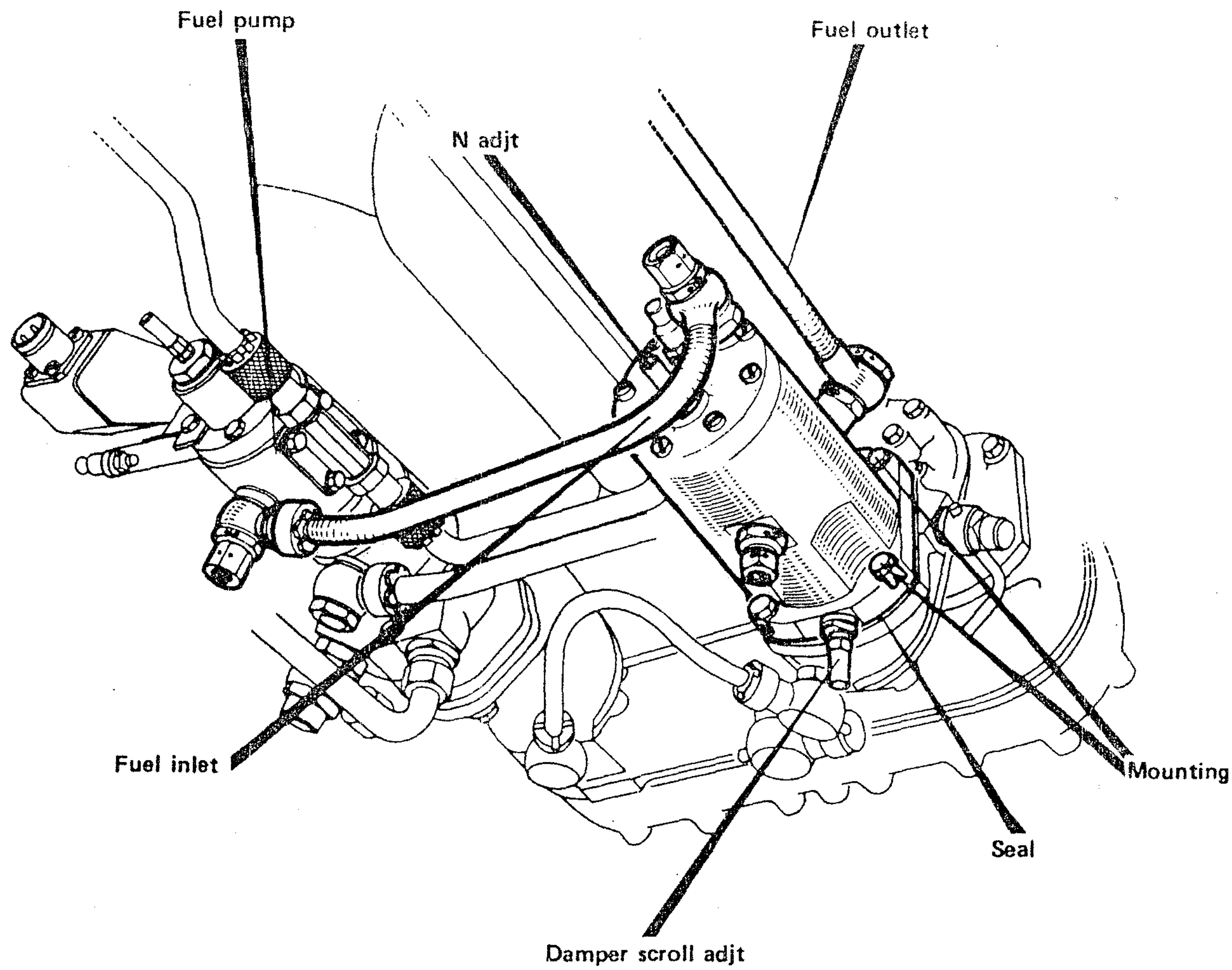
External leakage or passage of fuel into oil may occur.

