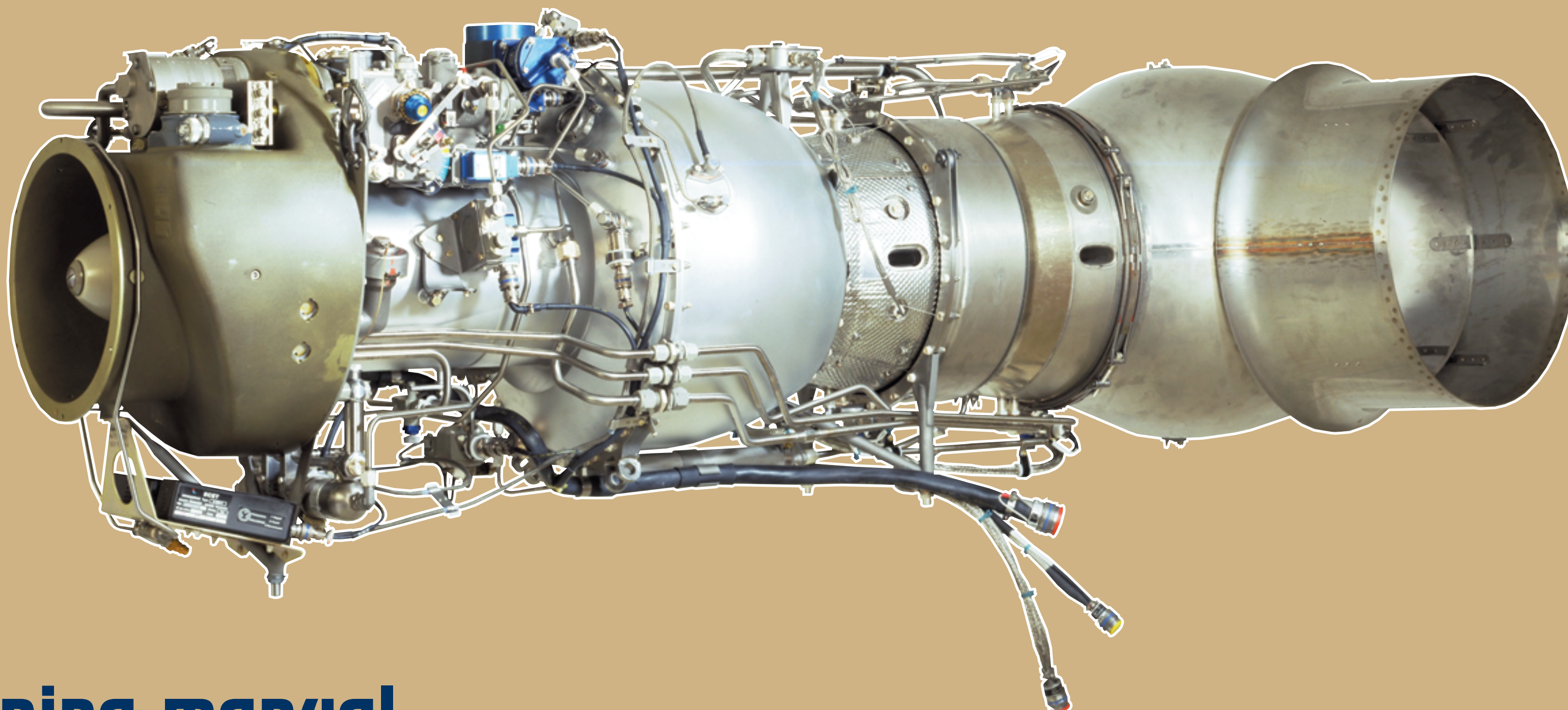
MAKILA 1A2

TURBOSHAFT ENGINE



Training manual

March 2000

Ref.: X 298 H2 960 2

Turbomeca
snecma group

FOREWORD

This document provides, in a teaching form, all the information required for the operation and the maintenance of the MAKILA 1A2 Turboshaft engine, for training purposes only.

It will not be updated, and if required, modifications will be included in a new issue.

TURBOMECA Training Centre

SUMMARY

TABLE OF CONTENTS

For training purposes only

TABLE OF CONTENTS

(CONTINUED)

TABLE OF CONTENTS

(CONTINUED)

TABLE OF CONTENTS

(CONTINUED)

This training manual is established to meet training requirements and takes into consideration, to a certain extent, ATA 104 specifications.

This document has 591 pages. It was produced using a desktop publishing system.

LIST OF ABBREVIATIONS

The abbreviations / symbols shown below may be used during training :

A/C	Aircraft
AC	Alternating Current
ARMS	Automatic Recording Monitoring System
ACW	Anti-clockwise
AEO	All Engines Operating
ATA	Air Transport Association
BITE	Built In Test Equipment
C	Torque
CFT	Frequency/Voltage Converter
CH	Fuel consumption
CW	Clockwise
DC	Direct Current
DECU	Digital Engine Control Unit
DGAC	Direction Générale de l'Aviation Civile
Ec	Kinetic energy
EGT	Exhaust Gas Temperature
FAA	Federal Aviation Agency
FADEC	Full Authority Digital Engine Control
FCU	Fuel Control Unit
FOD	Foreign Object Damage
FWD	Forward
G	Mass air flow
HE	High Energy
HP	Horse Power
HP	High Pressure
HUMS	Health and Usage Monitoring System
ID	Identification
IFDS	Integrated Flight Display System
ILS	Integrated Logistic Support
ISA	International Standard Atmosphere
ISV	Servo-valve intensity
LRU	Line Replaceable Unit
LTT	Learning Through Teaching
LVDT	Linear Voltage Differential Transducer
MAX	Maximum
MCP	Max Continuous Power
MCQ	Multi Choice Questionnaire
MGB	Main gearbox

LIST OF ABBREVIATIONS

(CONTINUED)

MIN	Minimum
MTBF	Mean Time Between Failure
MTBUR	Mean Time Between Unscheduled Removal
MTCP	Maintenance Test Control Panel
N	Rotation speed
N1	Gas generator rotation speed
N2	Power turbine rotation speed
NMD	Navigation and Mission Display
NOVRAM	Non Volatile Random Access Memory
NR	Rotor rotation speed
OVSP	Overspeed
OEI	One Engine Inoperative
P	Pressure
P2	Compressor outlet pressure
PH	Oil pressure
POS	Position
PT	Power Turbine
Q	Fuel flow
RAM	Random Access Memory
ROM	Read Only Memory
RTD	Resistive Temperature Device
SFC	Specific Fuel Consumption
SI	International System
T/O	Take-Off
TBO	Time Between Overhaul
TET	Turbine Entry Temperature
TM	Turbomeca
t°	Temperature
t4	Gas temperature
t°H	Oil temperature
W	Power
Z	Altitude
Zp	Pressure altitude
cc/h	Cubic centimetres per hour
dB	Decibel
°C	Degrees Celsius
°F	Degrees Fahrenheit
°K	Degrees Kelvin
ft	Feet
Hz	Hertz
kHz	Kilohertz
kPa	Kilopascal

LIST OF ABBREVIATIONS

(CONTINUED)

kW	Kilowatt
lb	Pound
lb/hr	Pound per hour
lb/sec.	Pound per second
lb/HP.hr	Pound per Horse Power per hour
m	Metre
mA	Milliampere
MHz	Mega Hertz
mm	Millimetre
mV	Millivolt
PSI	Pound per Square Inch
PSIA	Pound per Square Inch Absolute
PSID	Pound per Square Inch Differential
PSIG	Pound per Square Inch Gauge
RPM	Revolutions Per Minute
Shp	Shaft horse power
t	Time
US G	US Gallon
VAC	Volt, Alternating Current
VDC	Volt, Direct Current
±	Min and max tolerance
±	Positive and negative for electrical circuits
Ω	Ohm
µP	Micro-processor
Δ	Difference
ΔP	Pressure difference
%	Percent
<	Is lower than
>	Is higher than

CONVERSION TABLE

Units	International System	British or American Systems
Length	1 mm 1 m	= 0.039 inch = 3.28 ft = 1.09 yard
Volume	1 dm^3 = 1 litre	= 0.26 US gallon
Mass	1 kg	= 2.2 lbs
Power	1 kW	= 1.34 HP
Temperature	° C ° K	= (°F-32). 5/9 = [(°F-32)5/9] + 273
Pressure	1 kPa = 0.01 bar	= 0.145 PSI
Flow (air, oil, fuel)	1 kg/s	= 2.2 lbs/sec.
Specific Fuel Consumption	1 g/kW.h	= 0.00164 lb/HP.hr

1 - INTRODUCTION

GENERAL INFORMATION

«The power of knowledge»

Adequate training is essential for obvious safety reasons, but also to reduce additional maintenance costs incurred by unjustified removals and excessive downtime.

"Greater knowledge leads to greater efficiency".

Objectives of training

The main objective is the acquisition of the knowledge required for the tasks to be achieved (know and know how).

Further information is also communicated to widen the skill and the experience of the trainee.

Training approach

- **Performance based training** with classroom sessions, student involvement, practical work and troubleshooting techniques
- **Training aids :** training manual, overhead projection, CBT,video, mock-ups and demonstration equipment
- **Experienced and formally** trained instructors.

Training Centre

The Training Centre is located in one of the buildings of TURBOMECA's TARNOS factory.

TARNOS .... 5 kms north of the BAYONNE - ANGLET - BIARRITZ district - Access by train (BAYONNE station), by plane (BIARRITZ-PARME airport), by road (A63 highway, TARNOS exit).

Address ...... TURBOMECA - 40220 TARNOS FRANCE

Telex 570 042

Telephone .. (33) 5 59 74 40 07 or 05 59 74 40 07

Fax .... (33) 5 59 74 45 15 or 05 59 74 45 15

E-mail .... centre.instruction@turbomeca.fr

The training centre is organized in order to answer to training demands (administration, training aids, instructors).

Training courses can also be conducted in subsidiaries or on site :

- by a resident instructor, in certain subsidiaries or approved training centres
- or by an instructor detached from TURBOMECA France in our subsidiaries or in the clients premises.

TRAINING

«The power of knowledge»

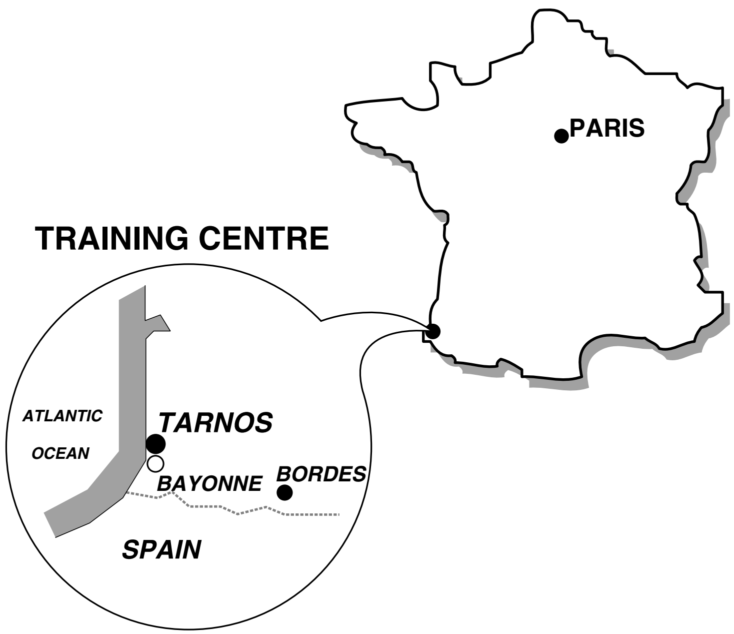
Adequate training is essential for obvious safety reasons, but also to reduce additional maintenance costs incurred by unjustified removals and excessive downtime.

"Greater knowledge leads to greater efficiency".

→ **OBJECTIVES OF TRAINING**

→ **TRAINING APPROACH**

TRAINING CENTRE



Training courses can also be conducted in subsidiaries or on site

GENERAL INFORMATION

TRAINING METHOD

The required knowledge is transmitted in such a manner that the student may use it efficiently in various circumstances.

The training is conducted in accordance with a process which considers :

- A phase of **explanation** for understanding
- A phase of **assimilation** leading to the complete acquisition and long-term retention of the knowledge.

Continuous checking of knowledge helps to ensure the information is assimilated. It is more a method of work than a testing in the traditional sense (refer to chapter 16).

The training method is a carefully balanced combination of :

- Lecture
- Discussions
- Exercises
- Practical work.

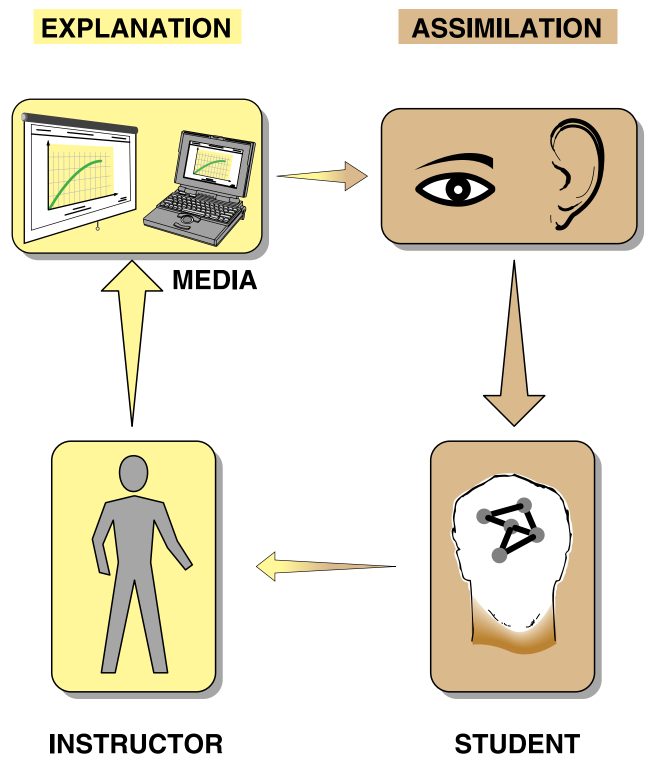
KNOWLEDGE TRANSMISSION, PHASES :

- Explanation
- Assimilation

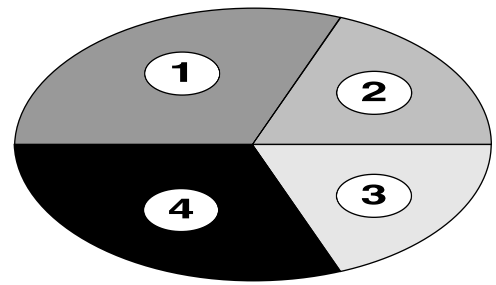
CHECKING OF KNOWLEDGE :

- Continuous checking, treated in chapter 16

KNOWLEDGE TRANSMISSION



TRAINING PROCESS



1 - LECTURE
2 - EXERCISES
3 - DISCUSSIONS
4 - PRACTICAL WORK

TRAINING METHOD

TRAINING METHOD

TRAINING AIDS

Training manual

The training manual is the basic source of information.

It contains, in a teaching form, all required information and explanations, following a layout derived from the ATA 104 standard, thus each subject is treated following a plan which allows the material to be adapted to different levels of training.

Typical plan :

- Generalities (function, position, main characteristics, main components)
- Description (general and detailed)
- Operation (phases, synthesis).

Other technical publications are also used during a course.

Overhead projection - Computer Aided Presentation

Overhead projection or Computer Aided Presentation is used to display the illustrations contained in the training manual (the instructor's explanations follow the manual).

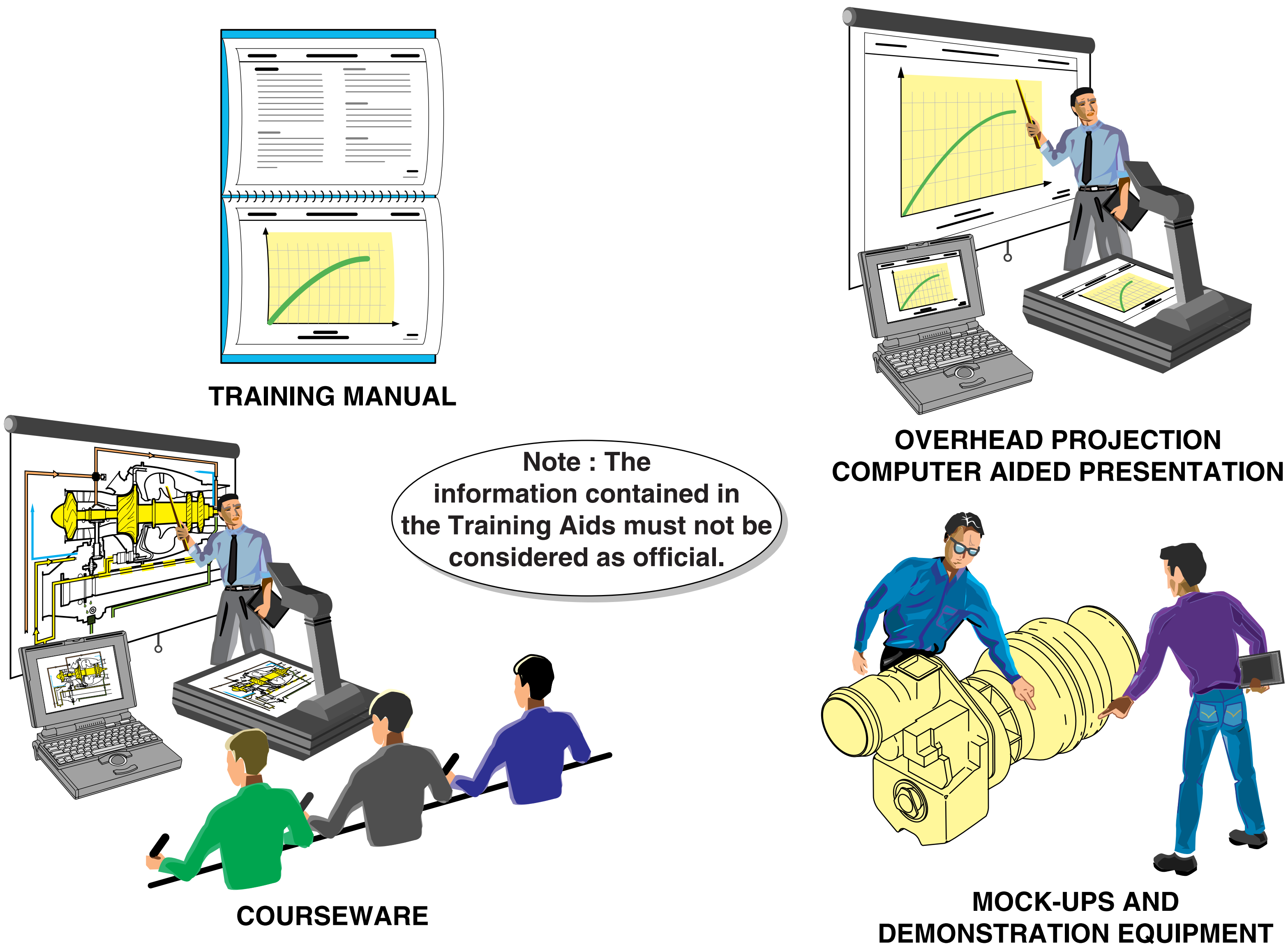
Courseware

Interactive computer based training is used to transmit information during a course and will be available for individual training. This multimedia system uses text, photos, illustrations, animation and video.

Mock-ups and demonstration equipment

Mock-ups and demonstration equipment are also used for component identification, procedure simulations, maintenance and practical work.

Note : *The information contained in the Training Aids must not be considered as official.*



TRAINING AIDS

TRAINING PROGRAMME

The **course programme** follows the manual. However, it should be noted that the "classroom sessions" alternate with periods devoted to demonstrations and practical work.

According to the contents, each session is mainly devoted to description and operation.

The engine maintenance aspect is mainly covered by the last part of the manual, which also deals with various elements related to maintenance (standard practices, technical publications, logistics and mainly fault analysis and fault finding).

Examples of programme :

The following pages provide examples of training programme :

- Familiarization course
- 1st line maintenance
- 2nd line maintenance
- 3rd line maintenance
- 4th line maintenance.

FAMILIARIZATION COURSE

Objective : At the end of this course, the student will be able to describe the engine, to explain its principle of operation and to identify the main components of the engine and systems.

Programme

FIRST DAY	- **Introduction** - **General presentation of the engine** - **Engine description** - **Engine systems**
SECOND DAY	- **Engine systems (continued)** - **Main aspects of maintenance** - **Revision - Checking of knowledge**

1st LINE MAINTENANCE COURSE

Objective : At the end of this course, the student will be able to identify the engine components, to describe and to explain the operation of the engine and its systems, to carry out 1st line maintenance procedures and to diagnose operating failures.

Programme

FIRST DAY	**- Introduction - General** **- Engine presentation - Engine description - Oil system**
SECOND DAY	**- Air system - Fuel system - Control system**
THIRD DAY	**- Engine indication - Engine start- Electrical system** **- Engine installation**
FOURTH DAY	**- Operating limitations and procedures - Various aspects of maintenance** **- Maintenance procedures - Troubleshooting - Fault analysis**
FIFTH DAY	**- Visits - Revision** **- Examination - Miscellaneous questions**

2nd LINE MAINTENANCE COURSE

Objective : At the end of this course, the student will be able to identify the engine components, to carry out all the 2nd line maintenance procedures (mainly the removal/installation of modules and shop replaceable unit).

Programme : The programme mainly includes practical work. This programme can be carried out after the 1st line maintenance programme.

FIRST DAY	- **Introduction** - **Revision (if this course is not conducted directly after the 1st line course)**
SECOND DAY	- **Removal of modules**
THIRD DAY	- **Removal of modules** - **Inspection and check of modules**
FOURTH DAY	- **Installation of modules**
FIFTH DAY	- **Installation of modules** - **Inspection and checks after installation**

3rd LINE MAINTENANCE COURSE

Objective : At the end of the course, the trainee will be able to carry out the 3rd line maintenance procedures (deep maintenance).

Programme :

FROM 3 DAYS TO 3 WEEKS ACCORDING TO THE PROCEDURES	**- Introduction** **- Definition of procedures** **- Practical work**

4th LINE MAINTENANCE COURSE

Objective : At the end of the course, the trainee will be able to carry out the specific tasks regarding the engine and related to his skills (eg : control system, assembly, machining procedures...).

Programme :

SEVERAL WEEKS	**- Introduction** **- Definition of procedures** **- Practical work**

2 - POWER PLANT

GENERAL PRESENTATION

Function

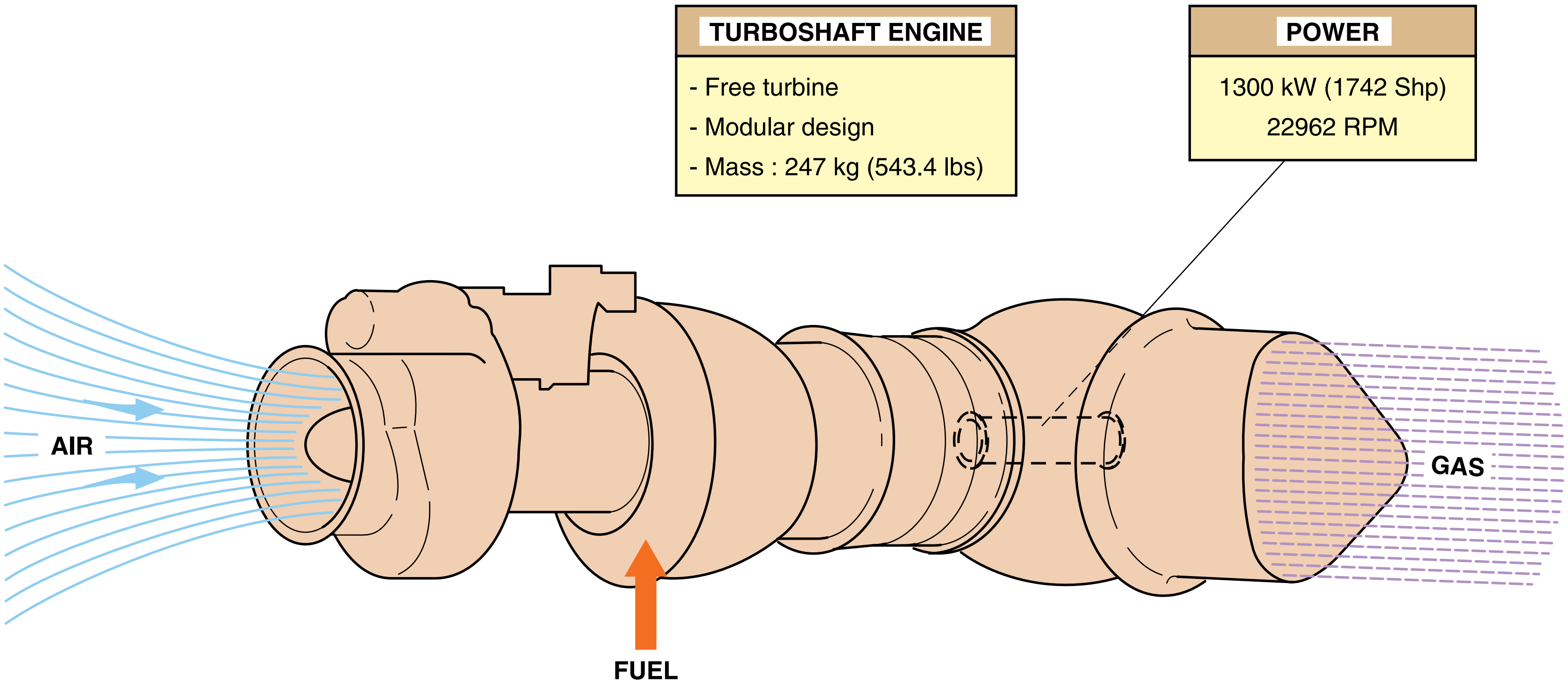
The engine provides mechanical power for the helicopter propulsion by transforming the energy contained in the ambient air and in the fuel into mechanical energy.

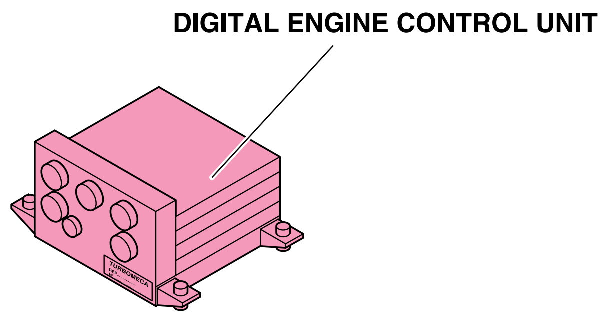
Main characteristics

- Type : free turbine turboshaft engine with rear direct power drive
- Design : modular
- Power : 1300 kW class (1742 Shp)
- Output shaft rotation speed : 22962 RPM
- Mass : 247 kg (543.4 lbs) with specific equipment and without fluid.

Main components

- Turboshaft engine with specific equipment
- Digital Engine Control Unit.





GENERAL PRESENTATION

ENGINE GENERAL DESCRIPTION

This description considers the engine main functional components.

Gas generator

- Annular air intake
- Three stage axial compressor
- Single stage centrifugal compressor
- Annular combustion chamber with centrifugal fuel injection
- Two stage axial turbine.

Power turbine

- Two stage axial turbine.

Exhaust pipe

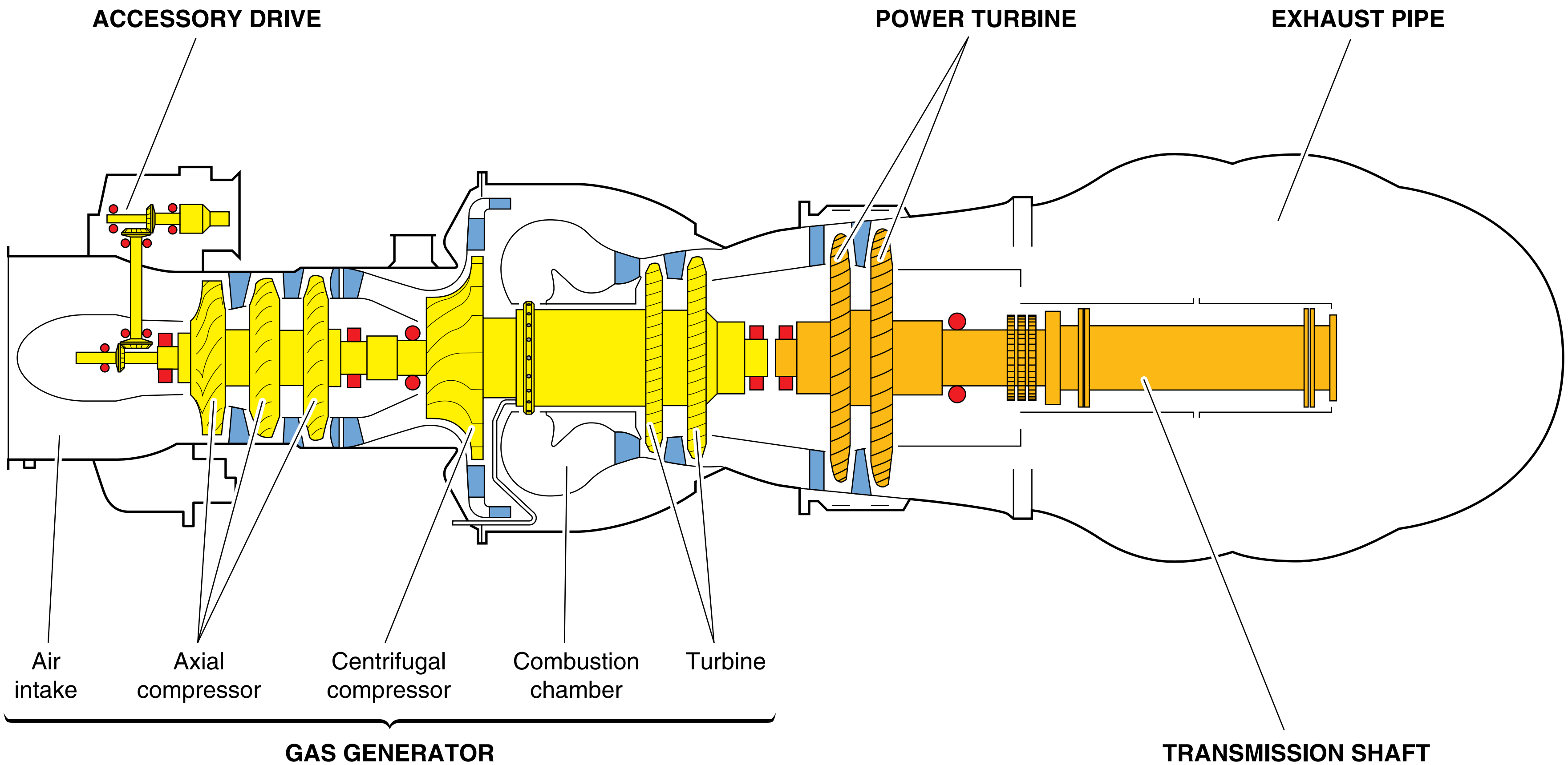
- Pipe with axial exhaust. It can be orientated to the left or to the right depending on the engine installation.

Transmission shaft

- Shaft (located in a linking tube) which connects the free turbine to the helicopter main gearbox.

Accessory drive

- Accessory drive train driven by the gas generator. The accessory drive train is located in the upper part of the air intake casing.



ENGINE GENERAL DESCRIPTION

ENGINE SYSTEMS - GENERAL DESCRIPTION

This description deals with the functions and systems of the engine, in a general way.

Oil system

The oil system lubricates and cools the engine components. Dry sump system. Synthetic oil. Integral tank and cooling unit. Pressure, temperature and magnetic plug indications.

Air system

Internal system to pressurise and cool engine internal parts. Accessory air supply system (ventilation of start injectors, control, bleed valve). Air supply to the aircraft.

Fuel system

Supply through gear type pump. Delivery through a metering unit and a valve assembly. Start injection through 2 simple injectors, main injection through centrifugal wheel.

Control system

Constant power turbine rotation speed. Acceleration control. Miscellaneous protection systems.

Mixed control system : digital electronic and hydromechanical.

Engine handling procedure

Entirely automatic, with manual reversion in the event of automatic control failure.

Engine indicating

Rotation speed. Gas temperature. Engine torque. Oil temperature and pressure. Miscellaneous indications. Monitoring system.

Starting

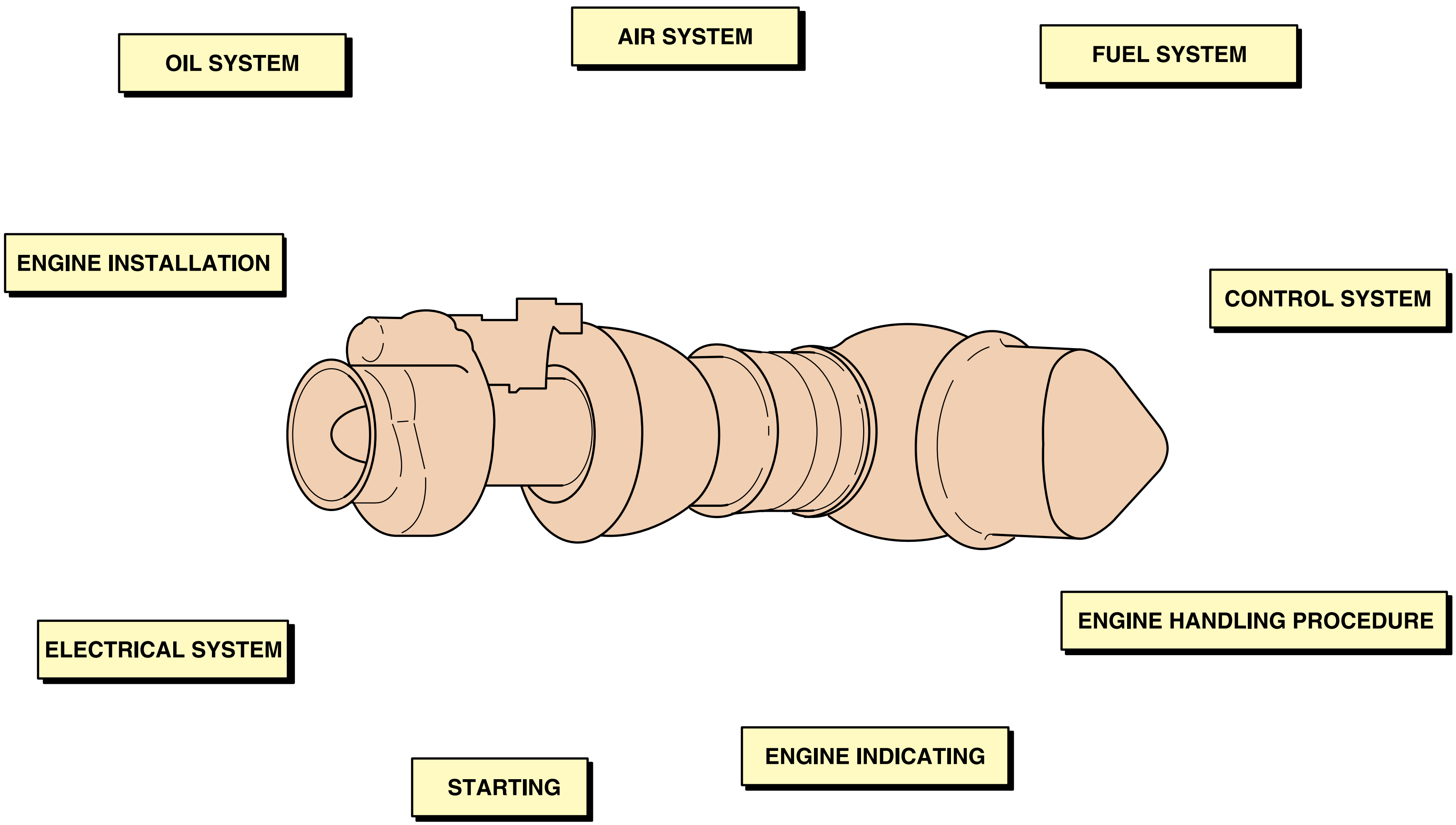
Cranking by an electrical starter. Ignition by High Energy ignition unit. Automatic start control. Manual starting is also possible.

Electrical system

Starting system. Control system. Indicating system. Overspeed system. Harness with three connectors.

Engine installation

- Interfaces designed for quick removal and installation of the engine
- Front and rear supports. Lifting rings
- Miscellaneous equipment.



ENGINE SYSTEMS - GENERAL DESCRIPTION

GENERAL OPERATION

This part deals with the basic functioning of the engine.

Gas generator

- Compression of the air in the axial and centrifugal compressors
- Combustion of the fuel/air mixture in the annular combustion chamber
- Gas expansion in the two stage turbine which drives the compressors and engine accessories.

Power turbine

- Expansion of the gas in the two stage turbine which drives the output shaft through the reduction gearbox.

Exhaust

- Discharge overboard of the gas, through the exhaust pipe.

Transmission shaft

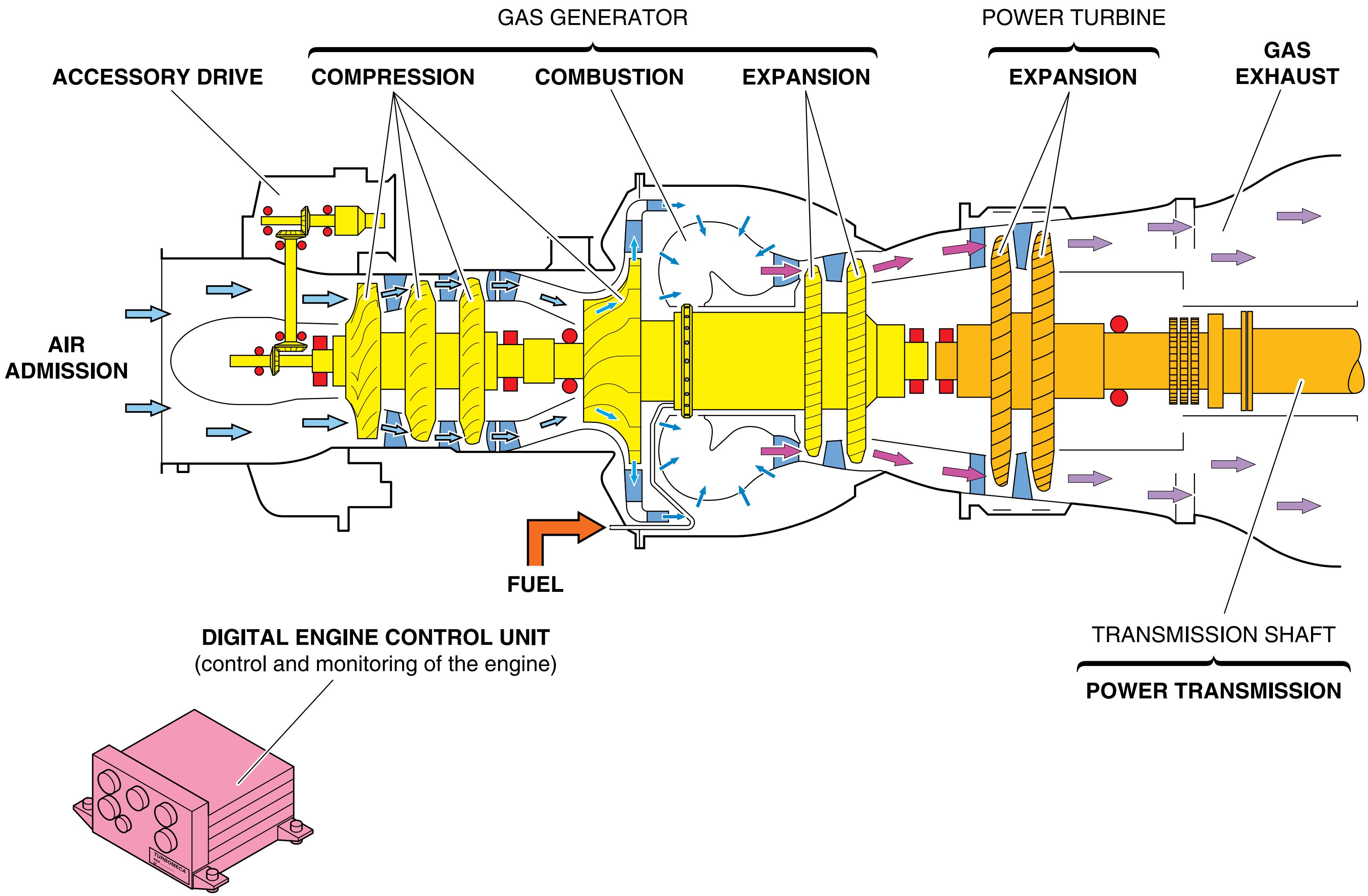
- Transmission of the power through a shaft driven by the power turbine.

Accessory drive

- Drive of the accessories by the gas generator through a bevel gear, a vertical drive shaft and a gear train.

Digital Engine Control Unit

- Control and monitoring of the engine operation.



GENERAL OPERATION

OPERATION - ADAPTATION

This part deals with the parameters and the adaptation of the gas generator and power turbine functional assemblies.

Component adaptation

For the engine operation, two functional assemblies can be considered :

- The gas generator which provides kinetic energy
- The power turbine which transforms the gas energy into mechanical power on a shaft.

The two assemblies have different rotation speeds.

Gas generator

The gas generator operation is defined by :

- The air mass flow G (air flow entering the engine)
- The air pressure P2 and air temperature t2 at the centrifugal compressor outlet
- The fuel flow Q injected into the combustion chamber
- The gas temperature TET at the turbine entry
- The rotation speed N1 of the gas generator
- The kinetic energy Ec supplied to the turbine.

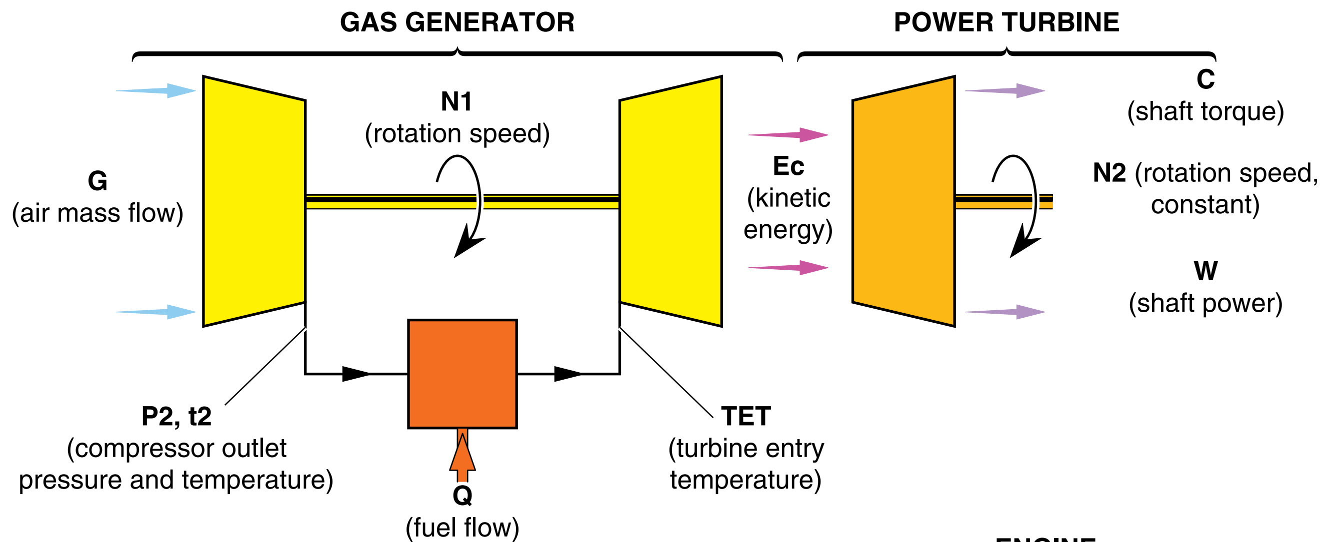
Power turbine

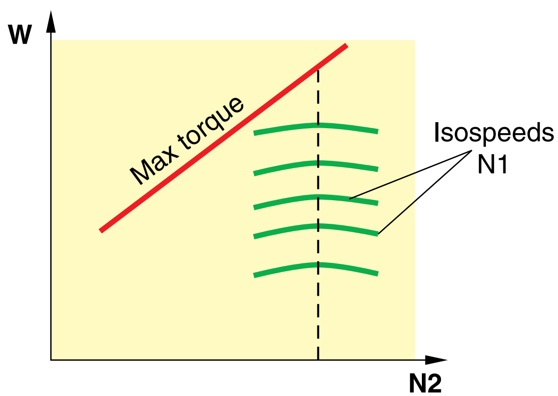
The power turbine operation is defined by the balance between the power received from the gas generator and the torque applied on the shaft ; that is : the torque C and the rotation speed N2.

Operation

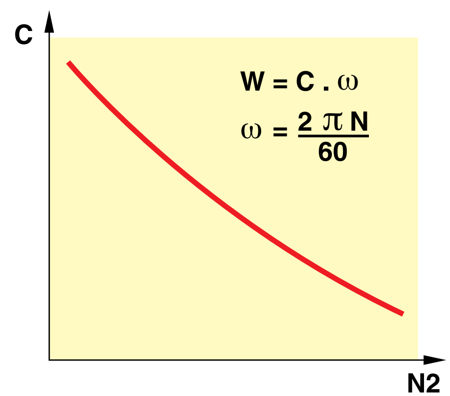
The operation is represented by the diagram below which shows the power W, the rotation speeds N1 and N2 and the max torque limit C imposed by the mechanical transmission.

- The torque C is a function of the N2 rotation speed (the torque is an inverse function of the speed)
- The power W is equal to the torque C multiplied by the angular velocity ω
- At constant N2 speed, the power is only a function of the torque
- The engine parameters can be represented as a function of a reference parameter ; N1 for example.



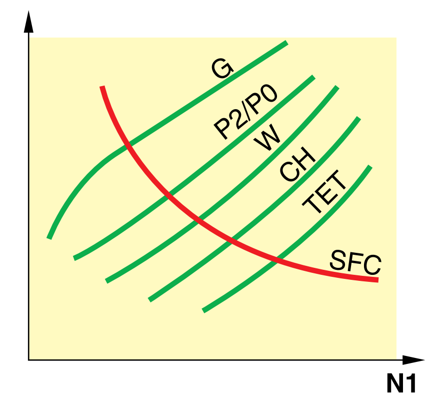


Power W and speeds N1, N2



Torque as a function of N2

ENGINE PARAMETERS



P2/P0: Compression ratio
CH : Hourly fuel consumption
SFC : Specific fuel consumption

COMPONENT ADAPTATION

OPERATION - ADAPTATION

PRINCIPLE OF ADAPTATION TO HELICOPTER

Power transmission

The mechanical power supplied by the engine, is used to drive the helicopter rotors through a mechanical transmission.

This power drives :

- The main rotor (approximately 82 %)
- The tail rotor (approximately 10 %)
- The main gearbox (approximately 8 %).

Twin engine configuration

In a twin engine configuration, the engines are installed in front of the main gearbox.

The power turbines of the two engines are mechanically connected to the main gearbox which drives the rotors (main and tail rotors).

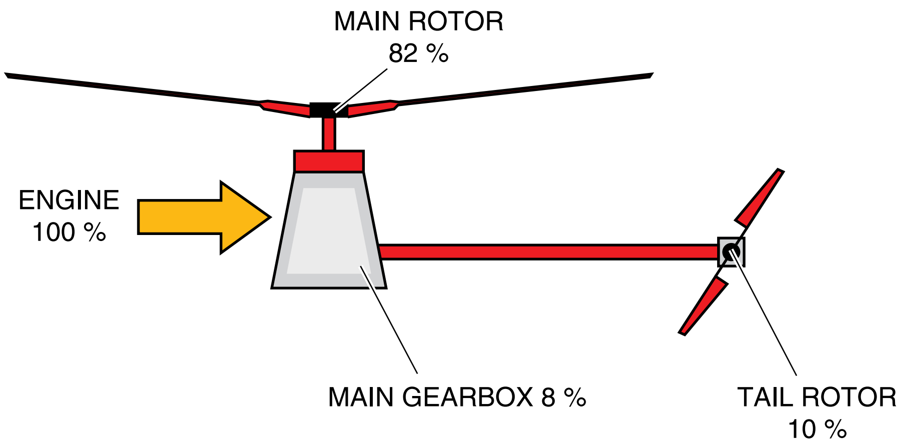
Installation requirements

The main functional requirements of the installation are :

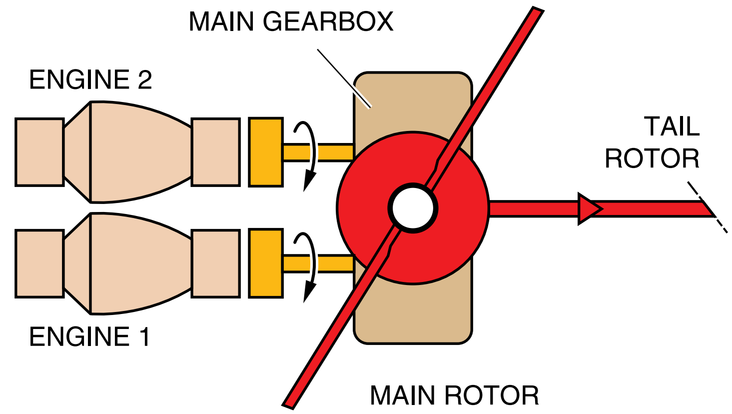
- Constant rotation speed NR in all operating conditions
- Max torque limit C (usually imposed by the aircraft transmission)
- Complete engine protection (against N1 and N2 overspeeds, TET overtemperature, compressor surge $\Delta Q/\Delta t$...)
- Good load sharing (in the case of a multi-engine configuration).

Adaptation to requirements

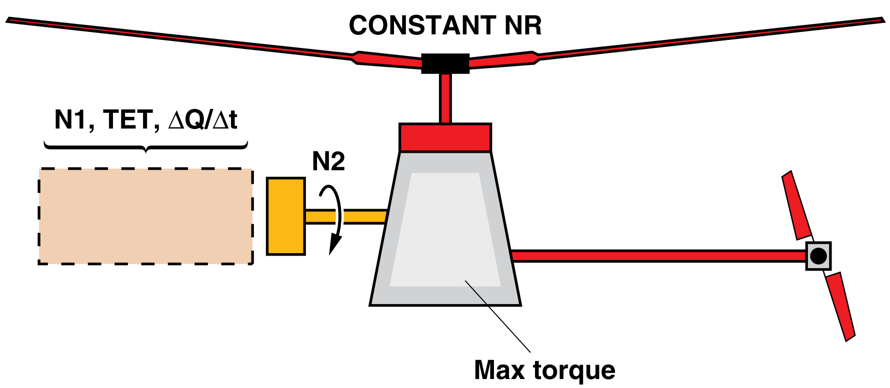
To have a constant rotation speed of the power turbine N2, the power supplied by the engine is automatically adapted to the demand. This adaptation is ensured by the control system which meters the fuel flow injected into the combustion chamber so as to deliver the required power (variation of the gas generator N1 rotation speed) while keeping the engine within its operational limits.



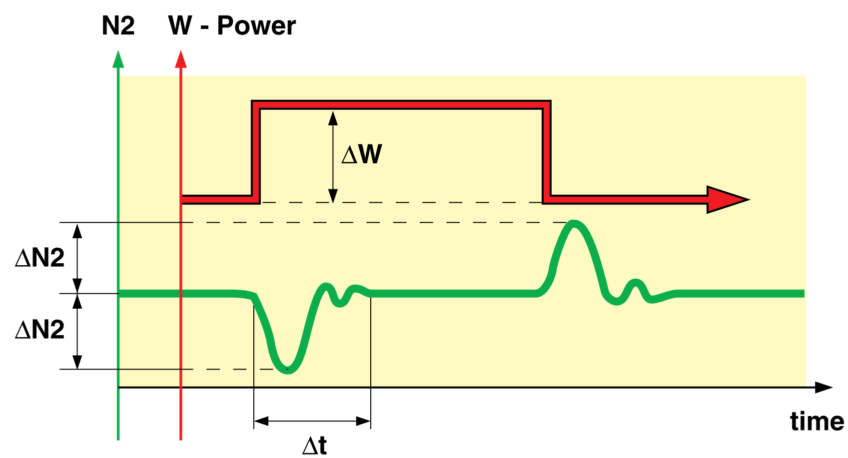
POWER TRANSMISSION



TWIN ENGINE CONFIGURATION



INSTALLATION REQUIREMENTS



ADAPTATION AUX EXIGENCES

PRINCIPLE OF ADAPTATION TO HELICOPTER

MAIN CHARACTERISTICS (1)

Mass and dimensions

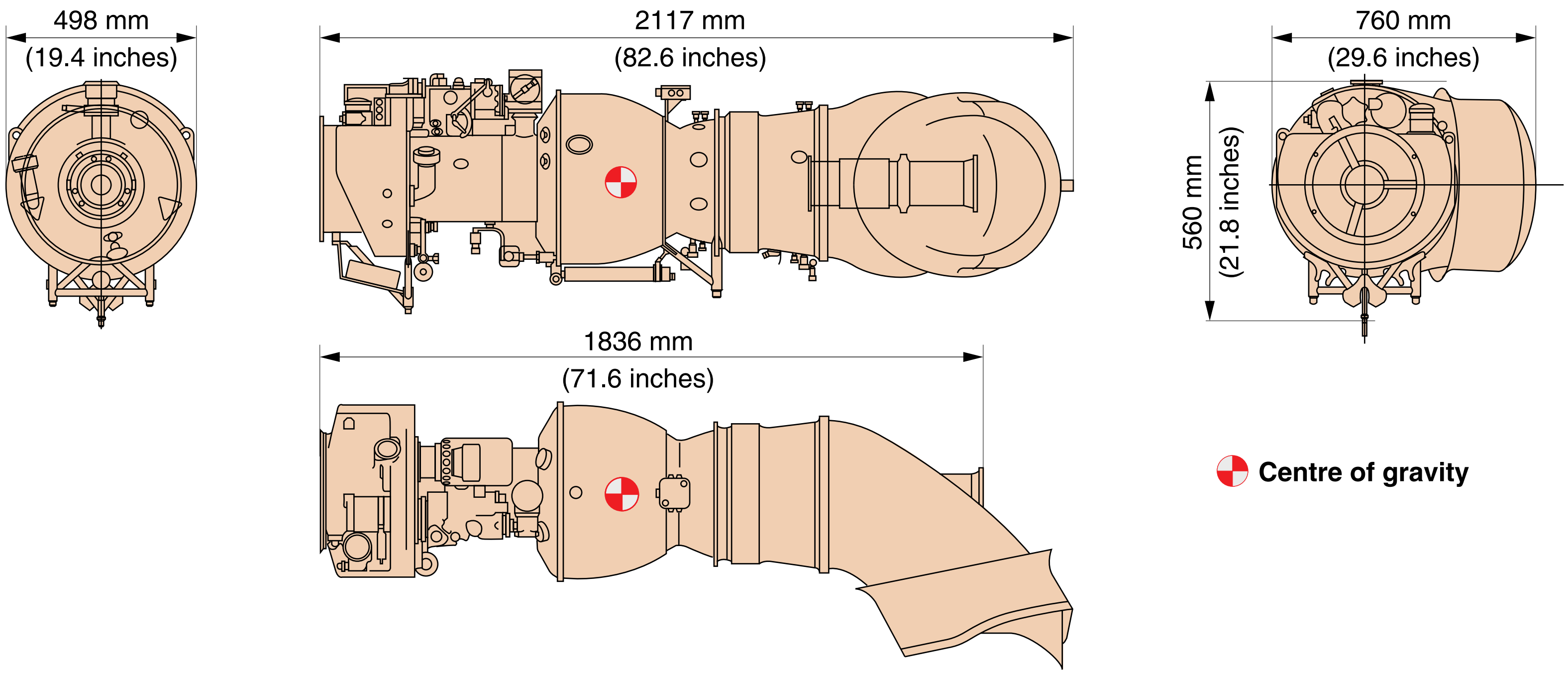
Mass (dry)

- Engine with specific equipment : 247 kg (543.4 lbs)
- Digital Engine Control Unit : 4.7 kg (10.34 lbs).

Dimensions

- Length : 2117 mm (82.6 inches) with exhaust pipe and 1836 mm (71.6 inches) without exhaust pipe
- Width : 760 mm (29.6 inches) with exhaust pipe and 498 mm (19.4 inches) without exhaust pipe
- Height : 560 mm (21.8 inches).

POWER PLANT MASS
(with specific equipment) 247 kg (543.4 lbs)



DIGITAL ENGINE CONTROL UNIT MASS
4,7 kg (10.34 lbs)

MASS AND DIMENSIONS

MAIN CHARACTERISTICS (1)

MAIN CHARACTERISTICS (2)

Performance

Operational ratings

The operational ratings correspond to given conditions of helicopter operation. The ratings are generally defined under determined speed and temperature conditions.