Driving shaft rupture

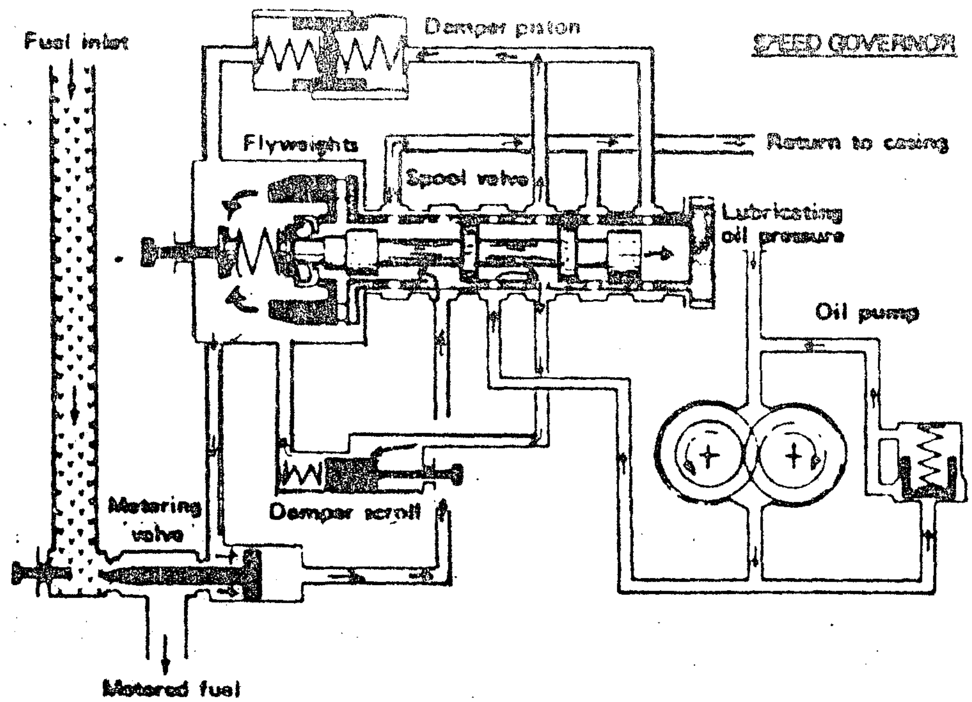
Risk of overspeed.

Practical works

- Locating
- Rotation speed check
- Rotation speed adjustment
- Isochronous scroll adjustment
- Installation and removal of the speed governor
- Removal of the isochronous scroll.