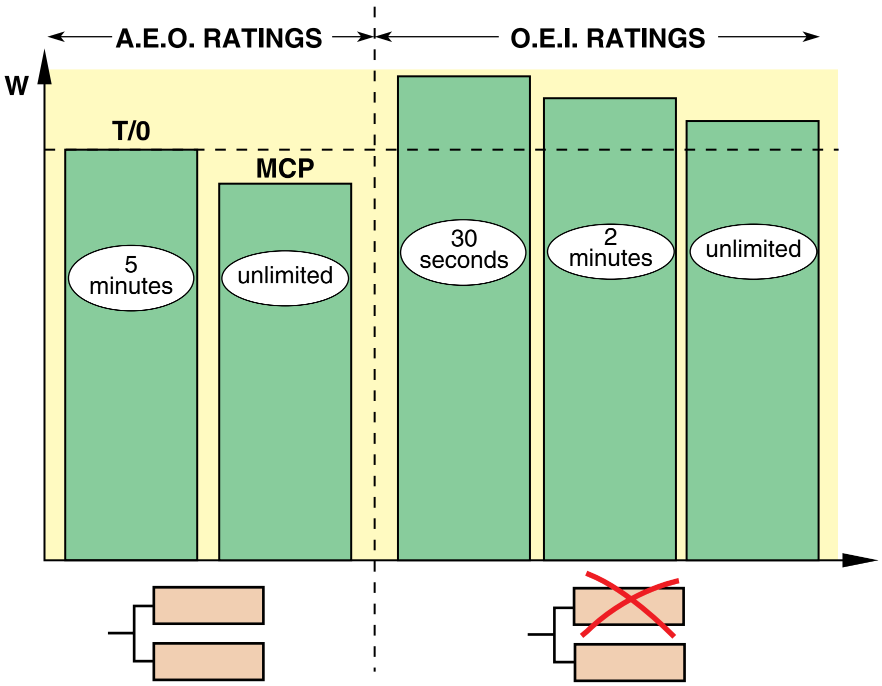
The following operational ratings are considered :

- AEO ratings (All Engines Operating) :
  - Max take-off power : max rating which can be used during take-off. This rating has a limited duration (5 minutes continuous)
  - Max continuous power : rating which can be used without time limitation (this does not imply that it is used permanently)
- OEI ratings (One Engine Inoperative) :
  - Max contingency power : rating which can be used in the case of one engine failure during take-off or landing. This rating is usually limited to a period of continuous operation :
    - OEI 30 sec
    - OEI 2 min
  - Intermediate contingency power : rating which can be used in the case of one engine failure in flight. This rating is usually limited to 30 minutes or unlimited.

Operational performance

The values given are min-guaranteed performance in determined conditions (atmosphere, bleeds, miscellaneous losses…).

- Power (W) : power available on the engine output shaft (expressed in kilowatts kW)
- Fuel consumption (CH) : fuel quantity consumed in a unit of time (expressed in kilogrammes per hour ; kg/hr)
- Specific fuel consumption (SFC) : quantity of fuel required to produce one unit of power in one unit of time : SFC = CH/W (expressed in grammes per kilowatt per hour ; g/kW.hr).



OPERATIONAL RATINGS

Ratings	Power		Specific fuel consumption SFC
	kW	Shp	
OEI 30 sec.	1573	2108	At cruise rating (700 kW / 938 Shp) 335 g/kW.h (0.55 lb/HP.hr)
OEI 2 min	1467	1966	
OEI Unlimited	1420	1903	
T/0 5 min	1376	1844	
MCP	1236	1656	

OPERATIONAL PERFORMANCE
(ISA sea level, engine uninstalled)

PERFORMANCE
MAIN CHARACTERISTICS (2)

MAIN CHARACTERISTICS (3)

Limitations

Introduction

The limitation principle is essentially based on one limit parameter : the gas generator rotation speed (N1 or Ng) which is the main flying parameter.

The other parameters are automatically kept within their limits by engine and control system design.

N1 rating limitation

The max N1 speeds corresponding to the twin-engine ratings (AEO) and single-engine ratings (OEI) are automatically limited by the control system, according to pressure altitude Zp and atmospheric temperature t0.

This allows max power to be available at any time while protecting the engine and the transmission (torque and gas temperature limits).

Limit illustration

The diagram below shows the limit values with or without stop and the stop application conditions.

On this diagram we can distinguish :

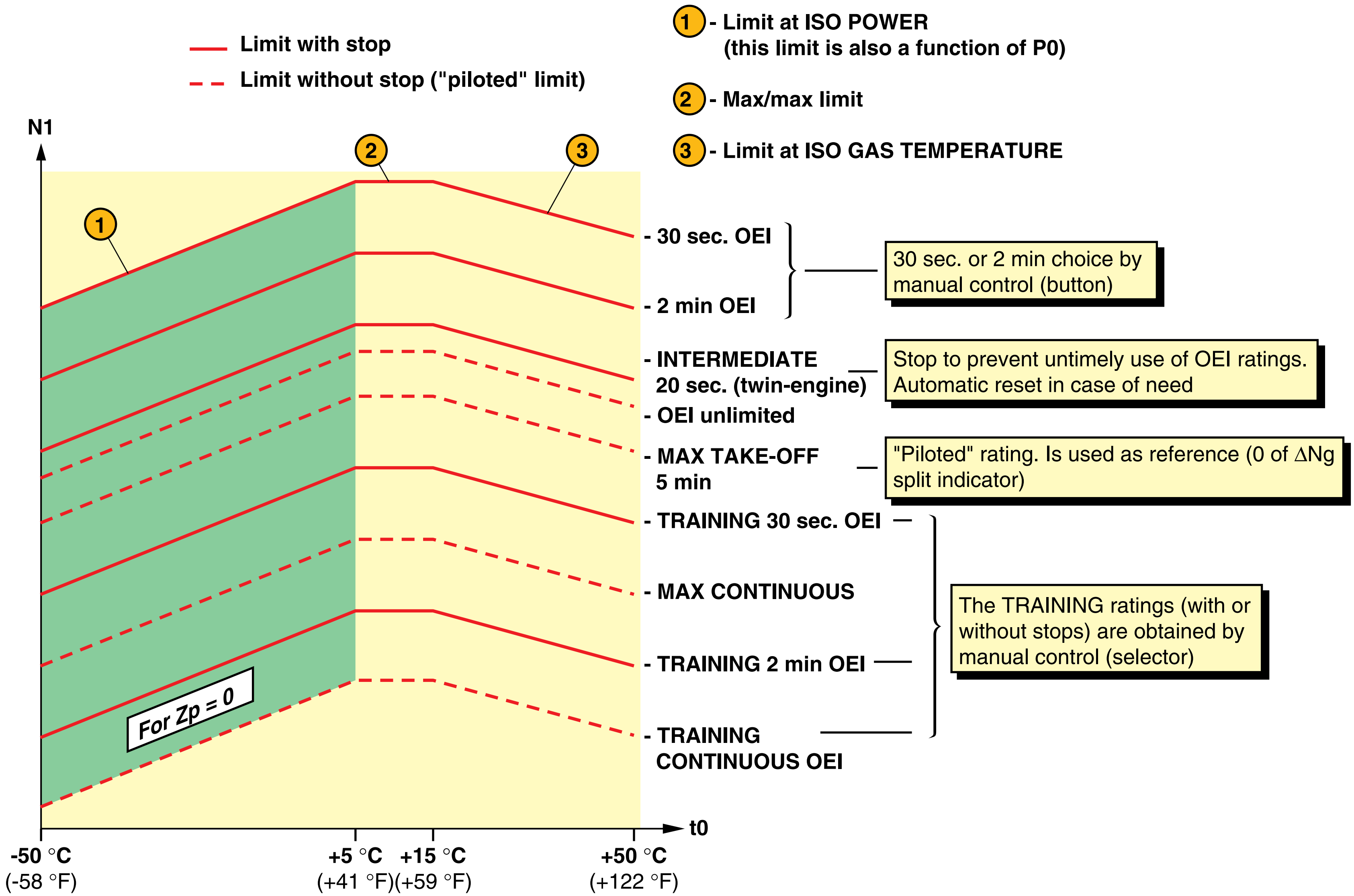
- N1 lines at iso-power (constant power) determined according to P0 and t0. It is in fact the torque limitation to protect the mechanical transmission (helicopter main gearbox). For Zp = 0, N1 increasing between -50 and +5 °C (-58, +41 °F).

- Invariable maxi/maximum N1 line. For Zp = 0, obtained between +5 and +15 °C (+41, +59 °F)

- N1 lines at iso-gas temperature determined according to t0. It is in fact the engine thermal protection. N1 decreasing from +15 to +50 °C (+59, +122 °F).

The discontinuous lines represent the limits without stop ; ratings called "piloted", that is to say they are controlled by the pilot.

Note *: The limit values are determined by the Digital Engine Control Unit (DECU). The DECU determines first the OEI 30 sec. limit rating and then the others by subtraction of a constant value. E.g. : OEI 2 min = OEI 30 sec. - x.*



LIMITATIONS

MAIN CHARACTERISTICS (3)

MAIN CHARACTERISTICS (4)

Factors which affect performance

The engine performance is affected by flight and atmospheric conditions. The effects of these conditions are usually indicated by graphs which show the evolution of performance as a function of parameters likely to modify it (example : atmospheric temperature t0 and pressure altitude Z).

Power evolution (W)

The power delivered by the engine decreases when the altitude (Z) and the temperature (t0) increase (this is due to the air mass flow decrease through the engine).

The conditions of the engine installation on the aircraft should also be noted (miscellaneous losses due to installation) as well as the flight conditions (essentially the aircraft speed).

Evolution of fuel consumption (CH)

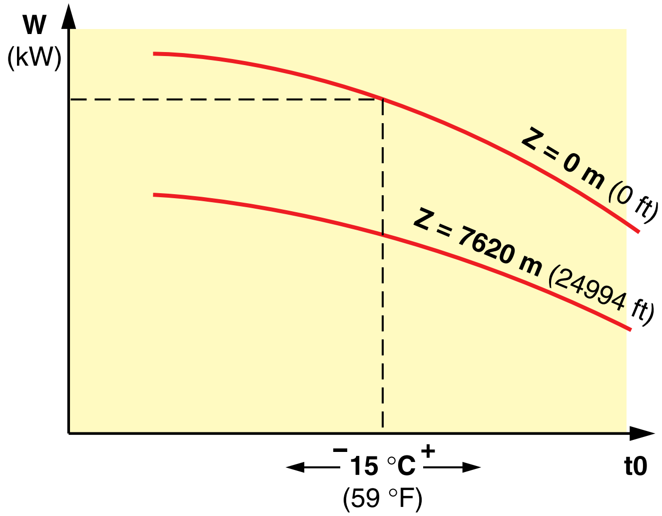
The fuel consumption decreases at a given rating, when the altitude (Z) and the temperature (t0) increase.

Evolution of specific fuel consumption (SFC)

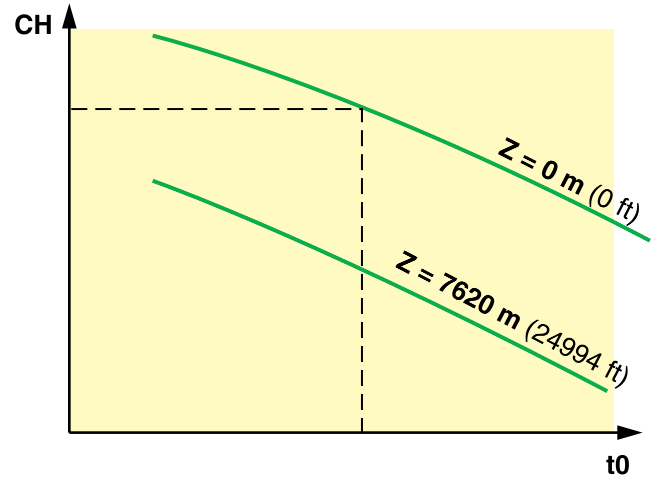
The specific fuel consumption varies with the operating conditions.

The specific consumption decreases, when the power (W) increases (better thermal efficiency).

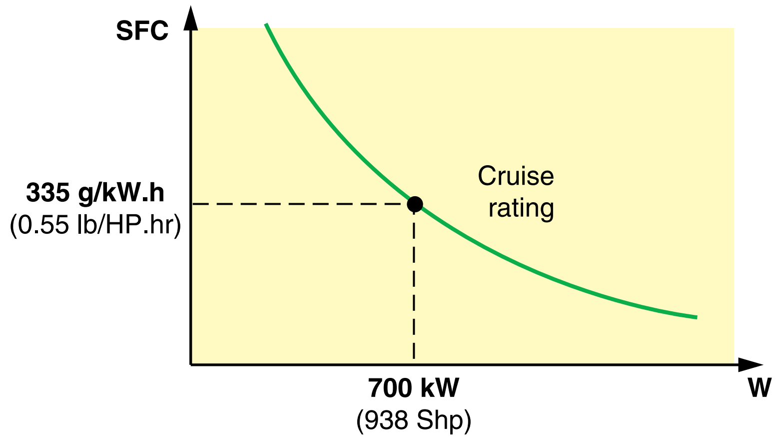
For this type of installation, the consumption which is mostly considered is that at the cruise rating.



POWER EVOLUTION (W)



EVOLUTION OF
FUEL CONSUMPTION (CH)



EVOLUTION OF SPECIFIC FUEL CONSUMPTION (SFC)

FACTORS WHICH AFFECT PERFORMANCE

MAIN CHARACTERISTICS (4)

MAIN CHARACTERISTICS (5)

Engine operating envelope

The engine is designed to operate within a given climatic envelope.

The envelope is defined by :

- The atmospheric temperature t0
- The pressure altitude Zp.

Flight envelope

The flight envelope is illustrated by the t0/Zp diagram. It is comprised between -500 and 7620 m (-1640, 24994 ft) for pressure altitude Zp and between -50 and +50 °C (-58, +122 °F)) for ambient temperature. However particular procedures (related to fuel and lubricant specifications) have to be applied above 6100 m (20008 ft) and below -30 °C (-22 °F).

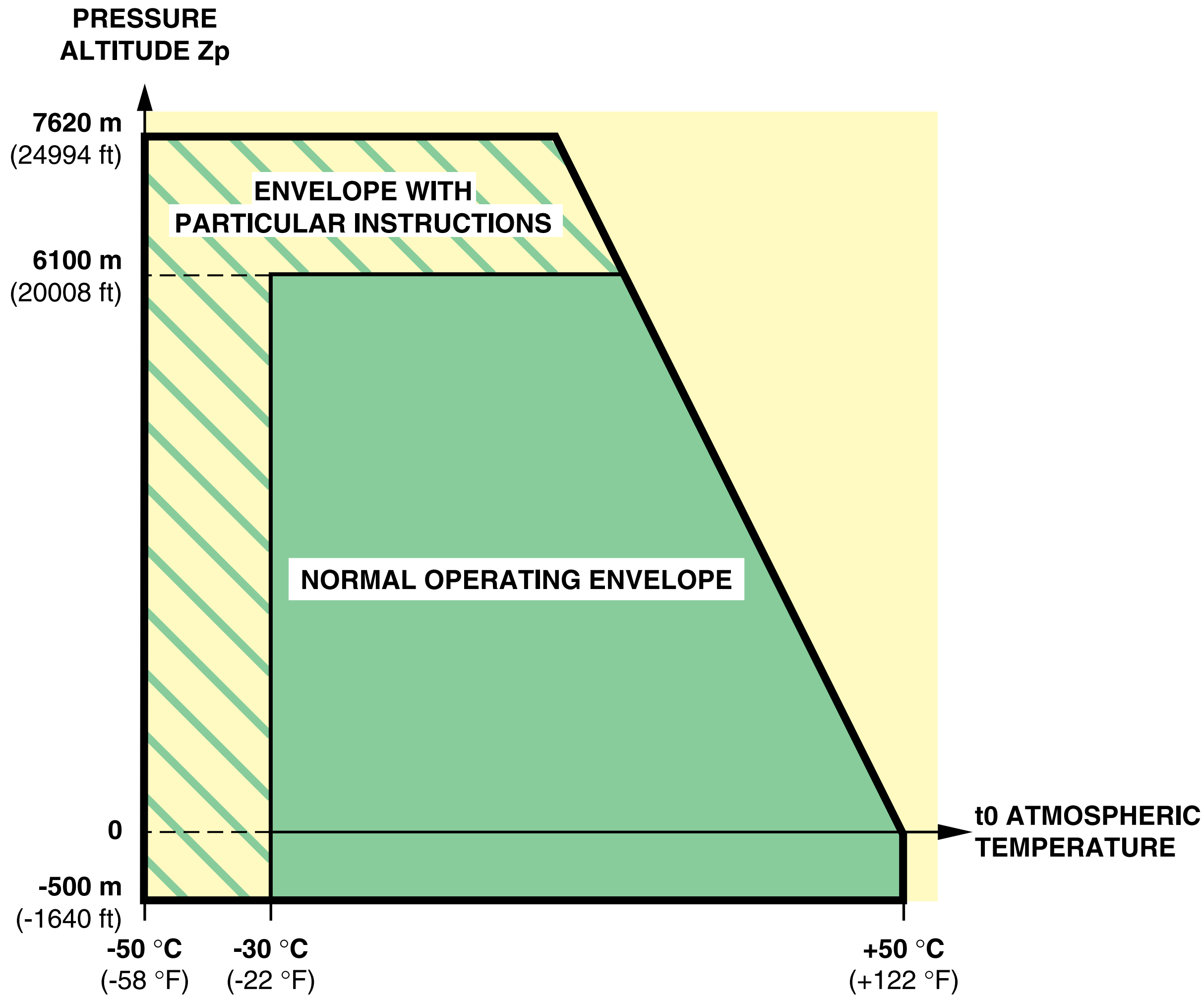
Engine starting envelope

The starting and relight envelope is defined in the same way, but it is also affected by the specifications of oil and fuel used, and sometimes by particular instructions.

Limitations

The engine operates within various limitations : rotation speeds, temperatures, pressures…

Refer to corresponding chapters and official publications.



FLIGHT, START AND RE-START ENVELOPE

ENGINE OPERATING ENVELOPE

MAIN CHARACTERISTICS (5)

DESIGN AND DEVELOPMENT (1)

Design principles

The engine is designed to meet the aircraft propulsion requirements.

The engine design is based on :

- An optimised thermodynamic cycle which gives high performance
- Simple and reliable components giving a good supportability, and a good maintainability to reduce the costs.

Engine development

The MAKILA 1A2 engine is based on the research and experience of other engines :

- First generation engines : ASTAZOU, ARTOUSTE and TURMO
- Second generation engines : ARRIEL, MAKILA.

The MAKILA 1A2 is an evolution of the MAKILA 1A. It benefits from the experience gained and from improvements in performance and cost.

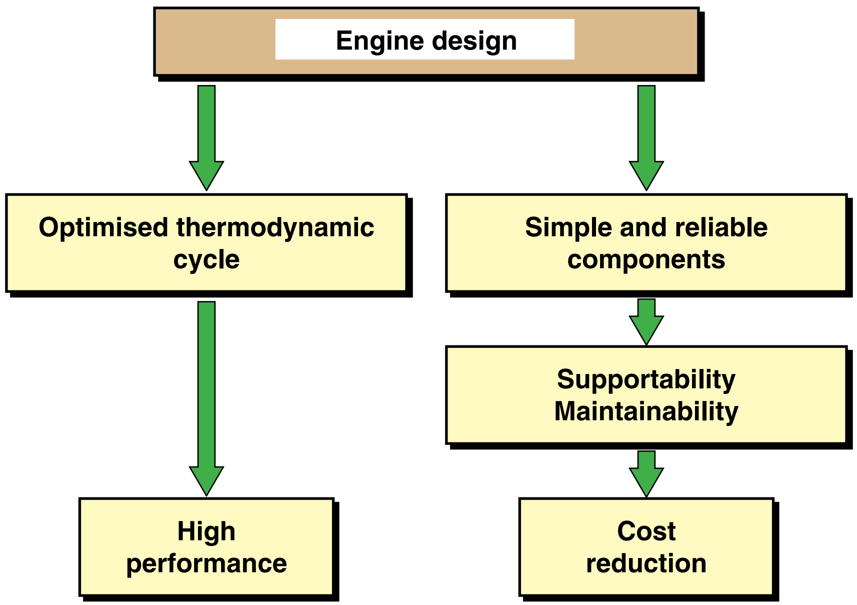
Development steps

- Basic version : 1979
- First production engine : 1980
- MAKILA 1A1 : 1985
- MAKILA 1A2 : 1988.

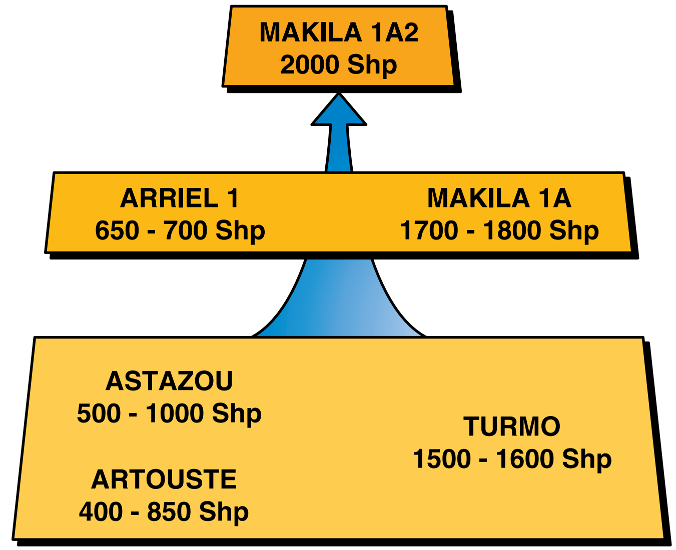
Engine designation

MAKILA ("Basque" word meaning stick) wooden stick with a sword in its handle.

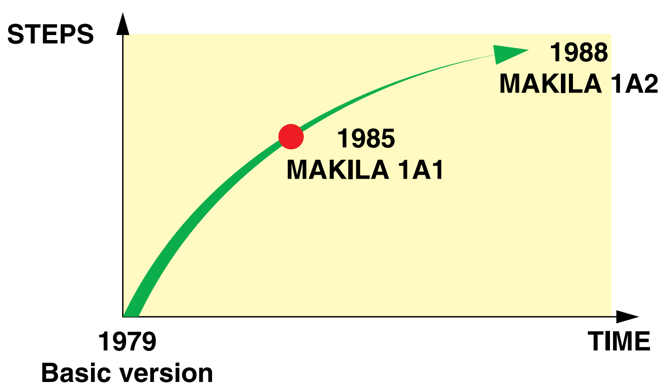
- 1 : Type
- A : Variant
- 2 : Version.



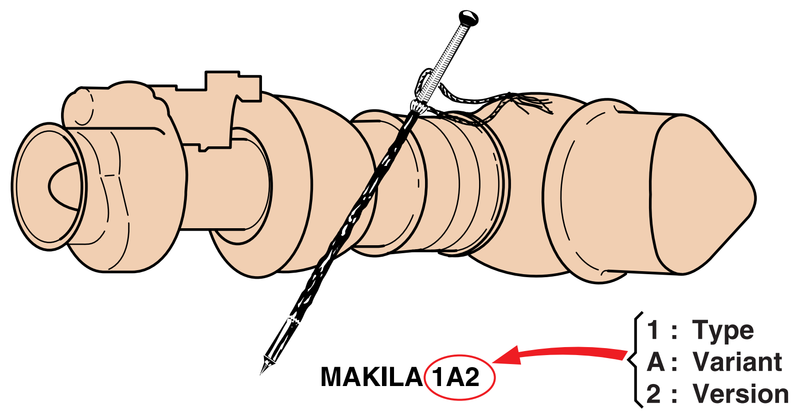
DESIGN PRINCIPLES



ENGINE DEVELOPMENT



DEVELOPMENT STEPS



ENGINE DESIGNATION

DESIGN AND DEVELOPMENT (1)

DESIGN AND DEVELOPMENT (2)

Application

The MAKILA 1A2 is presently destined for the SUPER PUMA Mark 2 twin engine configuration.

Maintenance concept

The MAKILA 1A2 is designed to provide a high availability rate with reduced maintenance costs.

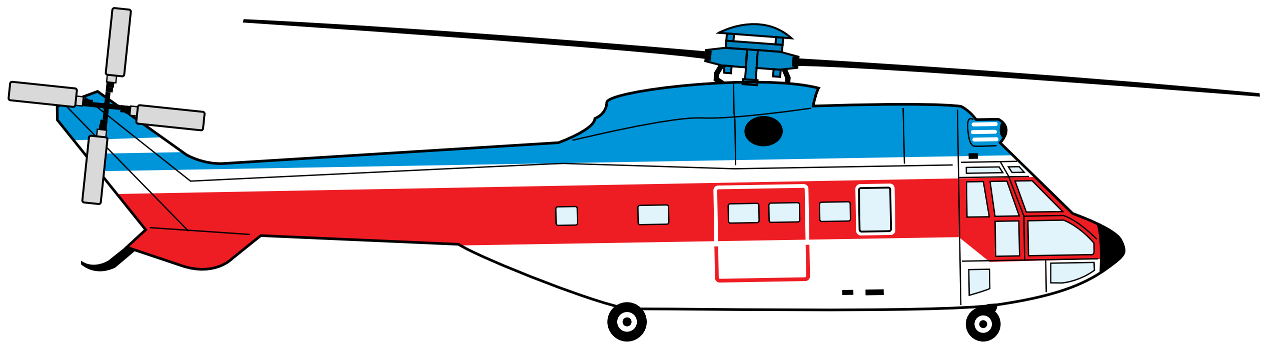
The main aspects of the maintenance concept are the following :

- Full modularity
- Good accessibility
- Reduced removal and installation times
- "On condition" monitoring
- High initial TBO
- Low cost of ownership :
  - Low production costs
  - Durability (TBO, defined and proven life limits)
  - High reliability
  - Low fuel consumption.

Engine fleet status

In ……, we can note :

- Number of engines produced : …………
- Number of engines in operation : …………
- Operating hours : …………



SUPER PUMA MARK 2

MAINTENANCE CONCEPT

- Actual modularity
- Good accessibility
- Reduced time of removal and installation
- Condition monitoring
- High initial TBO
- Low cost of ownership

FLEET STATUS

- Engines produced
- Engines in operation
- Operating hours

DESIGN AND DEVELOPMENT (2)

3 - ENGINE

ENGINE - GENERAL

Function

The engine transforms the energy in the fuel and air into mechanical power on a shaft.

Main characteristics

- Type : free turbine with rear direct power drive
- Power class : 1300 kW (1742 Shp)
- Specific fuel consumption at the cruise rating : 335 g/kW.h (0.737 lb/HP.hr) at 700 kW (938 Shp)
- Gas generator speed N1 : 33200 RPM (100 %)
  - Direction of rotation : anticlockwise
- Power turbine speed N2 : 22962 RPM (100 %)
  - Direction of rotation : anticlockwise
- Equipped engine mass : 247 kg (543.4 lbs).

Note *: Direction of rotation given viewed from the rear.*

Main components

- Air intake, oil tank and accessory drive
- Gas generator
  - Three stage axial compressor
  - High pressure section
    - Centrifugal compressor
    - Annular combustion chamber
    - Two stage turbine
    - Intermediate diffuser
- Two stage power turbine
- Exhaust pipe
- Power transmission shaft.

Type
Free turbine

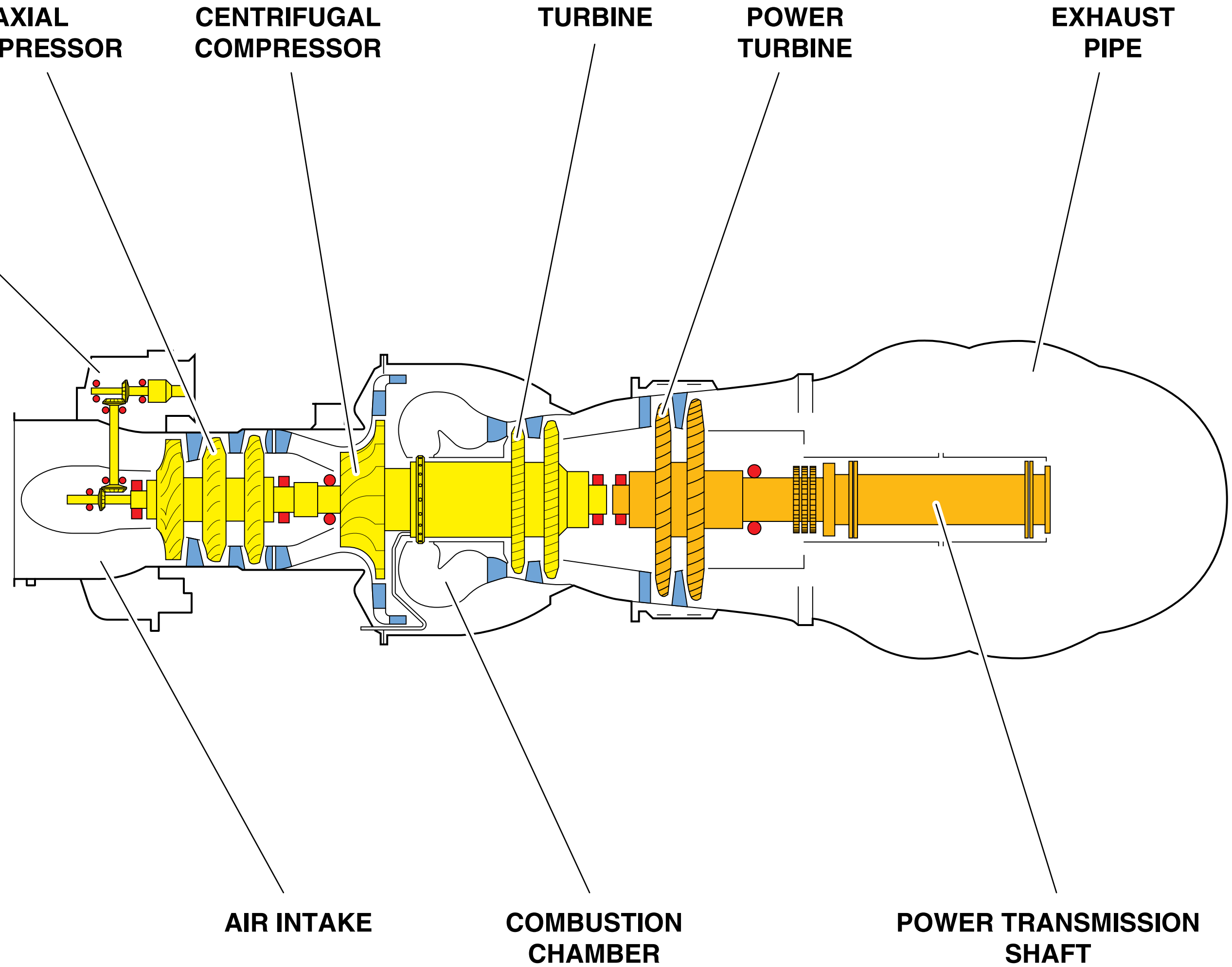
Power
1300 kW class (1742 Shp)

Specific consumption
335 g/kW.h (0.737 lb/HP.hr)

Gas generator (N1)
33200 RPM (100 %), anticlockwise

Power turbine (N2)
22962 RPM, anticlockwise

Equipped engine mass
247 kg (543.4 lbs)



ENGINE - GENERAL

ENGINE - DESCRIPTION (1)

Main components

- Air intake
- Gas generator
    - Axial compressor
    - Centrifugal compressor
    - Combustion chamber
    - Two stage turbine
- Two stage power turbine
- Exhaust pipe.

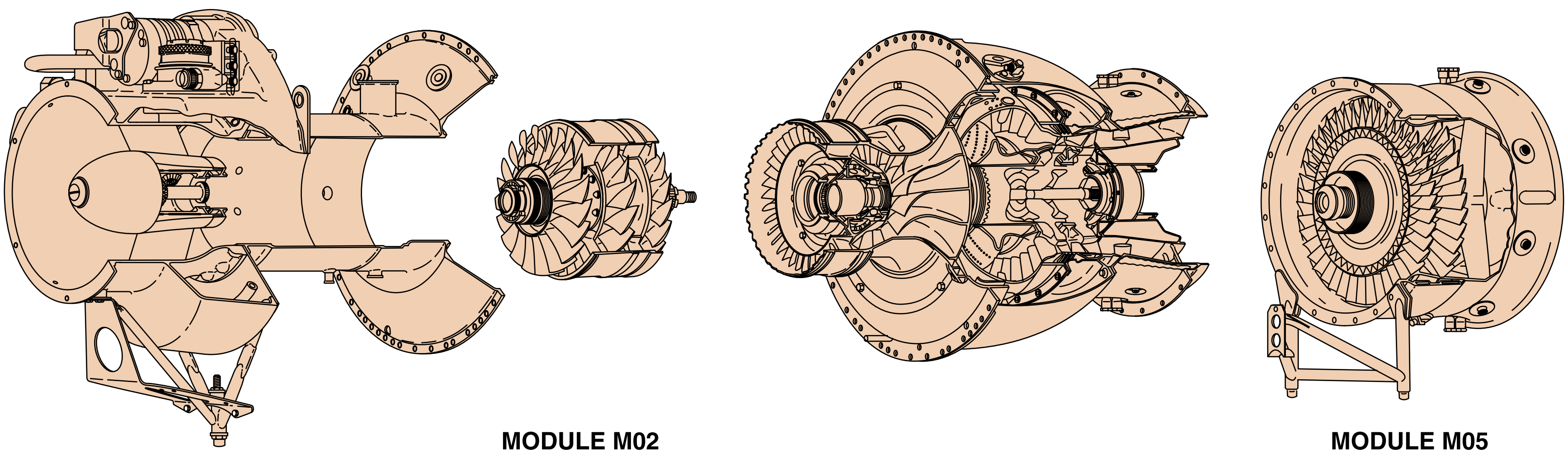
Modular layout

The engine comprises 4 modules :

- Module M01 : air intake, oil tank and accessory drive
- Module M02 : axial compressor
- Module M03 : gas generator high pressure section and intermediate diffuser
- Module M05 : power turbine.

Note 1 : *A module is a sub-assembly which can be replaced on-site (2nd line maintenance) without complex tooling or adaptation work.*

Note 2 : *The modules numbers are coming from the MAKILA 1A which embodies 5 modules. The module M04 is the intermediate diffuser which belongs to the module M03 on the MAKILA 1A2.*



ENGINE - DESCRIPTION (1)

ENGINE - DESCRIPTION (2)

Rotating assemblies and bearings

The rotating assemblies (carefully balanced assemblies) are supported by bearings which absorb axial and radial thrusts .

Gas generator bearings

- Axial compressor front bearing : roller bearing
- Axial compressor rear bearing : roller bearing
- Centrifugal compressor bearing : ball bearing in flexible cage
- Gas generator rear bearing : roller bearing.

Power turbine bearings

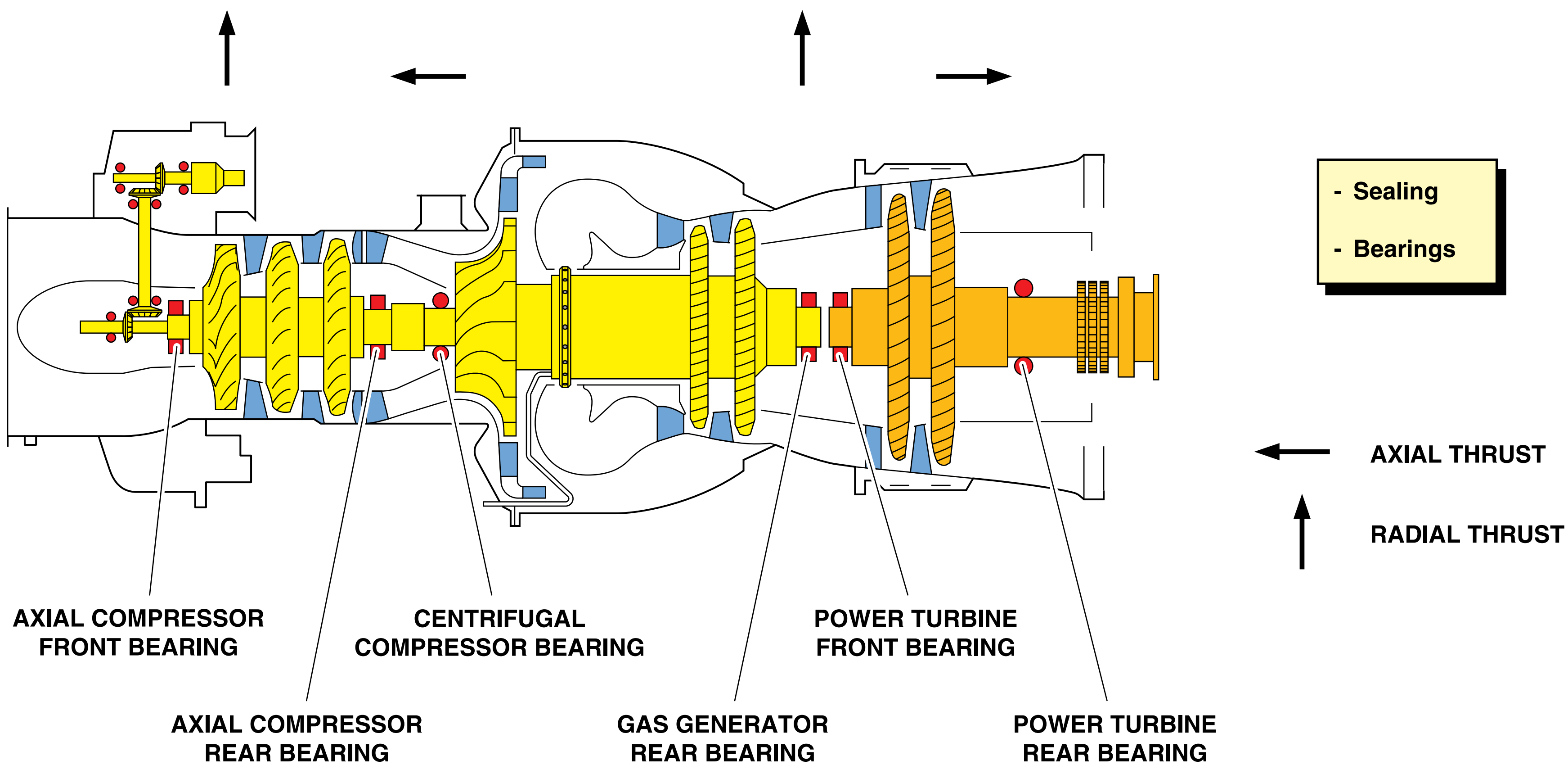
- Power turbine front bearing : roller bearing
- Power turbine rear bearing : ball bearing.

Sealing

All bearings are sealed by pressurised labyrinths, which are provided with abradable deposits.

Note : *Refer to the various modules for further details on the bearings.*

Refer to the chapter "AIR SYSTEM" for the pressurisation and to the chapter "OIL SYSTEM" for the lubrication.



ROTATING ASSEMBLIES AND BEARINGS

ENGINE - DESCRIPTION (2)

ENGINE - OPERATION

The engine provides power by transforming the energy in the air and fuel into mechanical energy on a shaft.

The process comprises compression, combustion, expansion and the transmission of the power.

Compression

The ambient air is compressed by an axial supercharging compressor and a centrifugal compressor.

This phase is essentially characterised by the air flow (approx. 5.5 kg/s ; 12.1 lbs/sec.) and the compression ratio (≈ 10.4).

Combustion

The compressed air is admitted into the combustion chamber, mixed with the fuel and burnt in a continuous process.

The air is divided into two flows :

- A primary flow for combustion
- A secondary flow for cooling the gas.

This phase is essentially characterised by the temperature rise, flame temperature of approx. 2500 °C (4532 °F), turbine inlet temperature of approx. 1180 °C (2156 °F), and a pressure drop of about 4 %.

Expansion

- The gas expands in the gas generator turbine which extracts the energy required to drive the compressors (max N1 speed : 34650 RPM, ACW).

  During this phase the pressure and temperature of the gas drop whilst the velocity increases.

- There is a further expansion in the power turbine which extracts most of the remaining energy to drive the power shaft (N2 speed : 22962 RPM at 100 %, ACW).

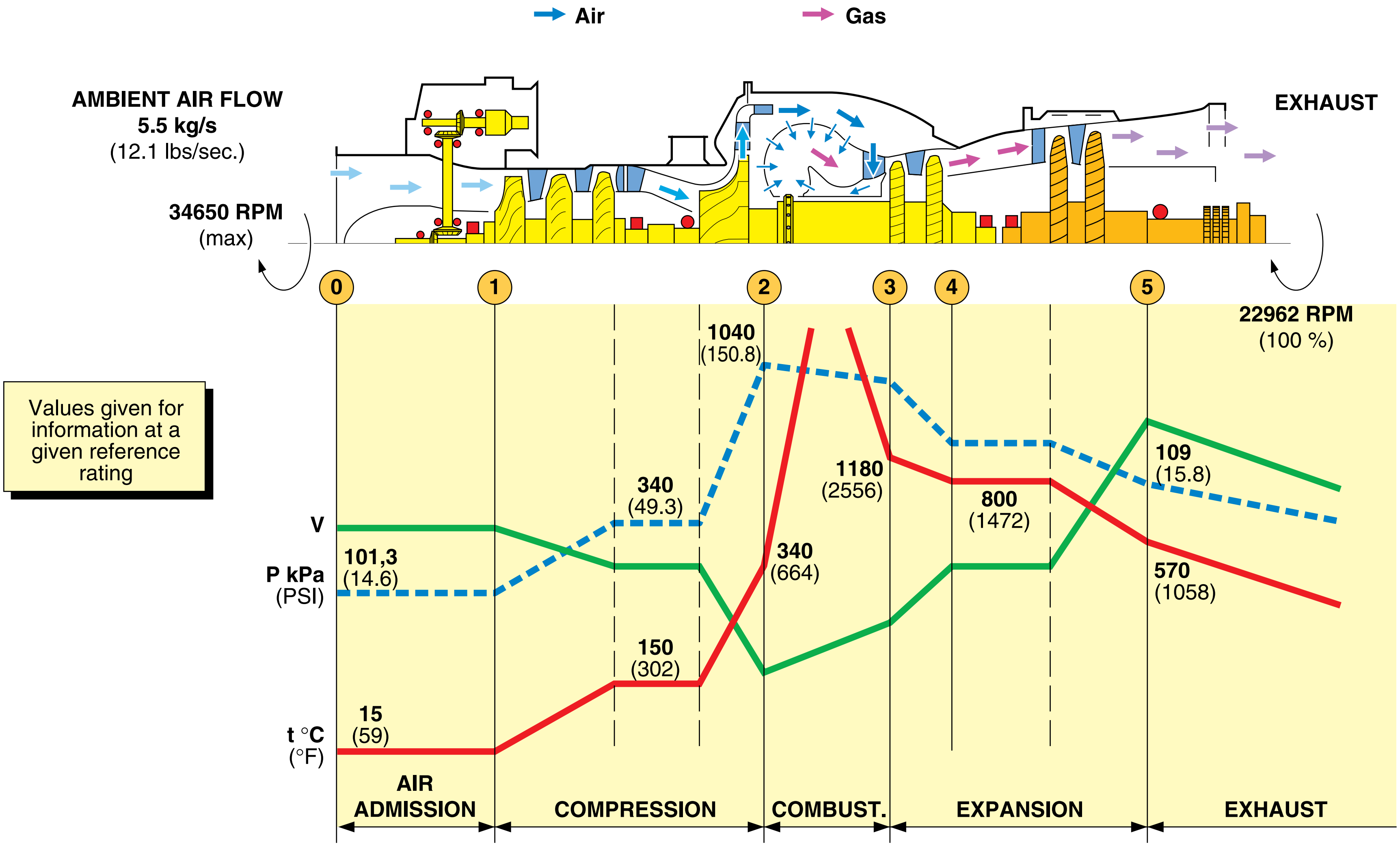
  After the power turbine the gas is discharged overboard via the exhaust pipe, giving a slight residual forward thrust.

Power transmission

The power is then transmitted by the power turbine shaft through a "Bendix" flexible transmission shaft.

Note *: The engine reference stations are :*

0 - Ambient air
1 - Air intake
2 - Centrifugal compressor outlet
3 - Gas generator turbine inlet
4 - Gas generator turbine outlet
5 - Power turbine outlet



ENGINE - OPERATION

AIR INTAKE - GENERAL

Function

The air intake directs the air into the axial compressor.

Position

The air intake also forms the oil tank and is located in front of the axial compressor.

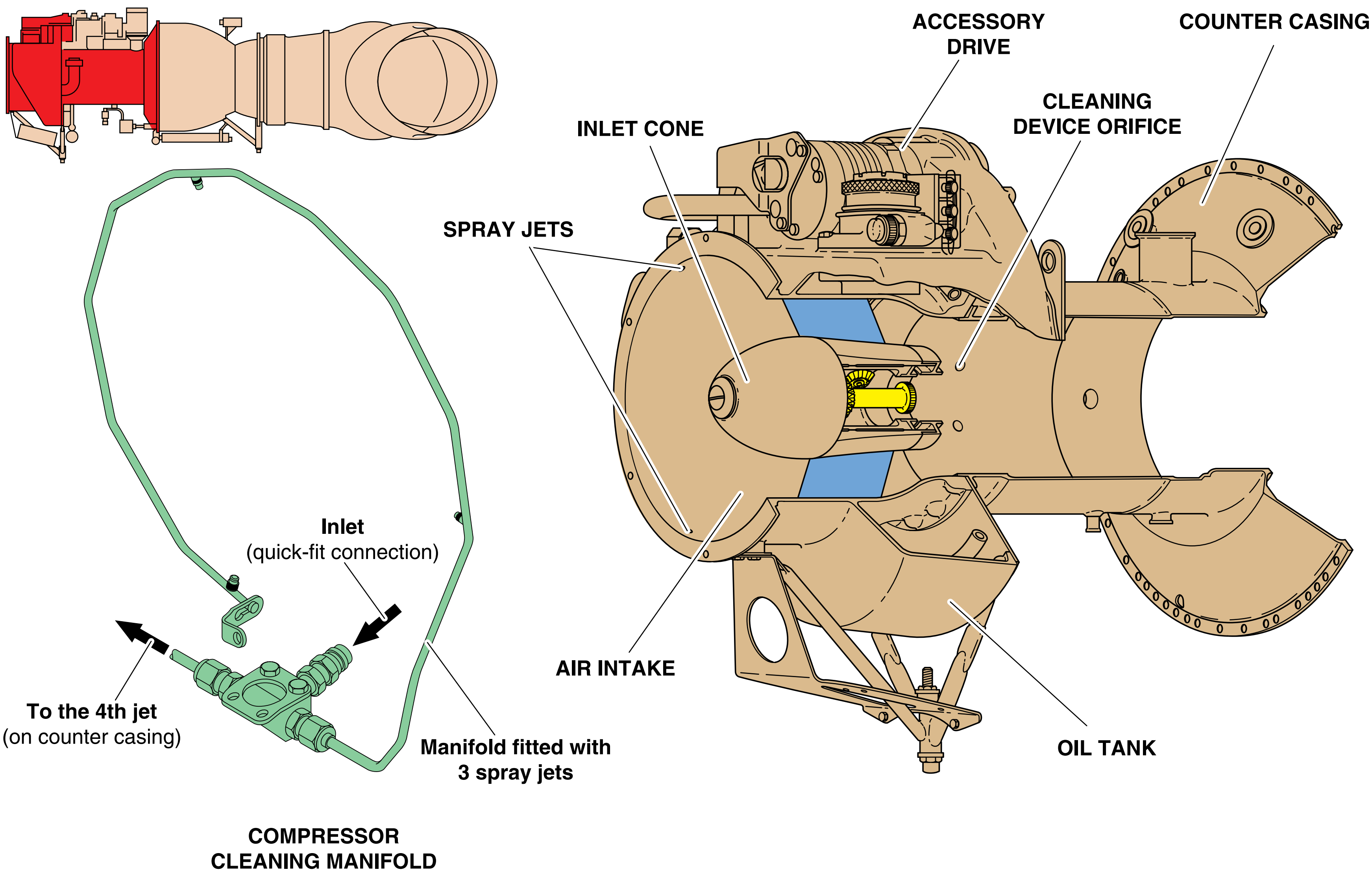
The assembly forms the module M01 and is secured to the module M03 by a ring of bolts.

Main characteristics

- Type : annular
- Air flow : 5.5 kg/s (12.1 lbs/sec.).

Main components

- Air intake
- Oil tank
- Accessory drive
- Counter casing
- Inlet cone
- Compressor cleaning manifold.



AIR INTAKE - GENERAL

AIR INTAKE - DESCRIPTION

The air intake module (module M01) includes stationary and rotating components.

Rotating components

The rotating assembly comprises the bevel gears and the accessory drive train.

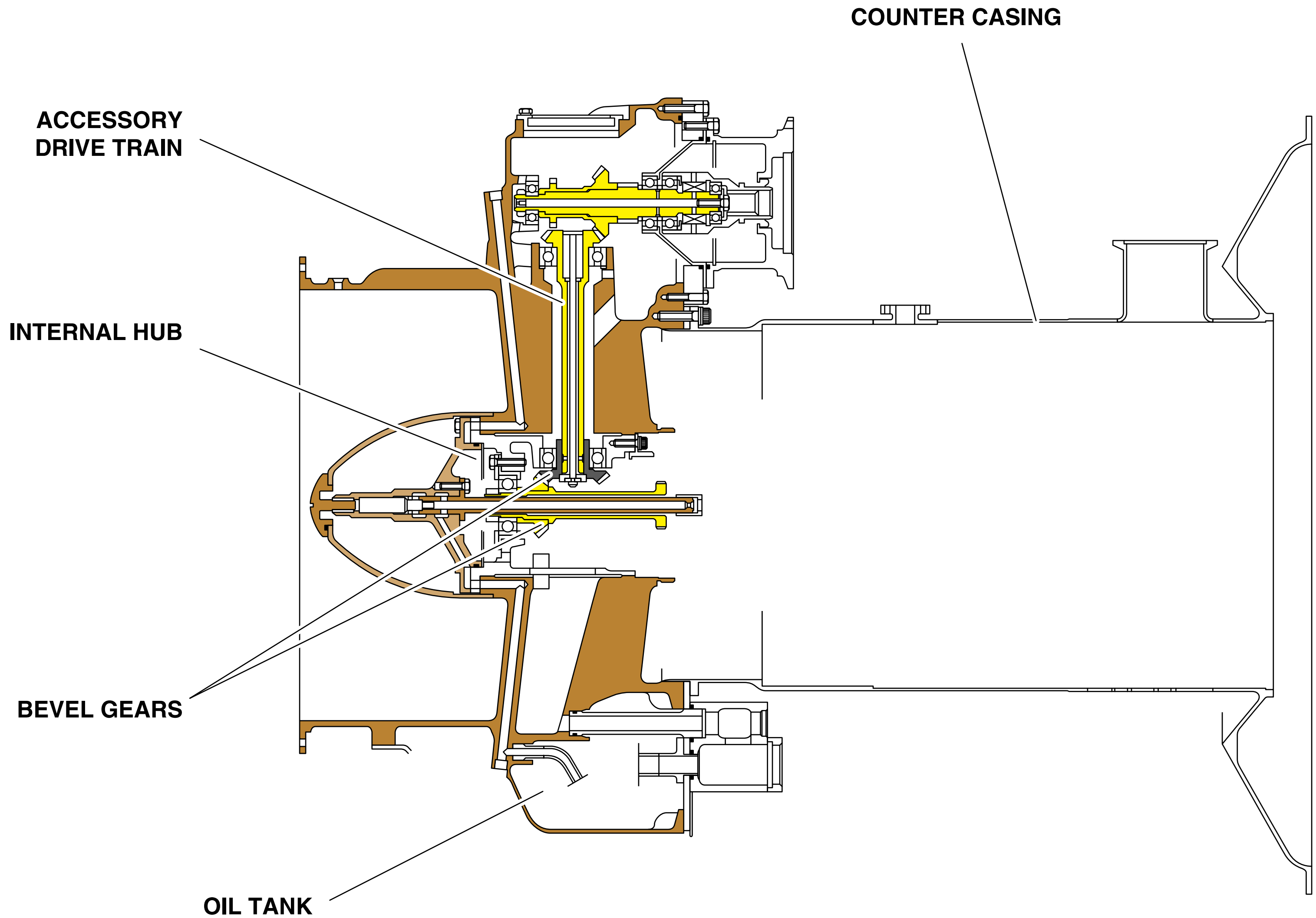
- **The bevel gears** driven by the gas generator shaft
- **The accessory drive train** in the upper part of the casing.

Stationary components

The stationary assembly comprises the oil tank casing, the internal hub and the counter casing.

- **The oil tank casing** made of cast and machined light alloy forms the air intake annular passage
- **The casing internal hub** houses the bevel gears for the accessory drive
- **The counter casing** made of steel, houses the axial compressor.

The oil tank and the counter casing are connected by a ring of bolts.



AIR INTAKE - DESCRIPTION

AIR INTAKE - OPERATION

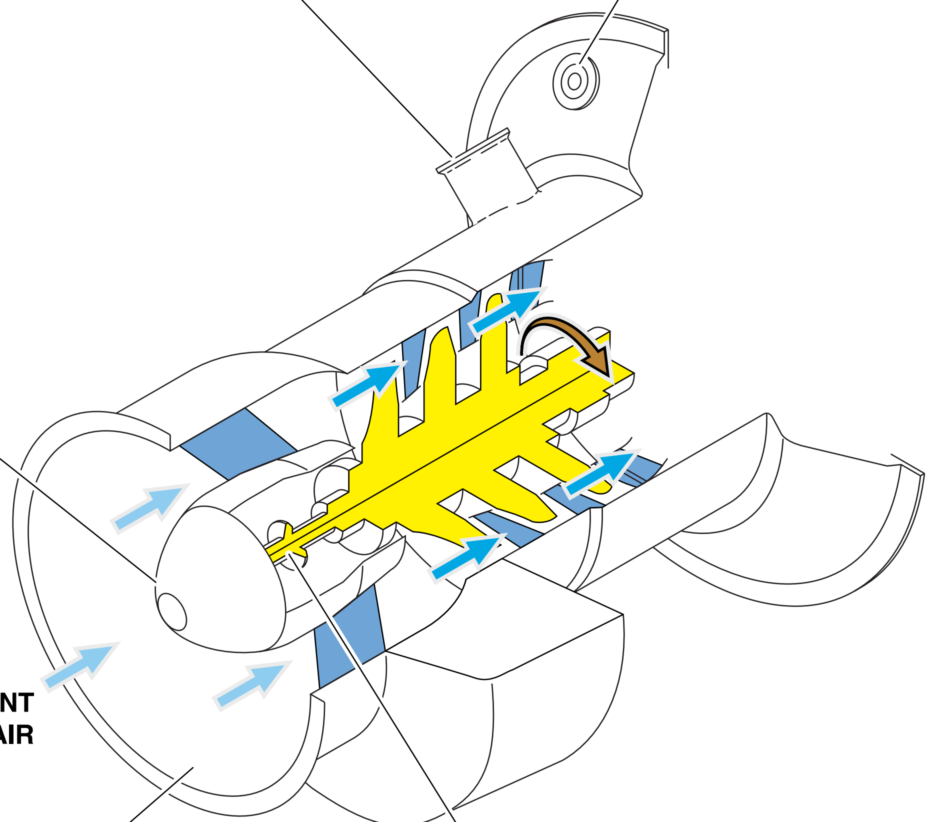
The air inlet to the engine is formed by a direct front intake mouth and a casing with an annular passage.

The inlet cone forms an air intake cowling, anti-iced by lubricating oil flow.

The accessory drive shaft passes through the casing upper strut.

The counter casing has mounting pads, air tapping unions and a mounting pad for the air bleed valve (refer to chapter "AIR SYSTEM" for more details on air tappings and air bleed valve).

The air intake operation is characterized by the P1/P0 recovery factor and the distortion rate.



AIR INTAKE - OPERATION

AXIAL COMPRESSOR - GENERAL

Function

The axial compressor ensures a first stage of compression to supercharge the centrifugal compressor.

Position

The axial compressor is located in the counter casing. It is connected to the module M03 by a tie-bolt for the rotor and by a ring nut for the stator. The axial compressor forms the module M02.