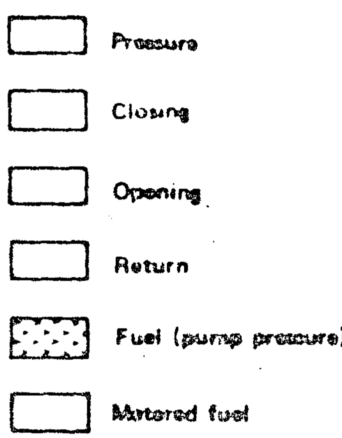


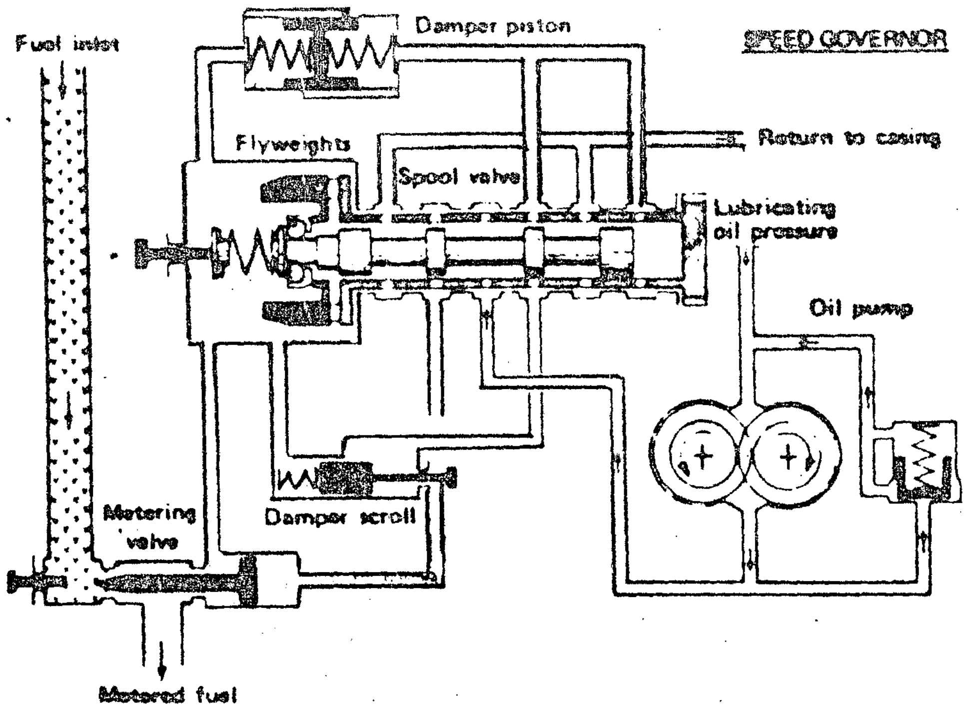
SPEED GOVERNOR – EXTERNAL VIEW



SPEED GOVERNOR SCHEMATIC DIAGRAM

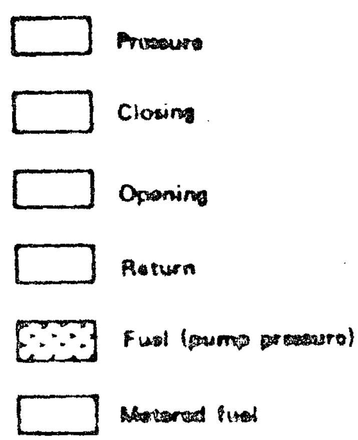
DECREASE IN ROTATION SPEED

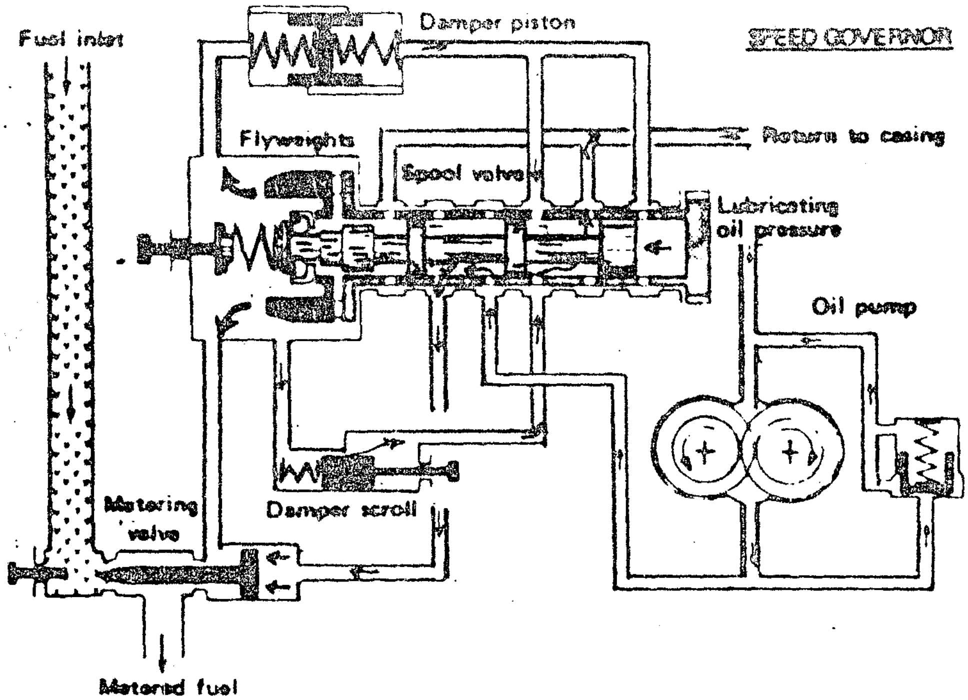




SPEED GOVERNOR SCHEMATIC DIAGRAM

NOMINAL CONDITION





SPEED GOVERNOR SCHEMATIC DIAGRAM

INCREASE IN ROTATION SPEED

- Pressure
- Closing
- Opening
- Return
- Fuel (pump pressure)
- Metered fuel

NOTES