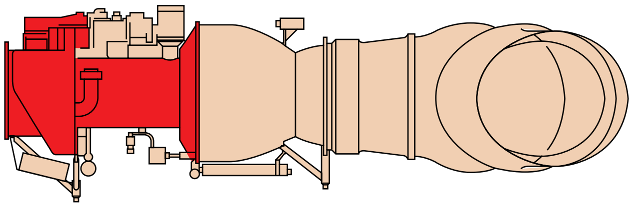
Main characteristics

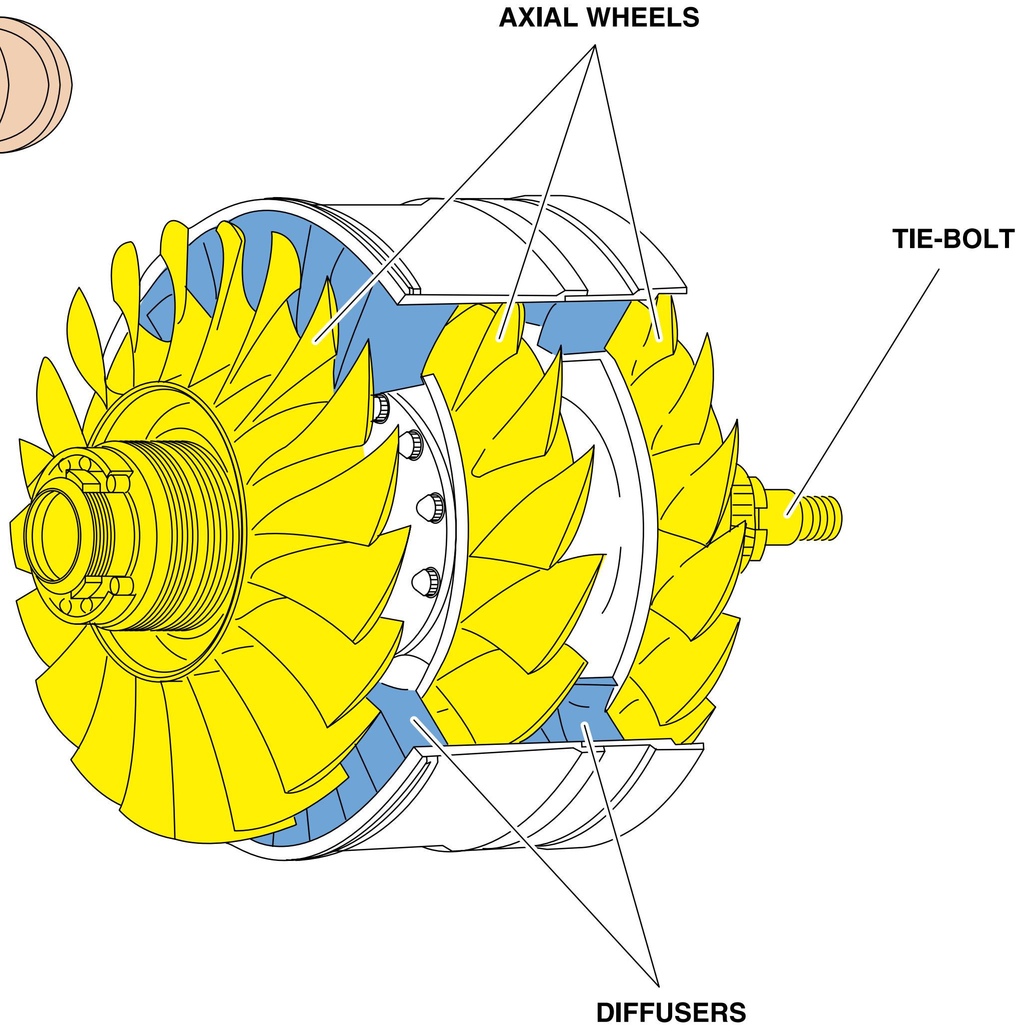
- Type : three stage axial transonic supercharging compressor
- Air flow : 5.5 kg/sec (12.1 lbs/sec.)
- Air outlet pressure : 340 kPa (49.3 PSI)
- Air outlet temperature : 150 °C (302 °F)
- Max N1 rotation speed : 34650 RPM, ACW.

Main components

- Rotating components : axial wheels (discs, shafts, bearings) and a tie-bolt
- Stationary components : diffusers (diffuser - straightener or stator vanes).

***Note** : The 3rd stage diffuser belongs to the module M03.*





Type
Axial transonic supercharging compressor

Air flow
5.5 kg/s (12.1 lbs/sec.)

Outlet pressure
340 kPa (49.3 PSI)

Outlet temperature
150 °C (302 °F)

Max N1 rotation speed
34650 RPM, ACW

AXIAL COMPRESSOR - GENERAL

AXIAL COMPRESSOR - DESCRIPTION

The axial compressor module (module M02) includes rotating and stationary components.

Rotating components

The rotating assembly comprises 3 axial wheels, 2 half shafts and a tie-bolt.

The wheels include a disc made of titanium with blades cut from the solid.

The 2 half shafts are bolted to the 2nd stage wheel.

The 1st and 3rd stage wheels are dogged onto the shafts and secured by nuts.

The assembly is supported by two bearings. The bearing sealing is ensured by labyrinth seals.

The tie-bolt secures the axial compressor to the centrifugal compressor. The axial assembly is driven by a coupling sleeve which belongs to module M03.

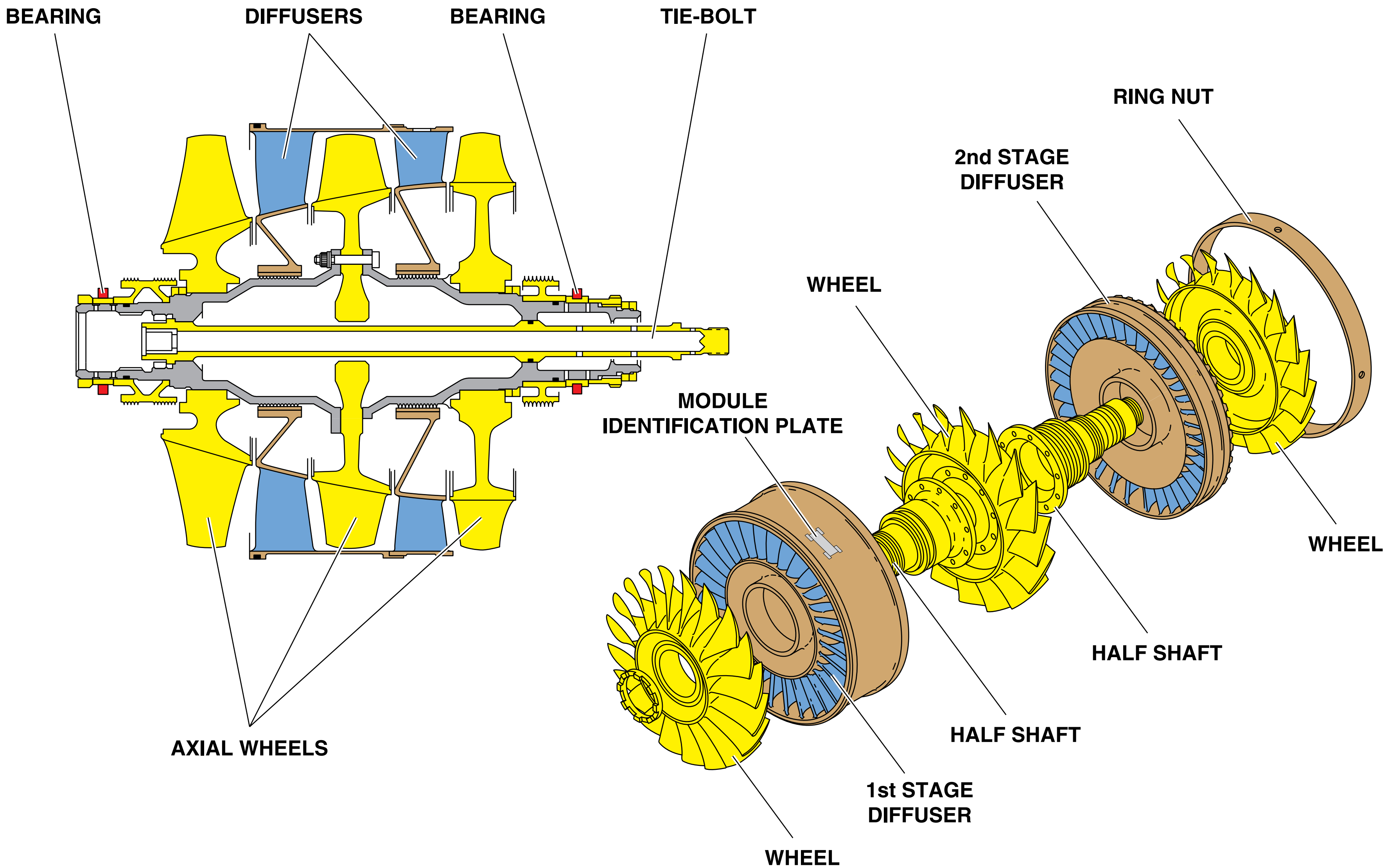
Stationary components

The stationary assembly includes the first and second stage diffusers.

The diffusers (diffuser - straightener) include a row of vanes with divergent area of passage (the third stage diffuser is mounted on the module M03).

A ring nut connects the module M02 to the module M03.

The module identification plate is mounted on the first stage diffusor.



AXIAL COMPRESSOR - DESCRIPTION

AXIAL COMPRESSOR - OPERATION

The axial compressor ensures a first stage of compression in order to supercharge the centrifugal compressor.

Compressor air flow

The ambient air, admitted through the air intake duct and guided by the inlet cone, flows between the blades of the axial compressor. The air is discharged rearwards with an increased axial velocity.

The air then flows through the diffuser vanes. Due to the divergent passage, the air velocity is transformed into pressure.

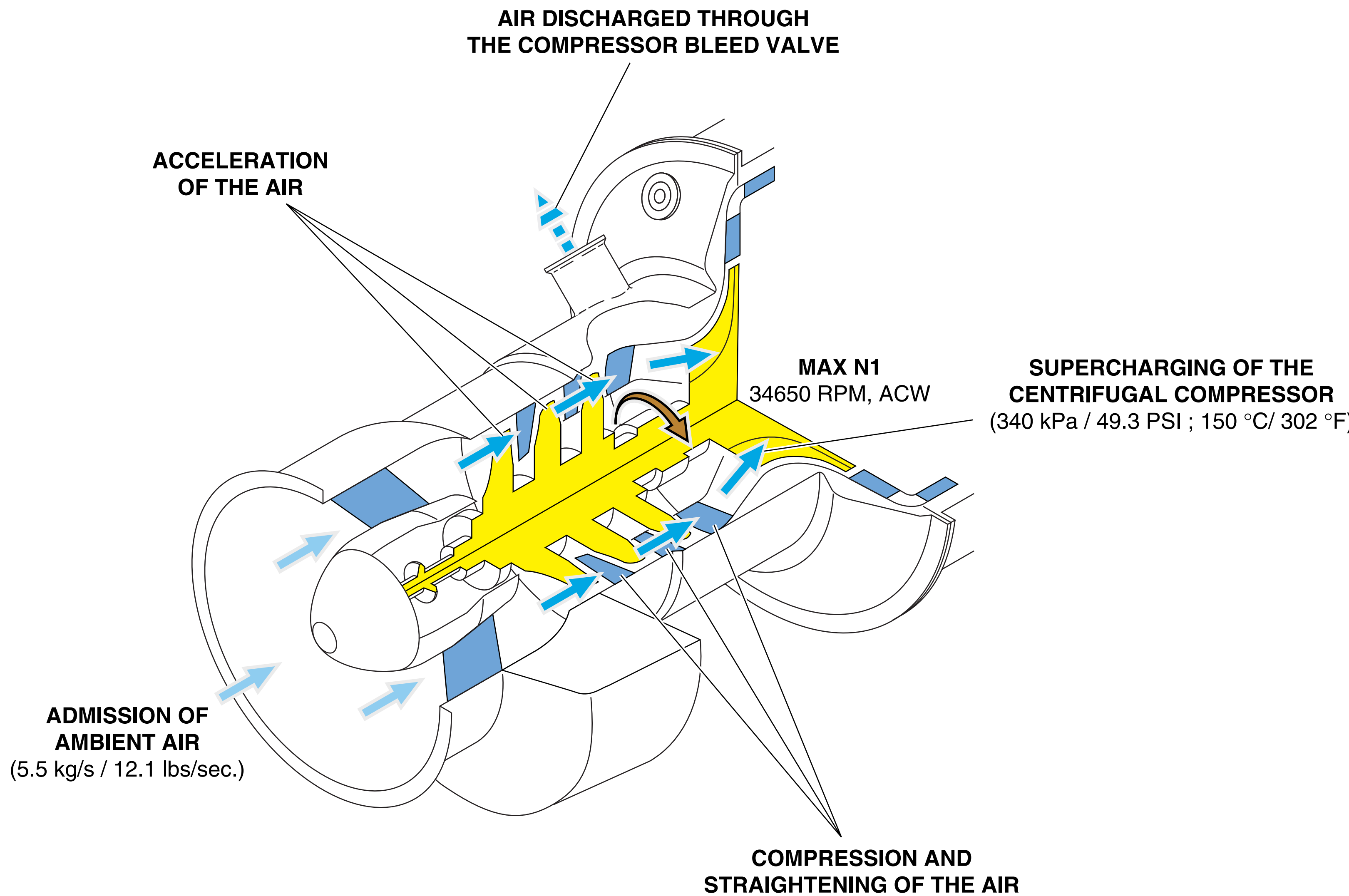
The flow is straightened by the stator vanes before being admitted, through an annular duct, to the centrifugal compressor.

Operating parameters

In standard conditions, the air flow is 5.5 kg/s (12.1 lbs/sec.), the outlet pressure 340 kPa (49.3 PSI) and the outlet temperature 150 °C (302 °F).

The rotation speed of the axial compressor wheel is obviously the gas generator speed.

In order to avoid compressor surge, a valve discharges overboard a certain amount of air in certain operating conditions (refer to "AIR SYSTEM" chapter for further details on the compressor bleed valve).



AXIAL COMPRESSOR - OPERATION

GAS GENERATOR HP SECTION

Function

The HP section of the gas generator ensures the phases of compression (second stage), combustion and expansion.

It provides the energy necessary to drive the power turbine.

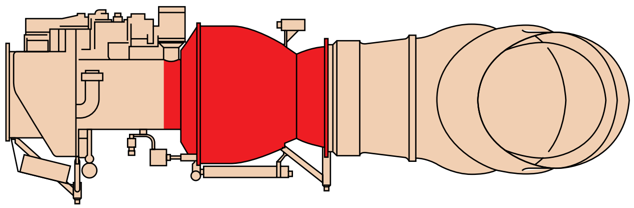
Position

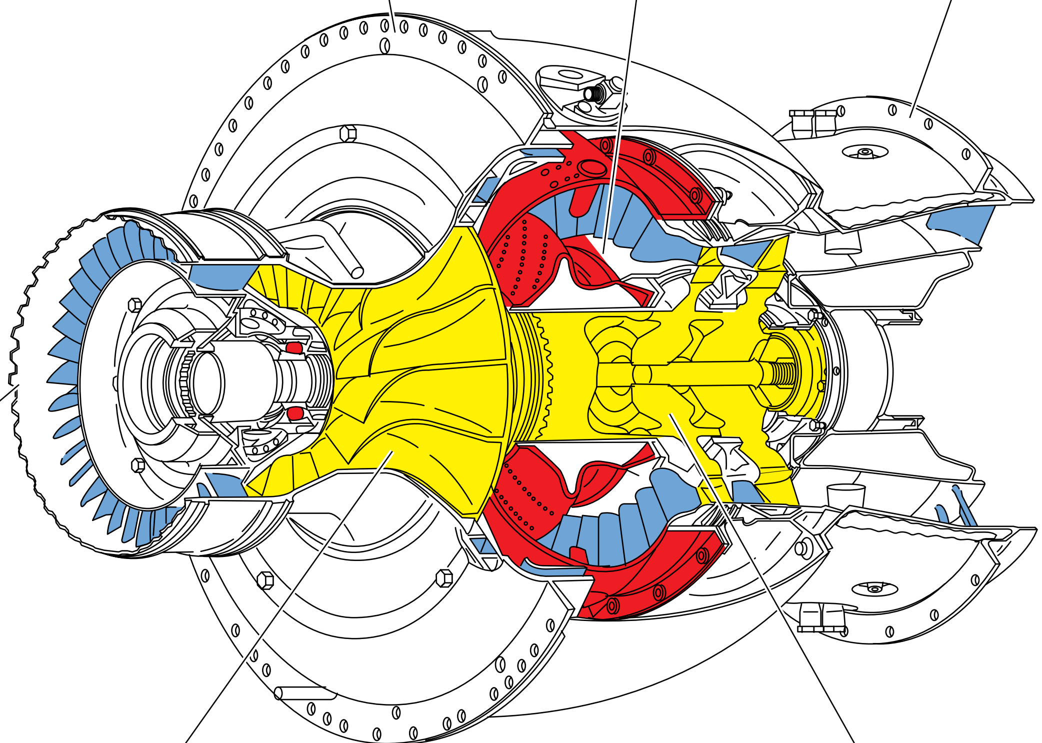
- Module M03 (gas generator HP section) is mounted between modules M02 and M01 at the front and module M05 at the rear.
  - Module M01 (air intake) secured by a ring of bolts
  - Module M02 (axial compressor) secured by a tie-bolt and a ring nut
  - Module M05 (power turbine) secured by a ring of bolts.

Main components

- Centrifugal compressor
- Combustion chamber
- Turbine.

Note : *The module M03 includes the 3rd stage diffuser of the axial compressor and the 1st stage nozzle guide vane of the power turbine.*





GAS GENERATOR HP SECTION

CENTRIFUGAL COMPRESSOR - GENERAL

Function

The compressor supplies the compressed air required for combustion.

Supercharged by the axial compressor, it ensures the second stage of compression.

Position

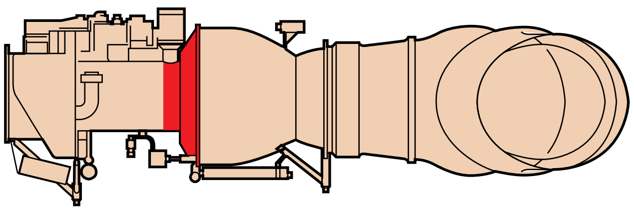
- At the front of module M03.

Main characteristics

- Type : centrifugal
- Air flow : 5.5 kg/s (12.1 lbs/sec.)
- Engine overall compression ratio : 10.4/1
- Outlet temperature : 340 °C (644 °F)
- Max N1 rotation speed : 34650 RPM, ACW.

Main components

- Rotating components (wheel, tie-bolt, bearing)
- Stationary components (diffusers, casings).



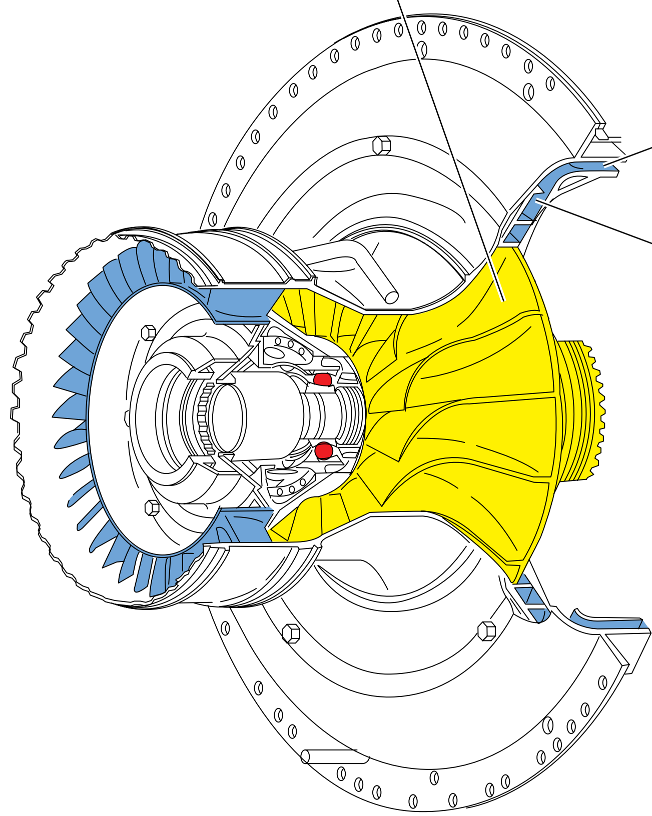
Type :
Centrifugal

Air flow :
5.5 kg/s (12.1 lbs/sec.)

Engine overall compression ratio :
10.4/1

Outlet temperature :
340 °C (644 °F)

Max N1 rotation speed :
34650 RPM, ACW



CENTRIFUGAL COMPRESSOR - GENERAL

CENTRIFUGAL COMPRESSOR - DESCRIPTION

The centrifugal compressor includes rotating and stationary components.

Rotating components

The main component is **the centrifugal wheel**. The wheel has blades which are cut from the solid in a disc of titanium alloy.

A coupling sleeve ensures the drive of the axial compressor.

The rear part has a curvic-coupling for connection to the centrifugal fuel injection wheel. A tie-bolt secures the rotating components.

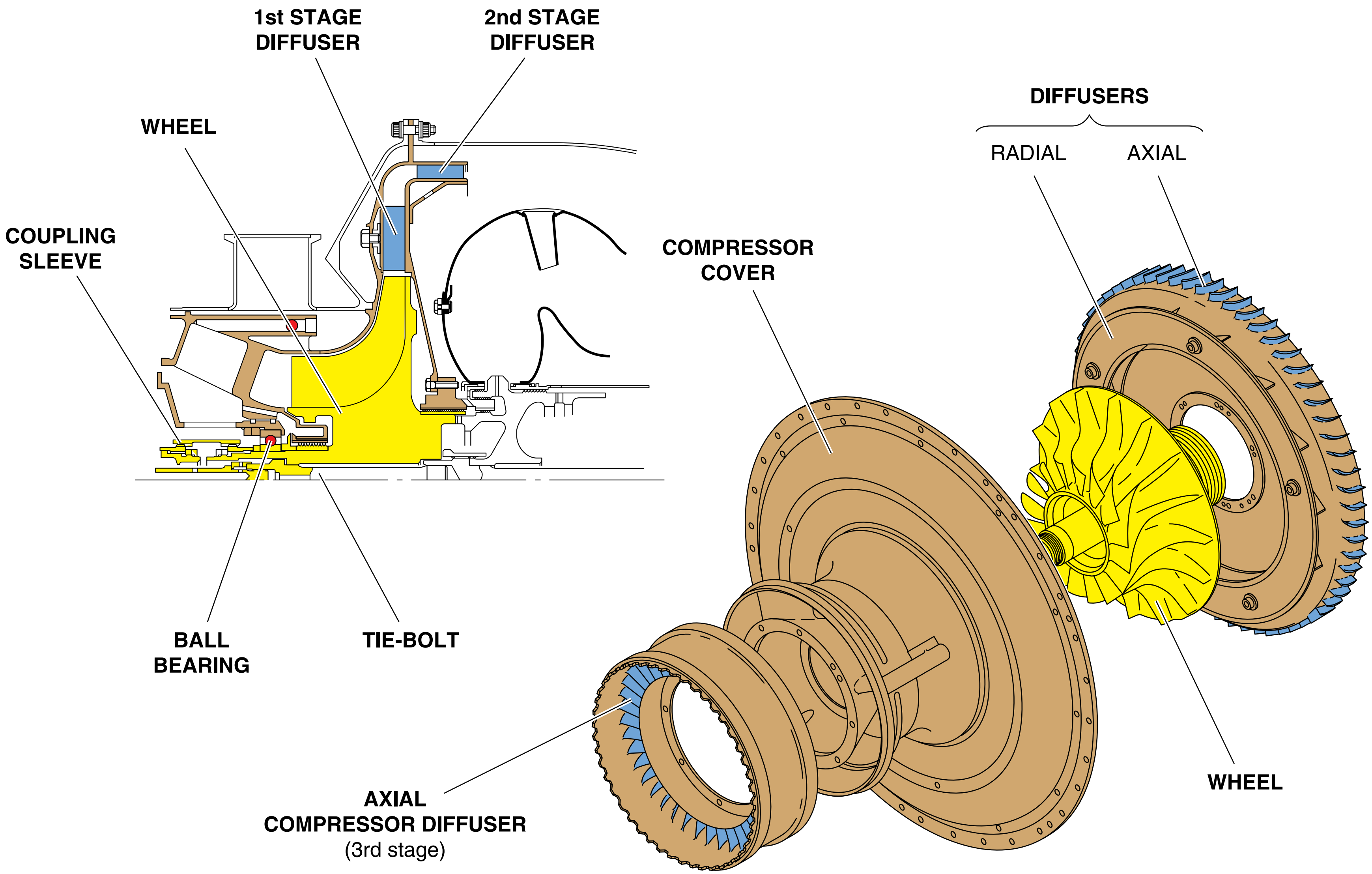
Stationary components

The stationary components include a cover and a diffuser assembly.

The compressor front cover is mounted by means of a ring of bolts onto the turbine casing.

The diffuser assembly includes the 1st stage diffuser (radial stator vanes) and the 2nd stage diffuser (axial stator vanes).

The diffuser assembly is mounted on the compressor cover by a ring of bolts.



CENTRIFUGAL COMPRESSOR - DESCRIPTION

CENTRIFUGAL COMPRESSOR - OPERATION

The centrifugal compressor ensures the main stage of compression.

Compressor air flow

The air supplied by the axial compressor flows between the blades of the centrifugal compressor. The air pressure increases due to the divergent passage between the blades and the air velocity increases due to the centrifugal flow.

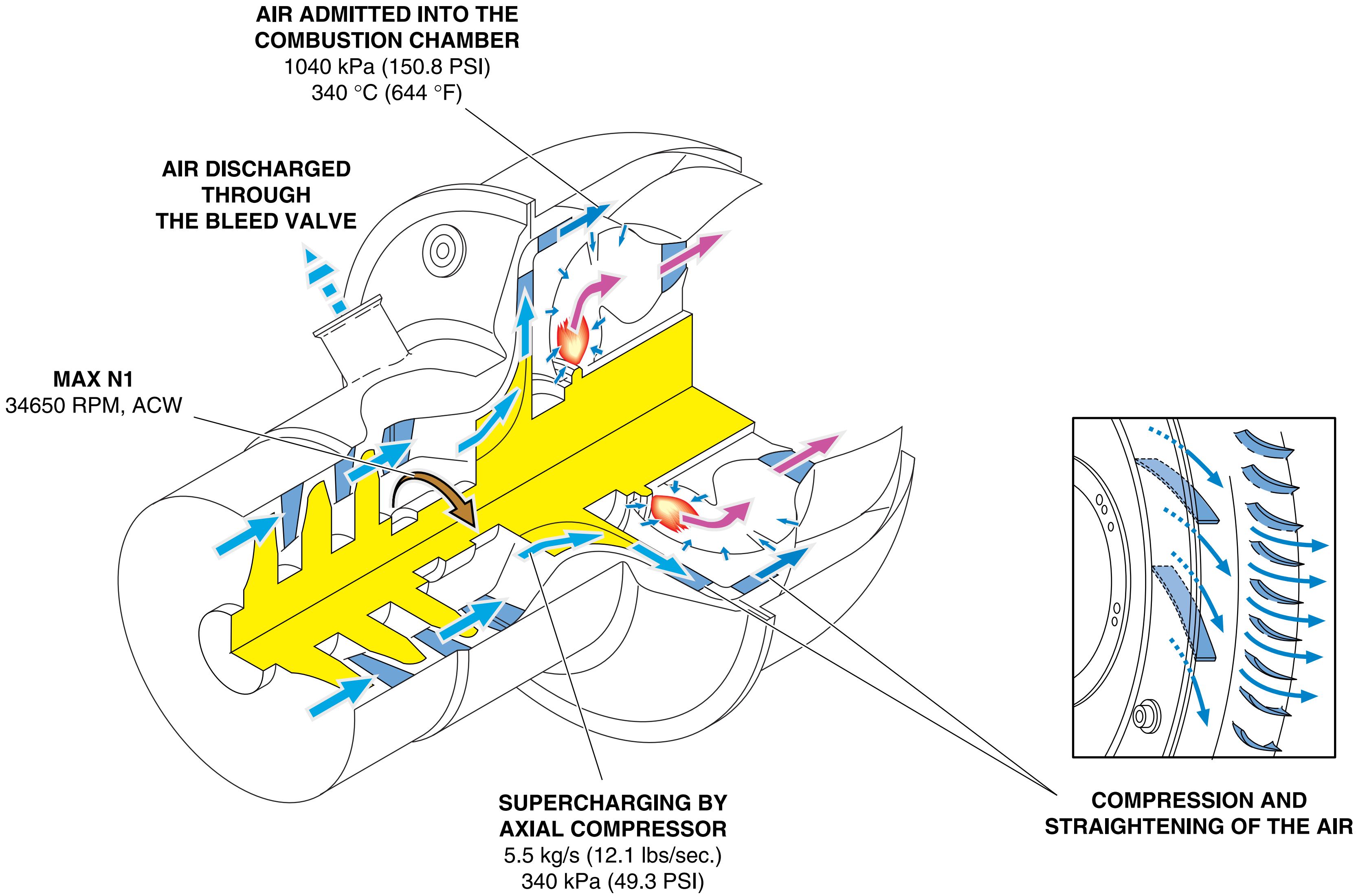
The air leaves the tips of the blades at very high velocity and then flows through the first stage diffuser vanes where the velocity is transformed into pressure.

The air then passes through an elbow and the flow becomes axial. In the second stage diffuser, the velocity is again transformed into pressure. The air is then admitted into the combustion chamber.

Operating parameters

In standard conditions, the air flow is 5.5 kg/s (12 lbs/sec.), the global compression ratio 10.4, the outlet pressure 1040 kPa (150.8 PSI) and the outlet temperature 340 °C (644 °F).

The compressor wheel rotation speed is obviously the gas generator speed.



CENTRIFUGAL COMPRESSOR - OPERATION

COMBUSTION CHAMBER - GENERAL

Function

The combustion chamber forms an enclosure in which the air-fuel mixture is burnt.

Position

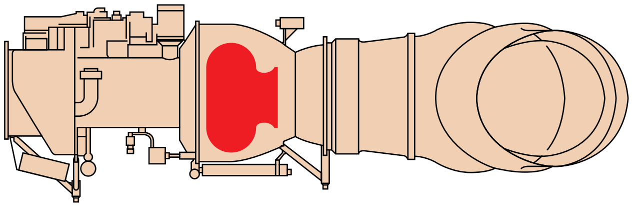
- Central section of the gas generator.

Main characteristics

- Type : annular with centrifugal fuel injection
- Overall fuel-air ratio : 1/45
- Turbine inlet temperature : 1180 °C (2156 °F).

Main components

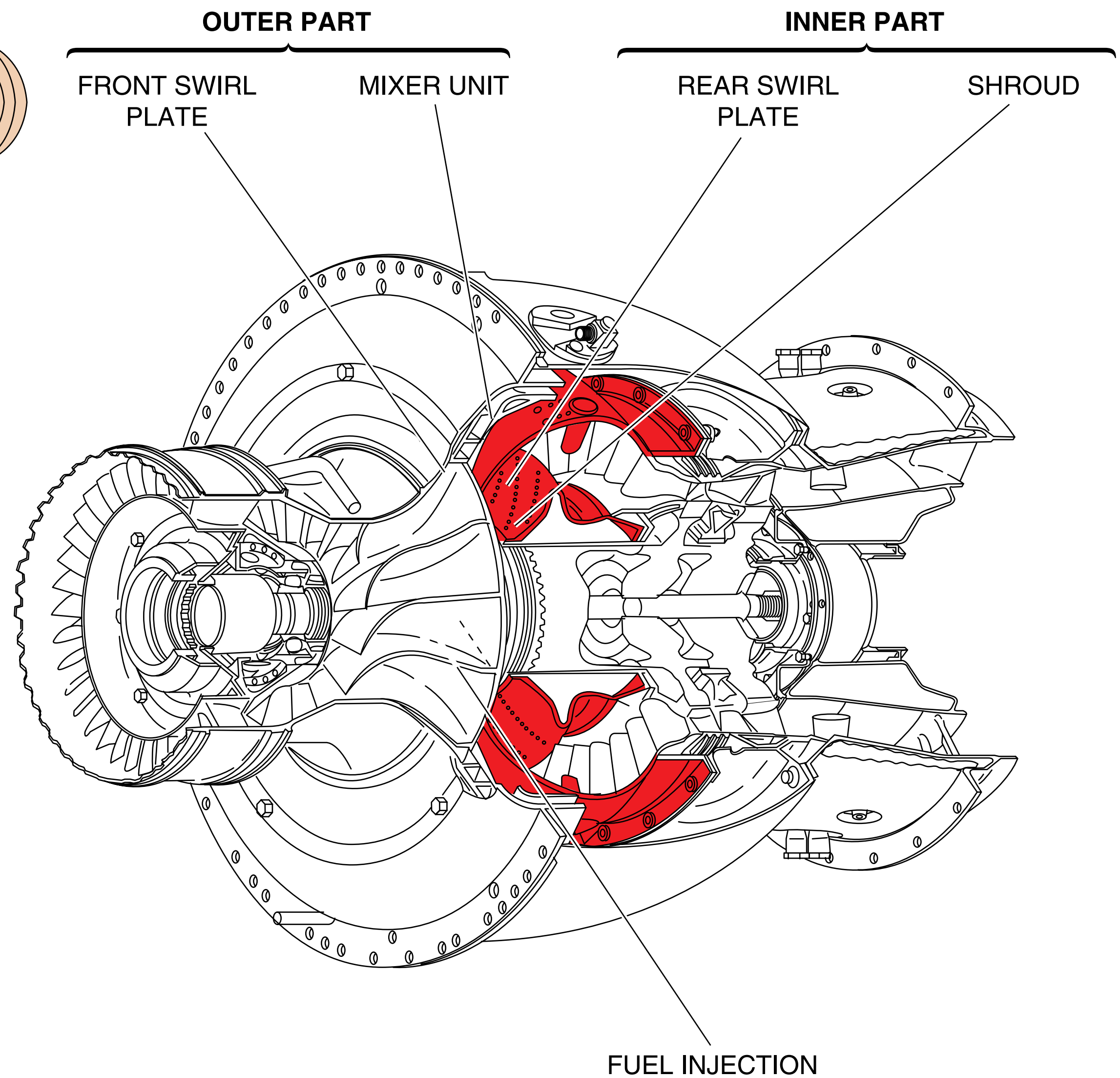
- Outer part (front swirl plate and mixer unit)
- Inner part (rear swirl plate and shroud)
- Fuel injection system
- Casing.



Type
Annular, with
centrifugal fuel injection

Overall fuel-air ratio
1/45

Turbine inlet temperature
1180 °C (2156 °F)



COMBUSTION CHAMBER - GENERAL

COMBUSTION CHAMBER - DESCRIPTION

The combustion chamber assembly includes the outer part, the inner part, the turbine casing and the fuel injection system.

Outer part

The outer part includes the front swirl plate and the mixer unit.

The front swirl plate is provided with calibrated orifices for the passage of primary air ; it is secured to the mixer unit with special rivets.

The mixer unit is provided with calibrated orifices for the passage of secondary air ; it is bolted to the inner flange of the turbine casing.

It also has 4 different holes giving the passage for start injectors and igniter plugs.

Inner part

The inner part includes the rear swirl plate and the shroud.

The rear swirl plate is provided with calibrated orifices for the passage of the second part of primary air.

The shroud surrounds the shaft ; it is bolted to the turbine nozzle guide vane.

Note : *The two parts are made of special alloy. The calibrated orifices are drilled using the electron beam process.*

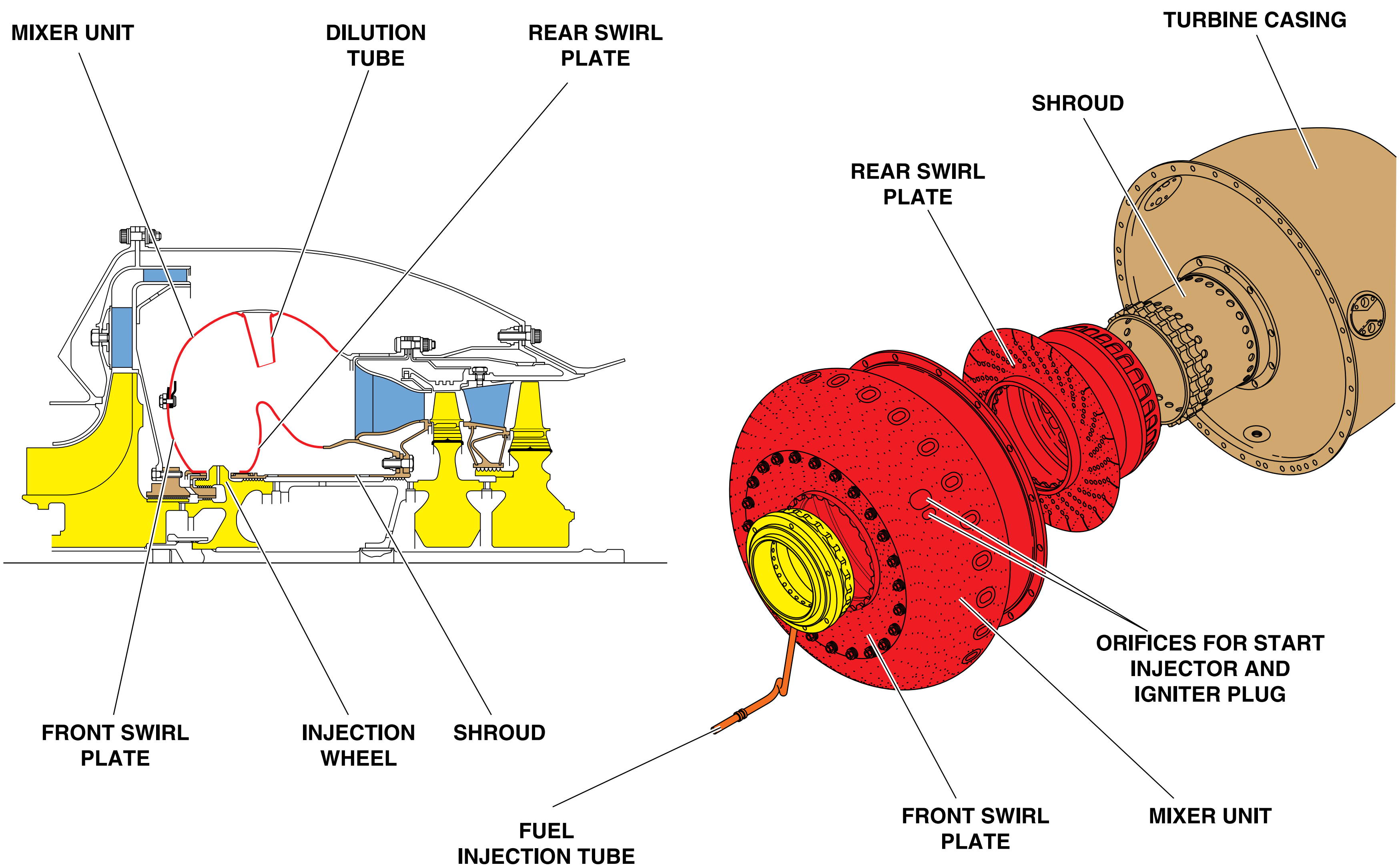
Turbine casing

The casing houses the combustion chamber and the turbine. It has various bosses and, particularly the boss for the combustion chamber drain valve at the bottom of the casing.

Fuel injection system

The main fuel injection system includes : the fuel inlet union, the inner fuel injection tube, the fuel distributor and the centrifugal injection wheel.

The injection wheel is mounted by means of curvic-couplings between the compressor and the turbine shaft (refer to "FUEL SYSTEM" chapter for further details on the fuel injection system).



COMBUSTION CHAMBER - DESCRIPTION

COMBUSTION CHAMBER - OPERATION

The combustion chamber forms an enclosure in which the fuel-air mixture is burnt.

Combustion chamber flow

In the combustion chamber, the compressed air is divided into two flows : a primary air flow mixed with the fuel for combustion and a secondary air flow (or dilution air flow) for cooling of the burnt gases.

Primary air

One part flows through the orifices of the front swirl plate.

A second part flows through the hollow vanes of the turbine nozzle guide vane (cooling of the vanes) and through the orifices of the rear swirl plate.

The primary air is mixed with the fuel sprayed by the injection wheel. The combustion occurs between the two swirl plates. The flame temperature reaches approximately 2500 °C (4532 °F).

Secondary air

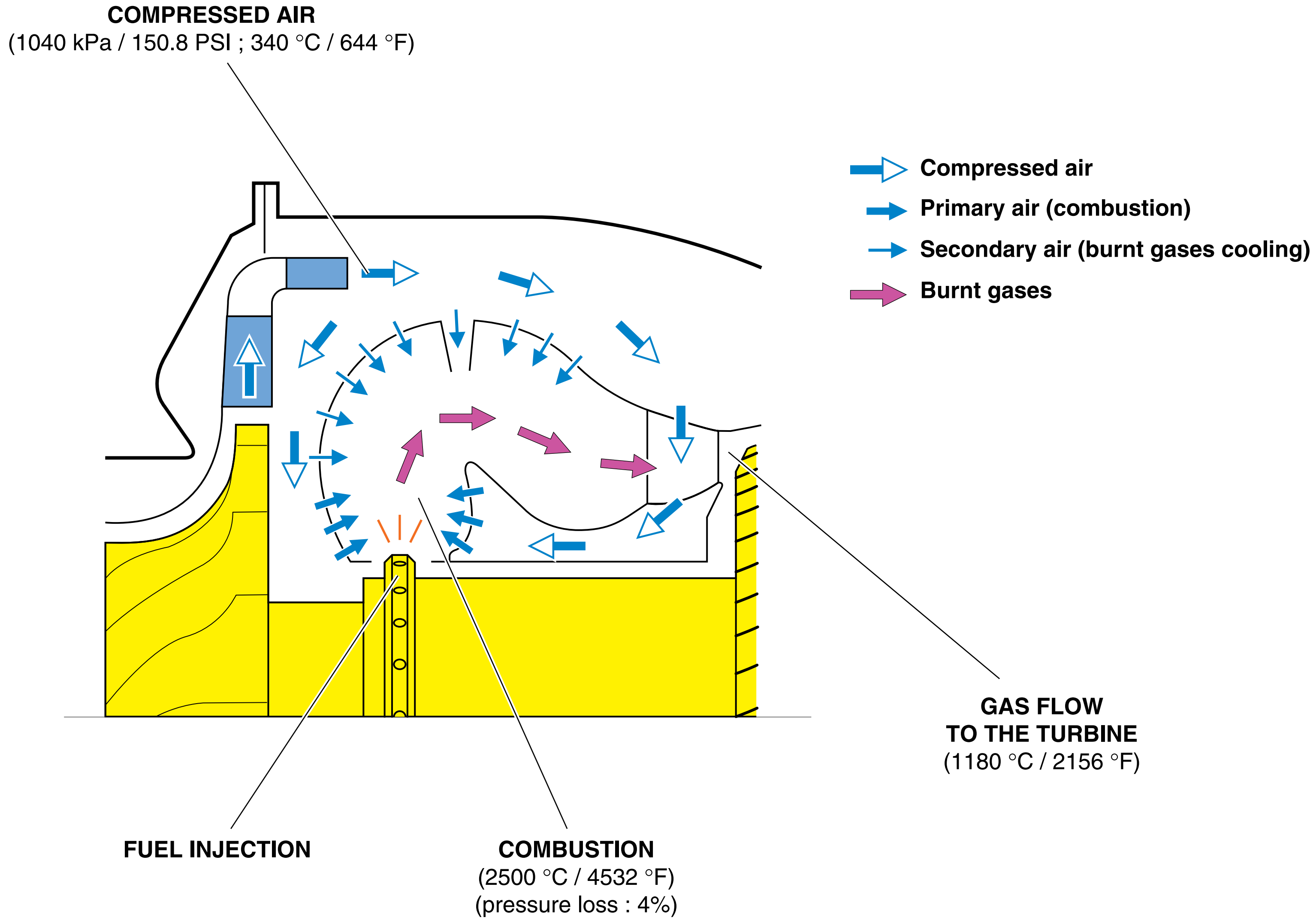
The secondary air (or dilution air) flows through the orifices of the mixer unit. It is calibrated to obtain flame stability, cooling of the burnt gases, and distribution of temperature on the turbine.

Operating parameters

The fuel-air ratio for combustion is approximately 1/15 ; the total ratio is approximately 1/45.

The pressure drop in the combustion chamber is approximately 4 %.

The turbine inlet temperature (at design point) is approximately 1180 °C (2156 °F).



COMBUSTION CHAMBER - OPERATION

GAS GENERATOR TURBINE - GENERAL

Function

The turbine extracts sufficient energy from the gas flow to drive the compressors and the accessories.

Position

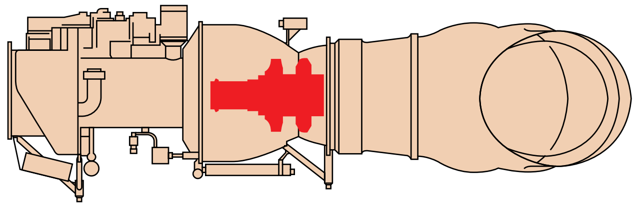
- At the rear of the gas generator.

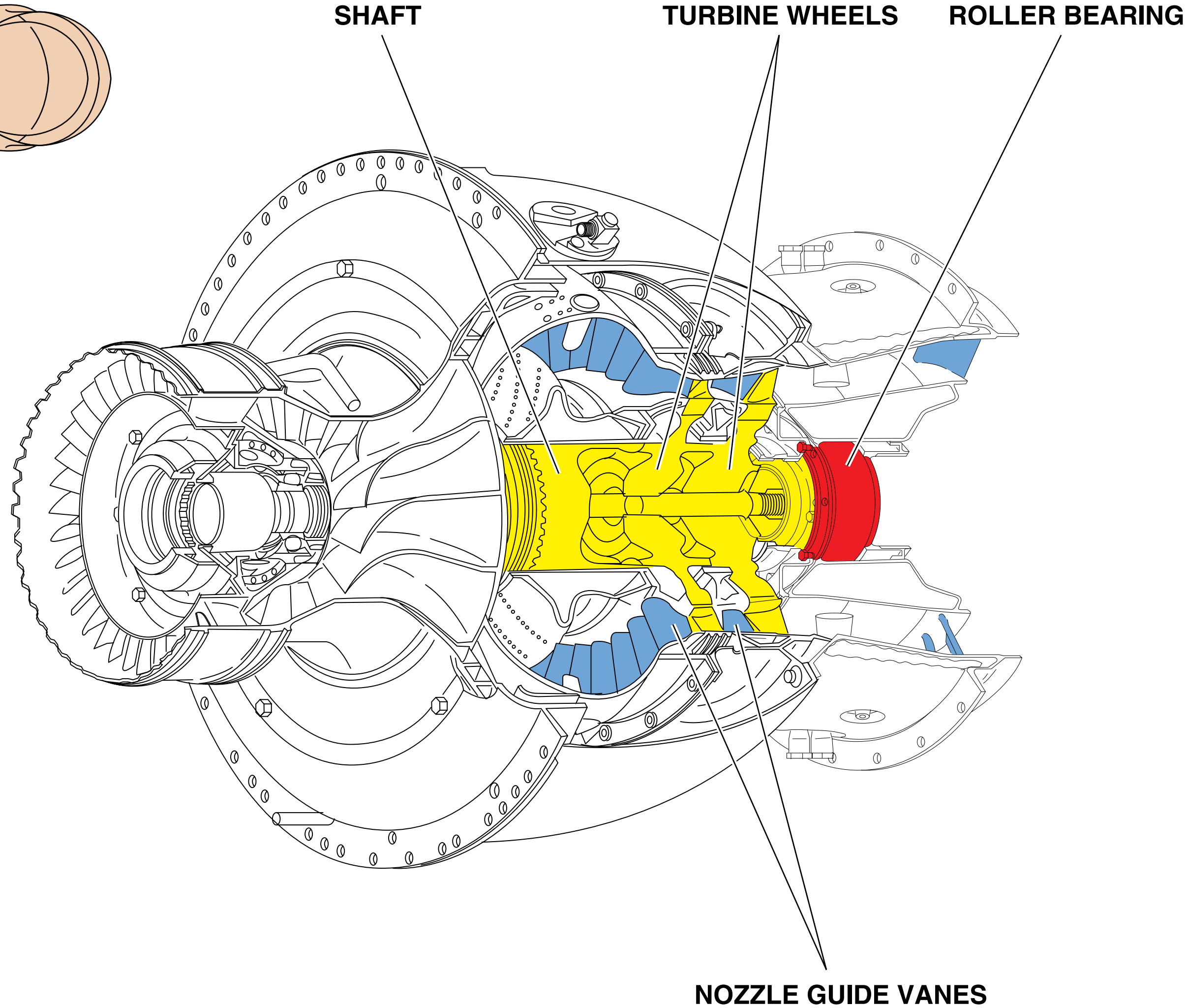
Main characteristics

- Type : 2 stage axial
- Turbine inlet temperature : 1180 °C (2156 °F)
- Turbine outlet temperature : 800 °C (1472 °F).
- Expansion ratio : ≈ 3.21
- Max N1 rotation speed : 34650 RPM, ACW.

Main components

- Rotating components (wheels, shafts, bearing)
- Stationary components (nozzle guide vane, containment shield, casing).





Type
2 stage axial

Turbine inlet temperature
1180 °C (2156 °F)

Turbine outlet temperature
800 °C (1472 °F)

Expansion ratio
≈ 3.21

Max N1 rotation speed
34650 RPM, ACW

GAS GENERATOR TURBINE - GENERAL

GAS GENERATOR TURBINE - DESCRIPTION

The gas generator turbine assembly includes rotating components and stationary components.

Rotating components

The main rotating components are the turbine wheels.

Each wheel consists of a disc and fir-tree mounted single crystal blades.

At the front, the 1st wheel is coupled by a curvic-coupling to the shaft connecting the turbine to the compressor. At the rear the 2nd wheel is coupled by curvic-coupling to a rear shaft.

The two turbine discs are coupled to each other by a curvic-coupling.

The rear part of the shaft is supported by a roller bearing. Rotating labyrinths provide sealing.

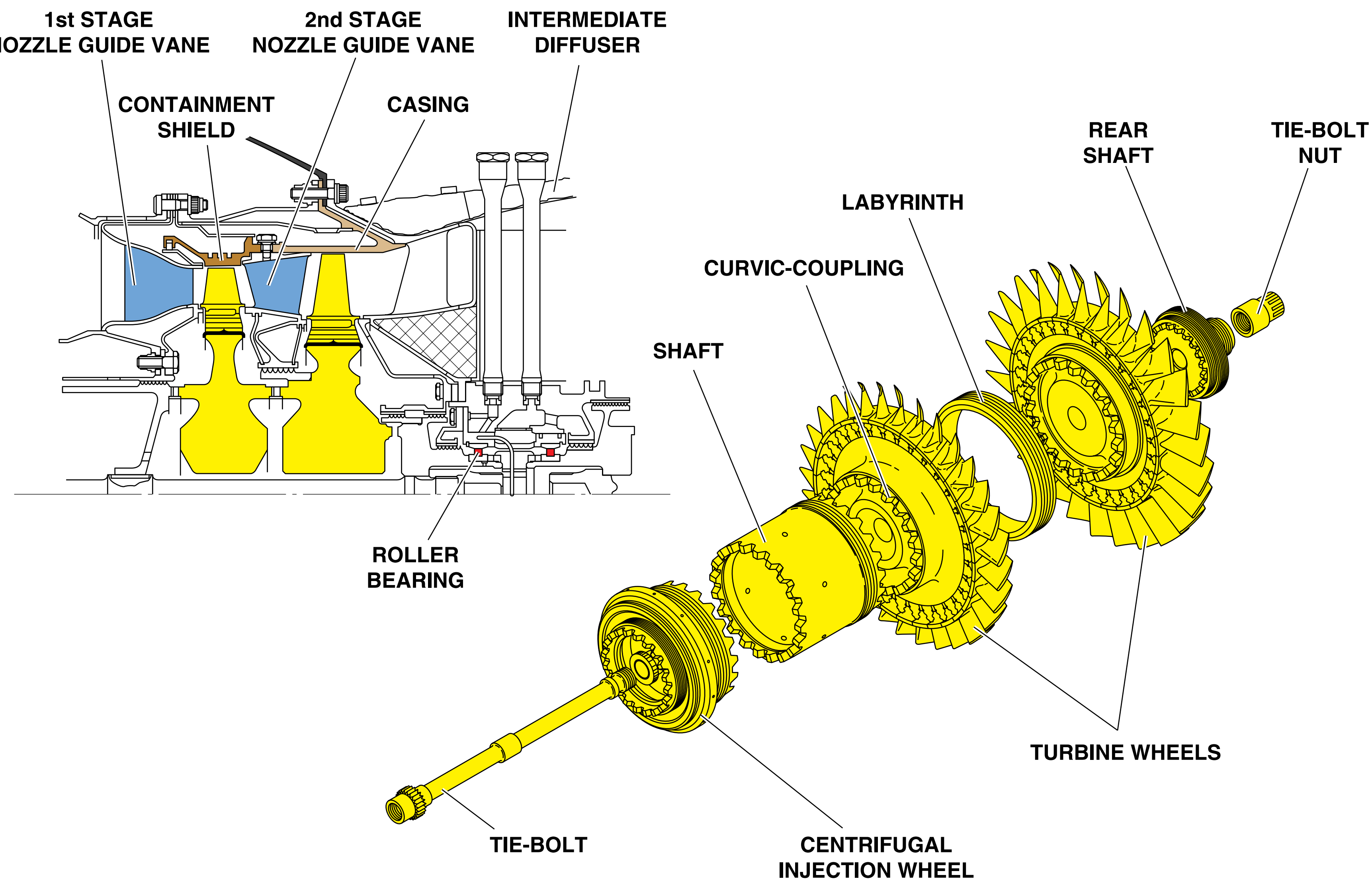
The assembly is hold together by a tie-bolt.

Stationary components

The stationary components are the turbine nozzle guide vanes the containment shield and the intermediate diffuser.

The 1st stage nozzle guide vane includes a row of hollow vanes. It is bolted to the combustion chamber inner part and to the containment shield.

The containment shield houses the turbine wheels and contains the pieces in the event of turbine failure. It is bolted to the **2nd stage nozzle guide vane** and to the inner mounting flange of the nozzle guide vane casing.



GAS GENERATOR TURBINE - DESCRIPTION

GAS GENERATOR TURBINE - OPERATION

The gas generator turbine transforms the gas energy into mechanical power to drive the compressors and various accessories.

The operation is characterized by the first phase of expansion.

Turbine gas flow

The burnt gases first flow through the turbine nozzle guide vanes. The gas velocity increases due to the convergent passage.

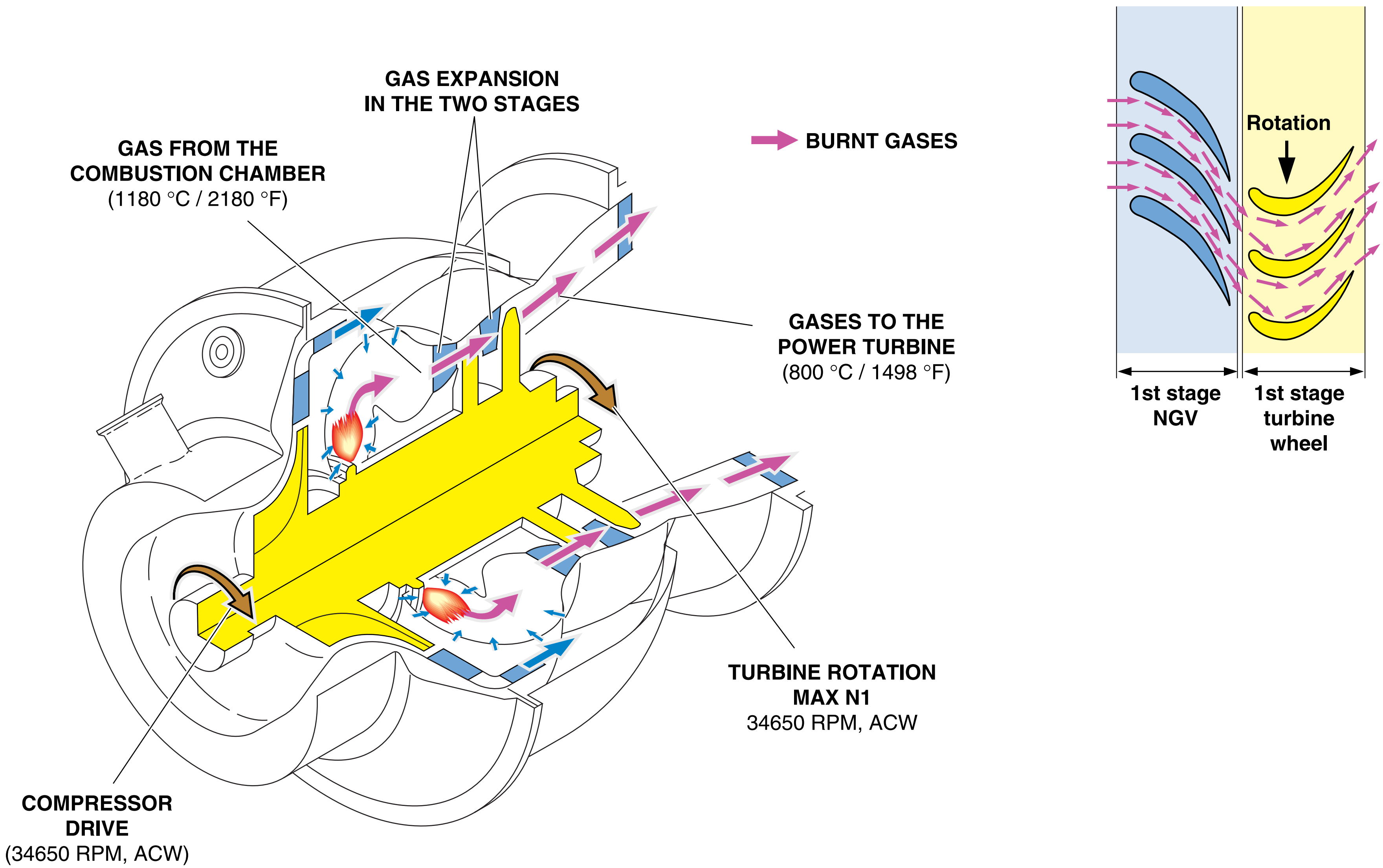
The flow on the blades results in aerodynamic forces whose resultant causes the rotation of the wheels.

The gas, still containing energy, is directed to the power turbine.

Operating parameters

The operation is characterised by the following parameters :

- Expansion ratio : approximately 3.21
- Turbine inlet temperature : 1180 °C (2156 °F)
- Turbine outlet temperature : 800 °C (1472 °F)
- Max N1 rotation speed : 34650 RPM, ACW.



GAS GENERATOR TURBINE - OPERATION

POWER TURBINE - GENERAL

Function

The turbine extracts the energy from the gas to drive the power shaft.

Position

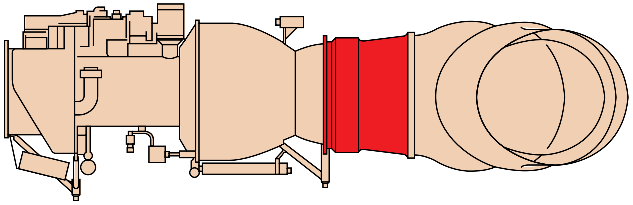
- After the gas generator. It forms the module M05.

Main characteristics

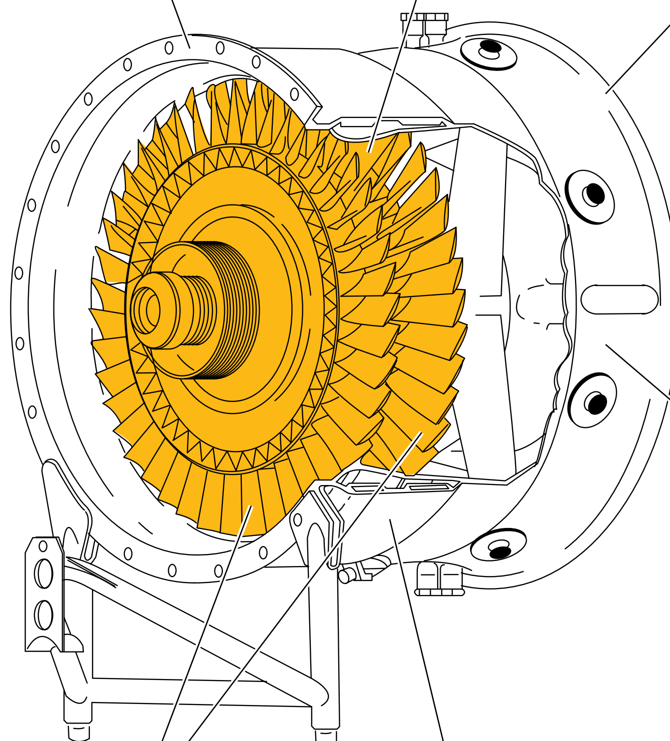
- Type : 2 stage axial
- Turbine inlet temperature : 800 °C (1472 °F)
- Turbine outlet temperature : 570 °C (1058 °F)
- Expansion ratio : ≈ 2.84
- Rotation speed : 22962 RPM at 100 % ; ACW.

Main components

- Rotating components (wheels, shaft, bearings)
- Stationary components (nozzle guide vanes, containment shields, casing).



Type 2 stage axial
Turbine inlet temperature 800 °C (1472 °F)
Turbine outlet temperature 570 °C (1058 °F)
Expansion ratio ≈ 2.84
Rotation speed 22962 RPM at 100 % ; ACW



POWER TURBINE - GENERAL

POWER TURBINE - DESCRIPTION

The power turbine assembly forms module M05. It includes rotating components and stationary components.

Rotating components

The main components are the turbine wheels.

The wheels consist of a disc with fir-tree mounted blades.

The power turbine assembly is supported by two bearings : a front roller bearing and a rear ball bearing.

The front and rear bearing sealing is ensured by pressurised labyrinth seals (pressurisation with compressor air directed to the power turbine through an external pipe).

The rear part of the shaft is the power drive.

Phonic wheels for speed measurement are mounted on the shaft.

Stationary components

The stationary components are the turbine nozzle guide vanes, the power turbine casing and the bearing housing.

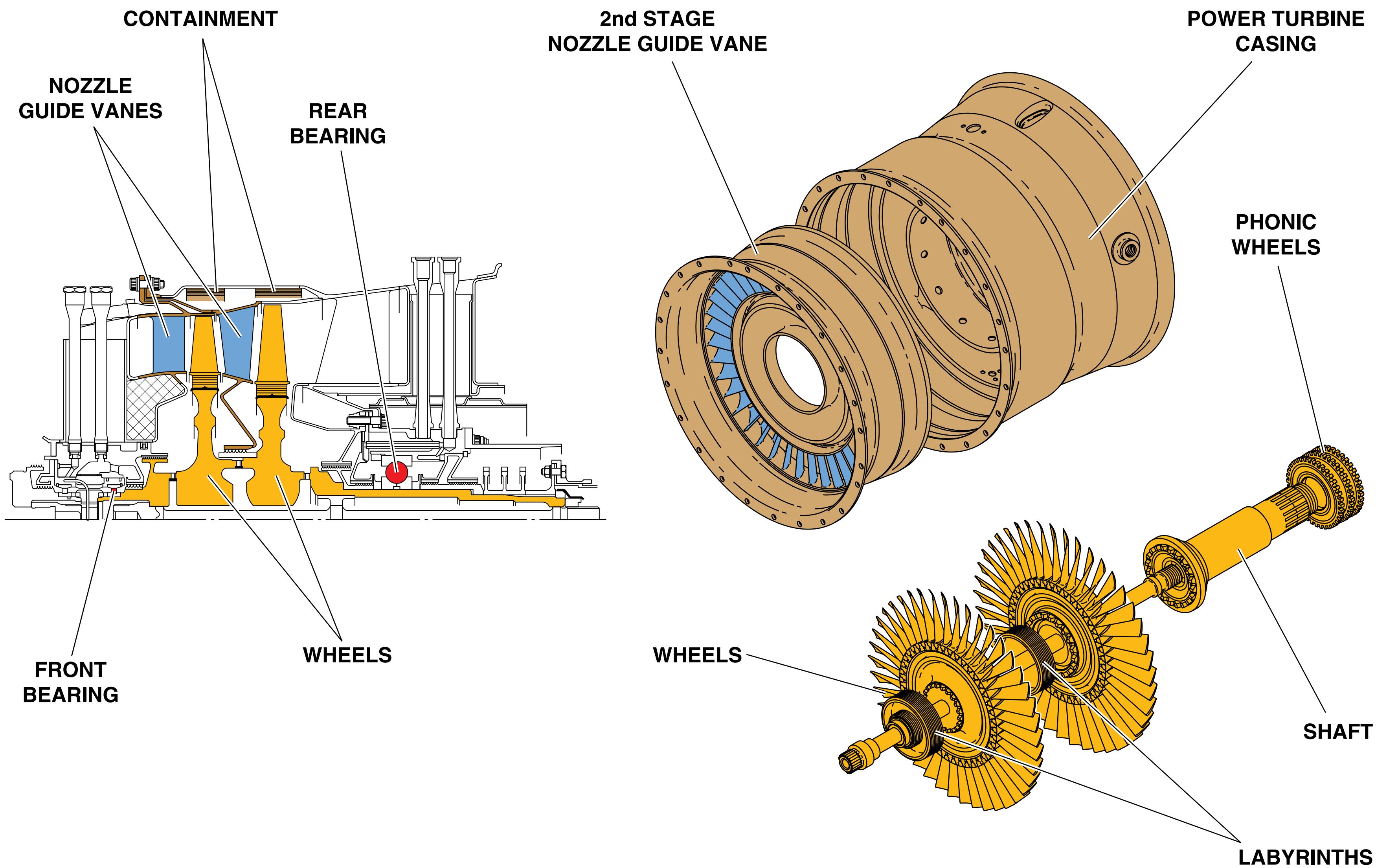
The nozzle guide vanes include a row of vanes.

The power turbine casing is mounted on module M03 by a ring of bolts.

The bearing housing is installed in the inner hub of the casing.

The identification plate is located at the upper part of the casing.

The 1st stage nozzle guide vane is mounted in the intermediate diffuser of module M03.



POWER TURBINE - DESCRIPTION

POWER TURBINE - OPERATION

The power turbine transforms the gas energy provided by the gas generator, into mechanical power.

The operation is characterised by the second phase of expansion.

Turbine flow

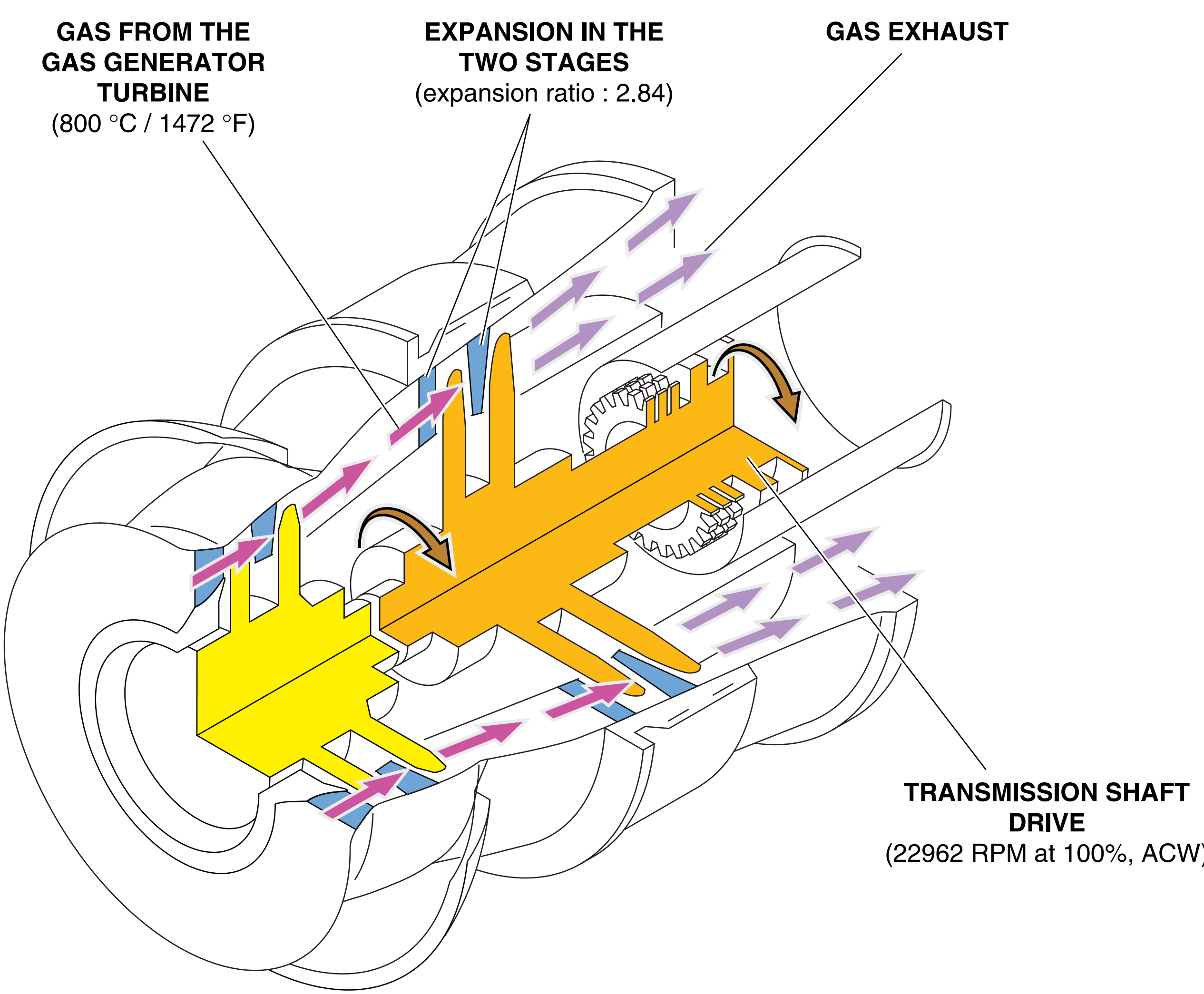
The gas supplied by the gas generator flows first through the nozzle guide vane. In the nozzle guide vanes, the gas velocity increases (increase due to the convergent passage).

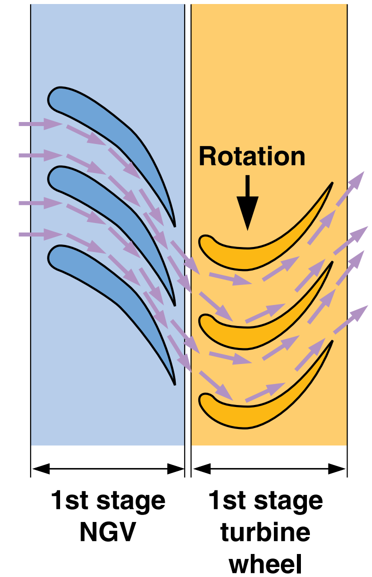
The gas is directed onto the turbine wheels and the resultant of the aerodynamic forces on the blades causes the wheel to rotate. The gases are then expelled overboard through the exhaust pipe.

Operating parameters

The operation is characterised by the following parameters :

- Expansion ratio : approx. 2.84
- Turbine inlet temperature : 800 °C (1472 °F)
- Rotation speed : 22962 RPM at 100 %, ACW
- Power extracted : ≈ 1300 kW (1742 Shp).





POWER TURBINE - OPERATION

EXHAUST PIPE - GENERAL

Function

The pipe continues the expansion phase and expels the gases overboard.

Position

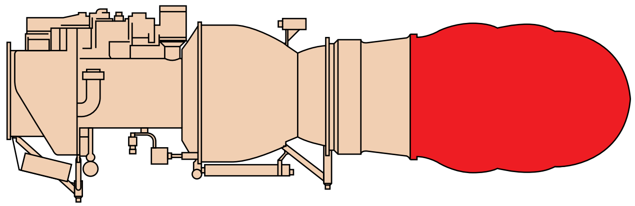
- Behind the power turbine.

Main characteristics

- Non modular component
- Type : rotatable to the left or right
- Gas temperature : 570 °C (1058 °F).

Main components

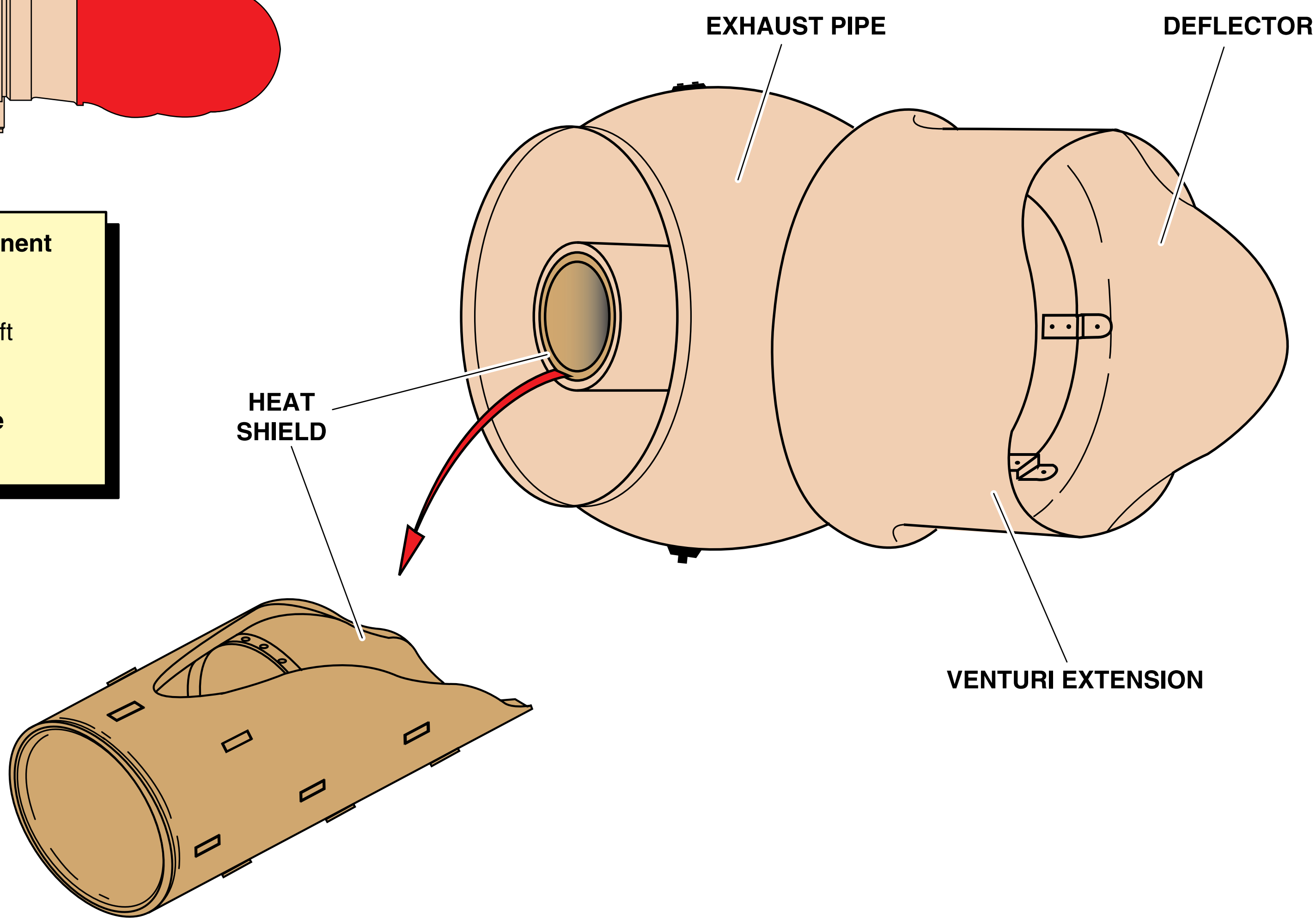
- Exhaust pipe
- Venturi extension
- Heat shield
- Deflector.



Non modular component

Type
Rotatable to the left
or right

Gas temperature
570 °C (1058 °F)



EXHAUST PIPE - GENERAL

EXHAUST PIPE - DESCRIPTION - OPERATION

Description

The exhaust pipe is secured on the rear mounting flange of the power turbine casing by means of a clamp. The exhaust pipe can be orientated to the right or to the left depending on the position of the engine in the aircraft.

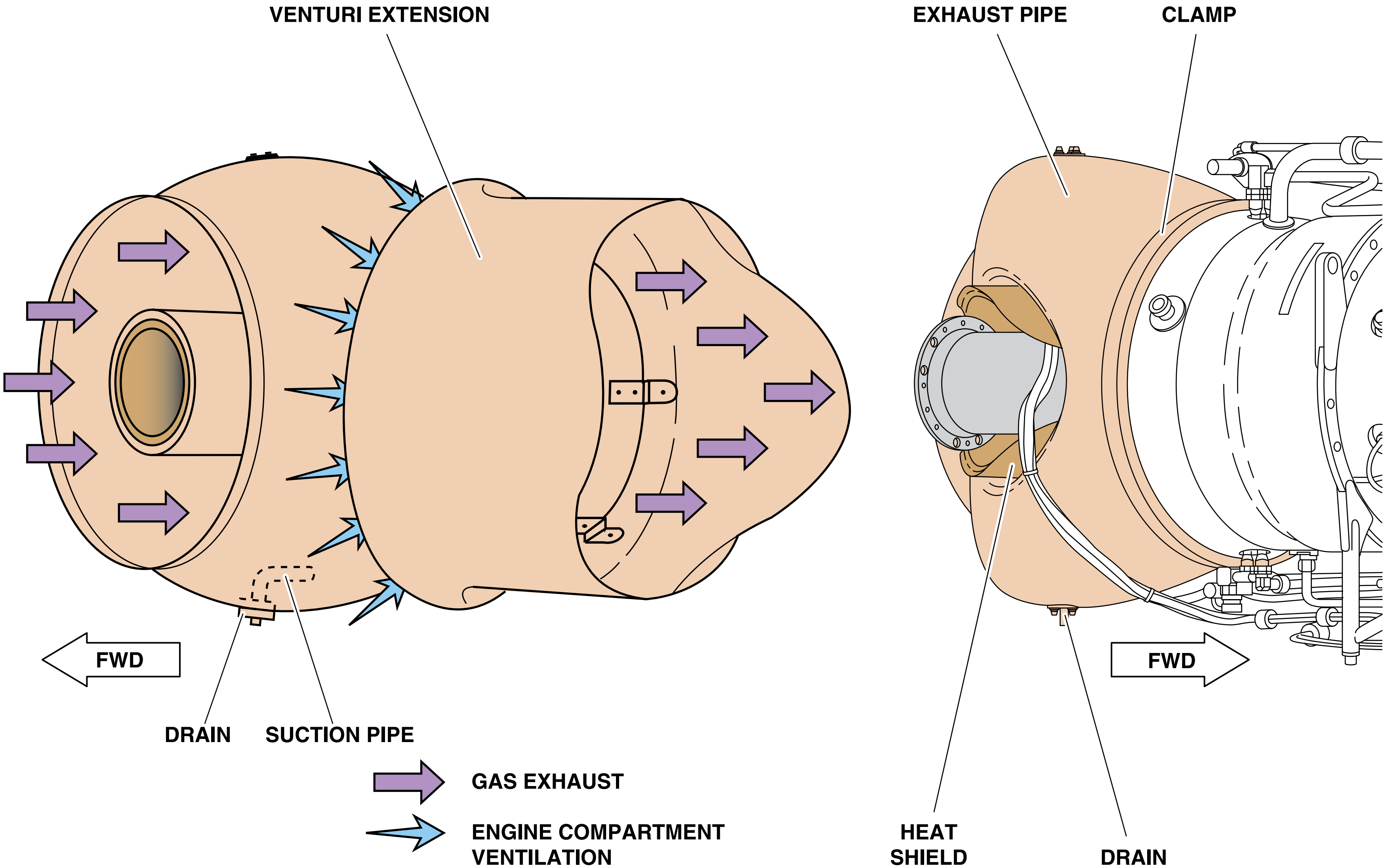
It is a sheet metal assembly made of stainless steel. A venturi extension accelerates the engine compartment ventilation. The exhaust pipe has a drain located at its lower part. It allows the drainage of the residual fuel, by gravity, when the engine is stopped.

It ventilates the airframe collector by venturi effect when the engine is running.

A heat shield is mounted between the exhaust pipe and the rear mounting tube in order to protect the tube against heat diffusion.

Operation

Functionally it should be noted that the exhaust gases still contain a certain amount of energy which produces a small residual thrust.



EXHAUST PIPE - DESCRIPTION - OPERATION

POWER TRANSMISSION SHAFT

General

Function

The shaft transmits the power provided by the power turbine to the main gearbox of the helicopter.

It is a flexible shaft, supplied by the aircraft manufacturer.

Position

The shaft is located between the power turbine and the main gearbox of the helicopter.

Main components

- "Bendix" shaft
- Linking tube.

Description

The "Bendix" shaft forms a flexible coupling. It includes diaphragms assembled by electron beam welding.

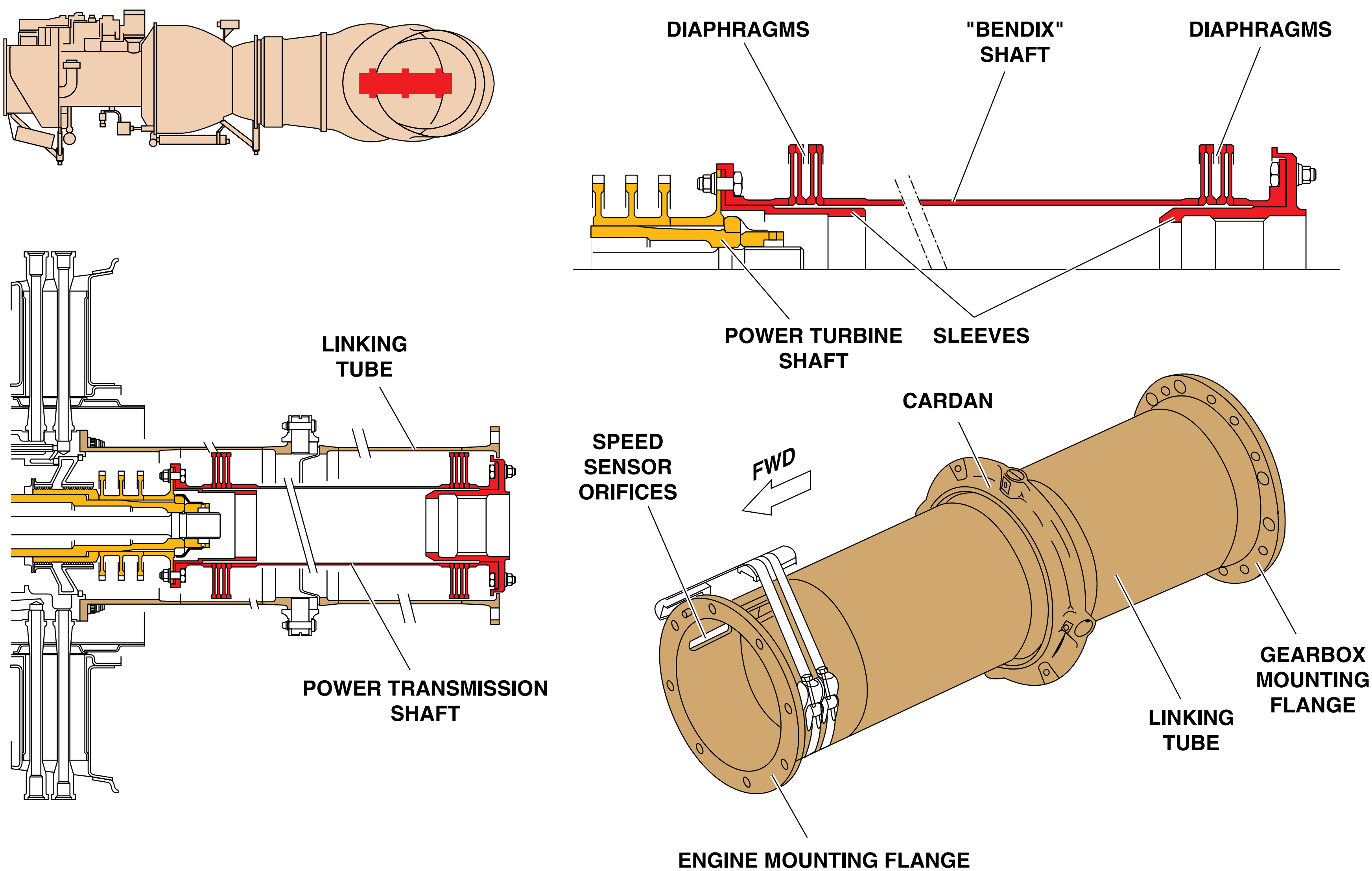
Two sleeves support the shaft in the event of shaft breakage.

The linking tube includes two orifices for the speed sensors and a central cardan which allows small displacement. The linking tube ensures the engine rear mounting.

Operation

The shaft transmits the engine power. It absorbs :

- The engine main gearbox misalignment
- The shear load and torque stresses
- The deformation due to expansion.



POWER TRANSMISSION SHAFT

ACCESSORY DRIVE - GENERAL

Function

The accessory drive train provides the drive for the engine accessories.

Position

The accessory drive train is located in the upper part of the air intake casing.

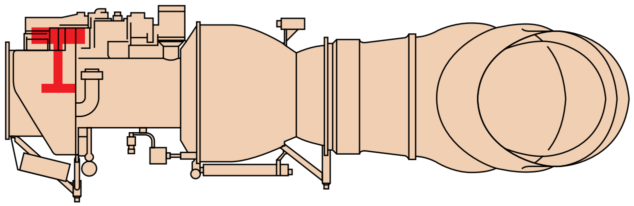
Main characteristics

- Gears made of steel
- Starter : 24376 RPM, ACW
- Fuel Control Unit : 4366 RPM, ACW
- Oil pump : 4366 RPM, CW
- Centrifugal breather gear : 5572 RPM, CW.

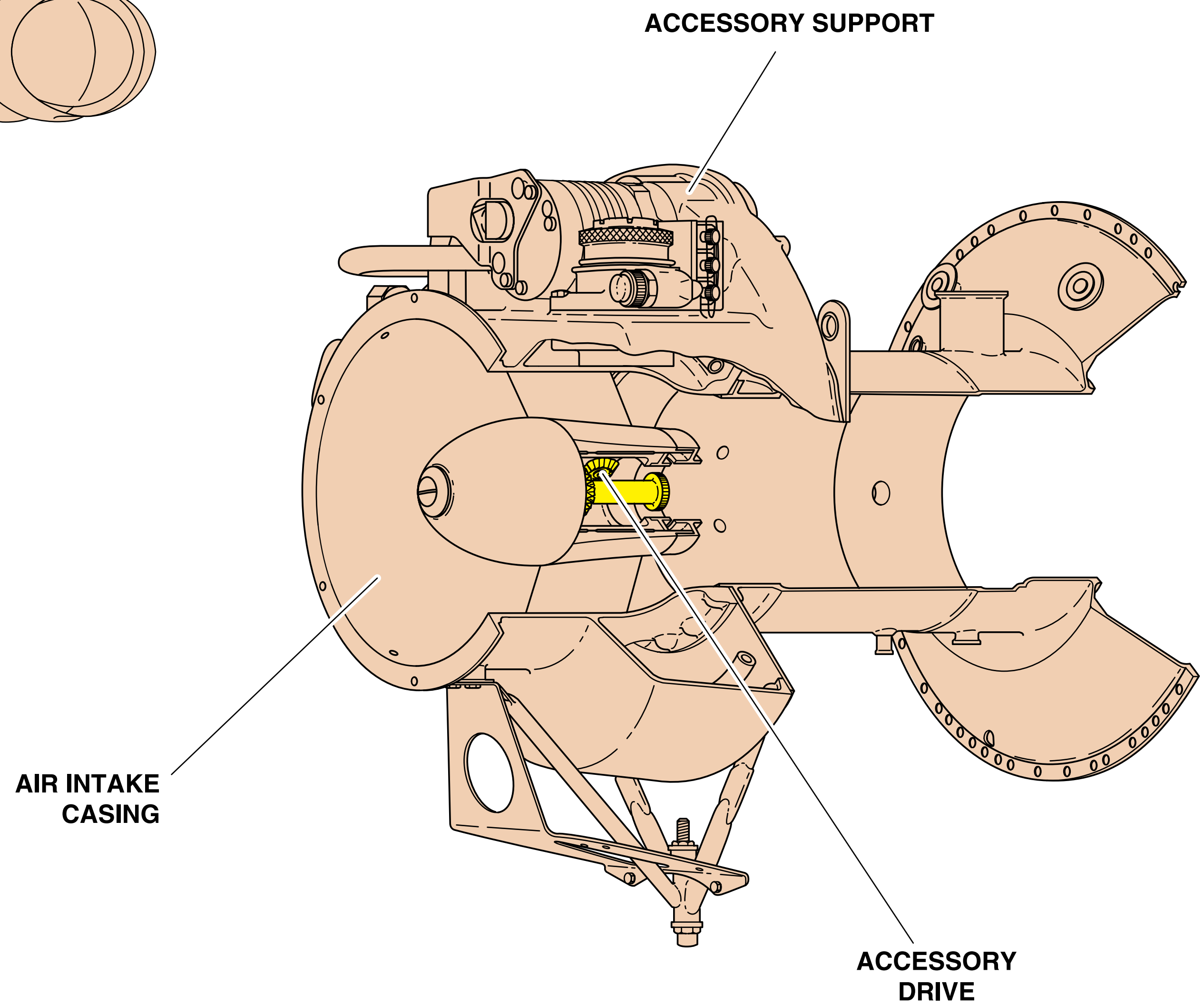
Main components

The main components of the accessory drive train are :

- Gears
- Bearings
- Phonic wheel
- Free wheel.



Gears made of steel
Starter 24376 RPM, ACW
Fuel Control Unit 4366 RPM, ACW
Oil pump 4366 RPM, CW
Centrifugal breather gear 5572 RPM, CW



ACCESSORY DRIVE - GENERAL

ACCESSORY DRIVE - DESCRIPTION

Splines in the front of the axial compressor engage in splines on the accessory drive shaft. A bevel gear on this shaft drives a vertical shaft which passes through the upper strut of the intake casing.

The accessory drive train includes 3 gears supported by ball bearings.

Starter drive gear

This gear is driven by the starter through a free wheel. It includes a phonic wheel for the N1 speed signal.

- Speed : 24376 RPM
- Direction of rotation : ACW.

Centrifugal breather gear

It is a double gear.

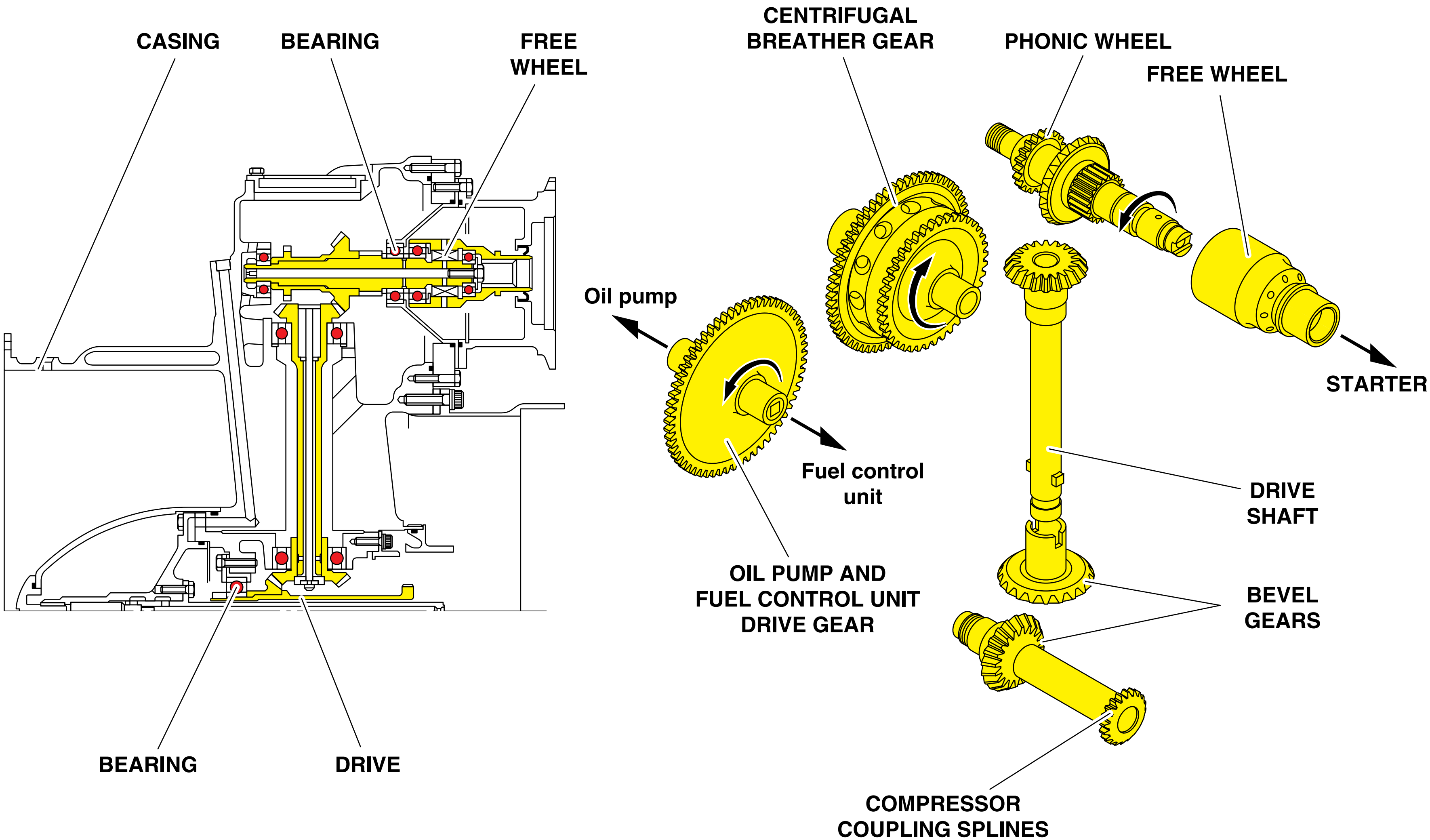
- Speed : 5572 RPM
- Direction of rotation : CW.

Fuel Control Unit and oil pump gear

This gear drives the oil pump at the front and the Fuel Control Unit at the rear.

- Speed : 4366 RPM.

Note : The gear rotation directions are given looking at the front face of the engine.



ACCESSORY DRIVE - DESCRIPTION

ACCESSORY DRIVE - OPERATION

The operation is considered during engine starting and in normal running.

Operation during engine starting

During starting, the starter motor drives the accessory gearbox and thus the gas generator rotating assembly.

The compressors supply air to the combustion chamber and the starting sequence continues.

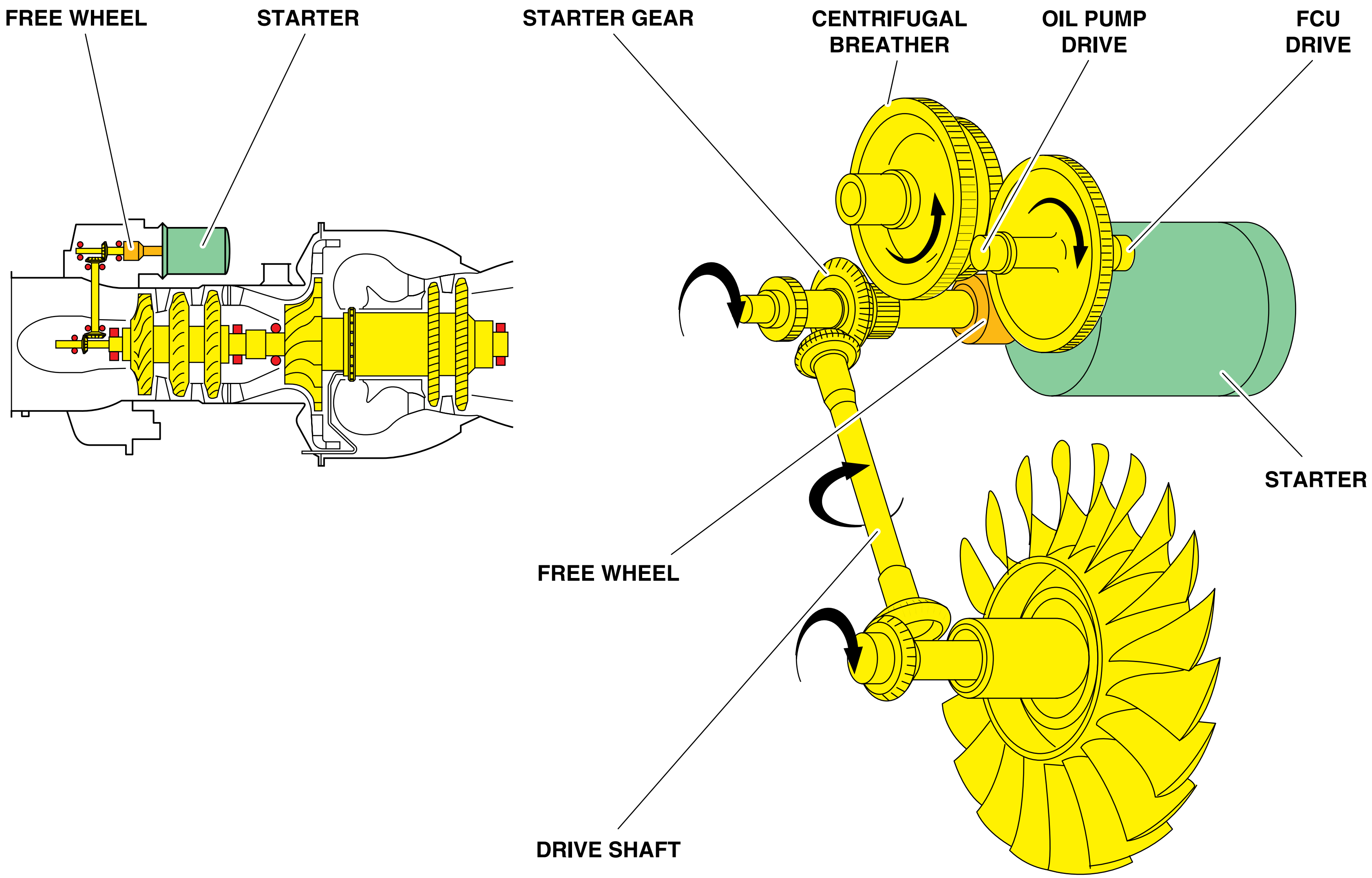
At self-sustaining speed (approximately 45 % N1) the electrical supply to the starter motor is automatically cut. Then the free wheel disengages the starter.

Engine normal running

The gas generator drives the accessory gear train through the bevel gear located at the front of the axial compressor.

The following accessories are driven :

- Phonic wheel
- Centrifugal breather
- Oil pump
- Fuel Control Unit.



ACCESSORY DRIVE - OPERATION

4 - OIL SYSTEM

OIL SYSTEM - GENERAL

Function

The oil system ensures lubrication and cooling of the engine.

The lubricating oil is also used for the air intake anti-icing.

Position

All the components are fitted on the engine.

Main characteristics

- System type : variable pressure, full flow, dry sump, synthetic oil
- Max oil temperature : 120 °C (248 °F)
- Max oil consumption : 0.15 l/h (0.33 lb/hr)
- Oil pressure : 170 kPa (24.7 PSI) < P < 600 kPa (87 PSI)
- Min oil pressure : 170 kPa (24.7 PSI)
- Total oil volume : 4.9 litres (1.27 US G).

Lubrication requirements

Lubrication is required for the following components :

- Front section :
  - Axial compressor front bearing
  - Accessory gearbox
  - Bevel gear
- Intermediate bearings :
  - Axial compressor rear bearing
  - Centrifugal compressor front bearing
- Turbine bearings :
  - Gas generator turbine rear bearing
  - Power turbine front bearing
- Power turbine rear bearing.

OIL SYSTEM

- Lubrication and engine cooling
- Air intake anti-icing

Type
Variable pressure, full flow, dry sump

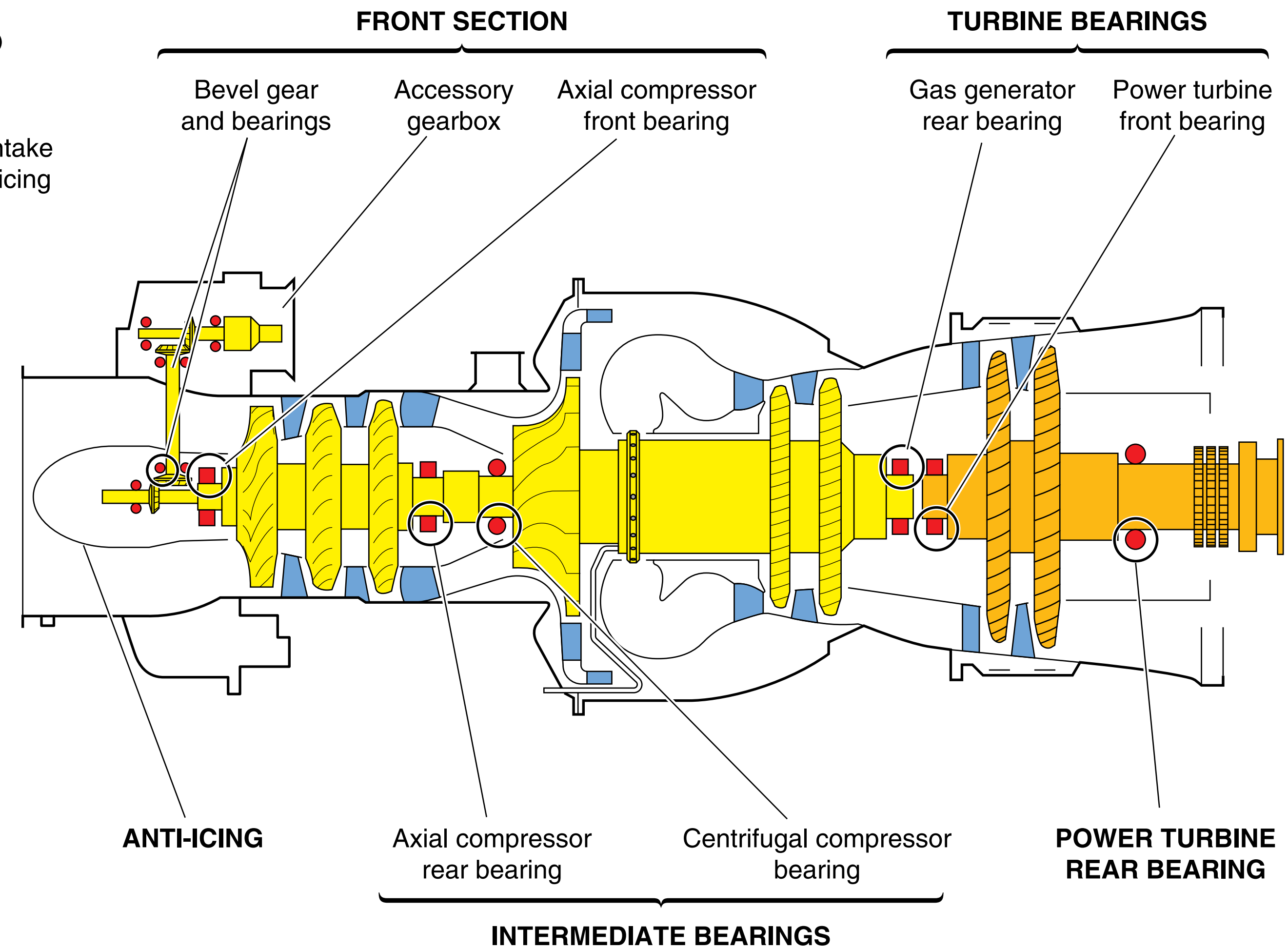
Max temperature
120 °C (248 °F)

Max consumption
0.15 l/h (0.33 lb/hr)

Oil pressure
170 kPa (24.7 PSI) < P < 600 kPa (87 PSI)

Min pressure
170 kPa (24.7 PSI)

Total oil volume
4,9 l (1.27 US G)



OIL SYSTEM - GENERAL

OIL SYSTEM - DESCRIPTION

The system contains all the components necessary for engine lubrication : tank, pumps, filter, heat exchanger, centrifugal breather and indicating devices.

Tank

The tank contains the volume of oil required to lubricate the engine. It is formed by the lower part of the air intake casing.

Pumps

The pump pack includes a pressure pump and four scavenge pumps. The spur gear type pumps are mechanically driven by the accessory gearbox. The pressure pump includes a pressure relief valve.

Check valves

There are three check valves in the supply :

- One at the filter outlet
- One in the supply to the turbine bearings
- One in the supply to the anti-icing system.

Filter

The filter retains any particles which may be present in the oil. It includes a filtering unit, a by-pass valve, a check valve and a pre-blockage indicator.

Strainers

The strainers protect the scavenge pumps.

Heat exchanger

The heat exchanger cools the oil by fuel circulation.

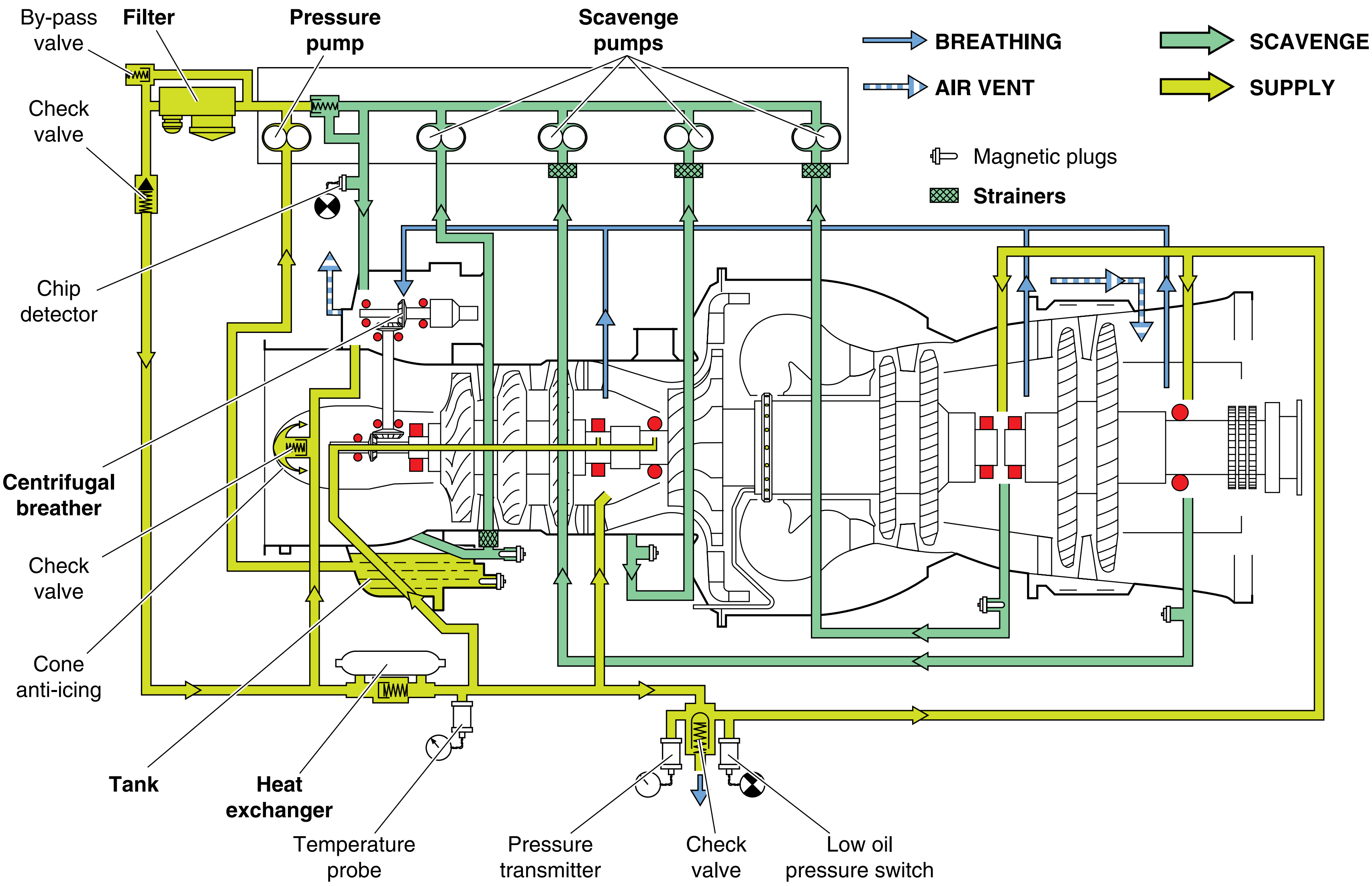
Centrifugal breather

The centrifugal breather separates the oil from the air/oil mist and vents the system.

Indicating devices

- Low oil pressure switch
- Pressure transmitter
- Magnetic plugs
- Chip detector
- Temperature probe.

Note : *The lubrication oil is also used for the anti-icing of the air intake cone.*



OIL SYSTEM - DESCRIPTION

OIL SYSTEM - GENERAL OPERATION

The main functions of the oil system are : supply, scavenge, breathing, indicating.

Supply

The pressure pump draws the oil from the tank and supplies the system. A pressure relief valve limits maximum pressure by returning oil to the pump inlet.

The oil is then delivered through the filter and a check valve. After the filter, the oil is delivered to the front section for the anti-icing of the air intake cone and the accessory drive train lubrication.

It is also delivered, after cooling in the heat exchanger, to lubricate the intermediate bearings and after a check valve to lubricate the turbine bearings.

The oil is sprayed by jets onto the parts to be lubricated. It also supplies a squeeze film for the gas generator bearings and the turbine bearings.

Scavenge

After lubrication, the oil falls by gravity to the bottom of the sumps. The oil is then immediately drawn away by the scavenge pumps and returned to the tank (dry sump system).

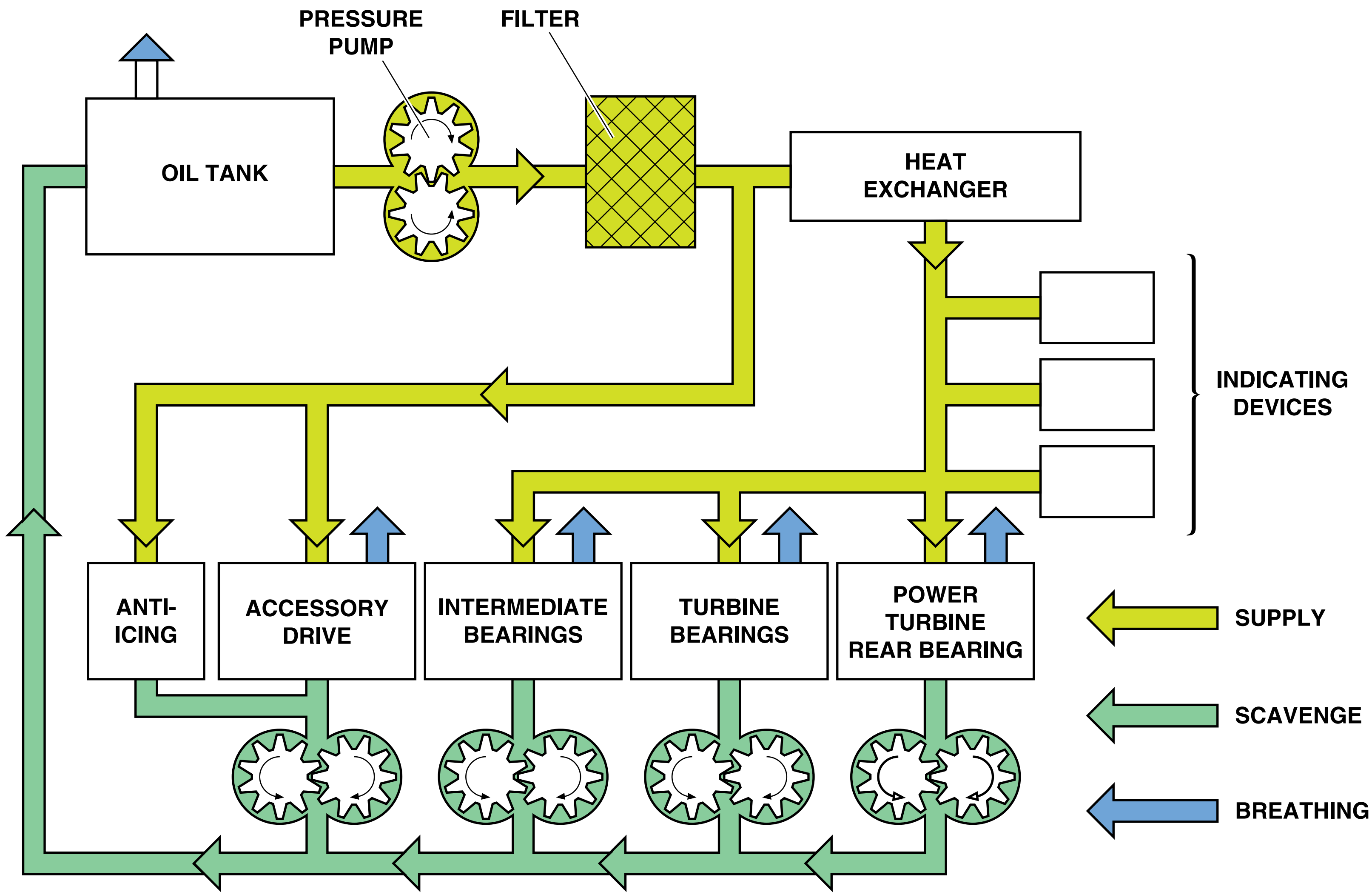
The strainers protect the scavenge pumps against any particles which may be held in the oil.

Breathing

The oil mist which results from lubrication is returned to the accessory gearbox, where the oil is separated from the air by a centrifugal breather which vents overboard.

Indicating

The system ensures the following indications : pressure, temperature, low pressure, particle detection and filter pre-blockage.



OIL SYSTEM - GENERAL OPERATION

OIL SYSTEM - OPERATION - SUPPLY

Supply

The oil contained in the tank formed by the lower part of the air intake casing, is drawn by the pressure pump (spur gear type driven at a speed proportional to the gas generator).

The pump delivers the oil under pressure ; full flow circulation (≈ 810 l/h ; 1782 lbs/hr), variable pressure as a function of rotation speed and oil temperature (170 - 600 kPa ; 24.7 - 87 PSI).

In case of overpressure, e.g. engine starting at a very low temperature, the pressure relief valve returns the excess oil to the tank. Its setting is approximately 800 kPa (116 PSI).

The oil under pressure then goes through the filter which retains any particles (filtering ability of 30 microns). If the filter becomes blocked, a differential valve set at ΔP = 160 kPa (32.2 PSID) opens and allows the oil to by-pass. The pre-blockage is indicated by a mechanical indicator when the pressure difference exceeds 100 kPa (14.5 PSI).

At the filter outlet, a low set check valve (13 kPa ; 1.9 PSI) prevents oil circulation at low pressures encountered during engine shut-down ; this prevents flooding and leaks through the sealing labyrinths which are not very efficient at low speed.

Before entering the heat exchanger, a certain quantity of oil is sent to the front section for the anti-icing of the air intake cone and the casing struts and for the accessory drive train lubrication.

The cone oil inlet comprises a check valve (setting 180 kPa ; 26.1 PSI) , which prevents oil flow through the anti-icing device under certain conditions which could cause a drop of oil pressure in the system (low N1 speed and high oil temperature).

The oil then flows through the heat exchanger, which cools the oil and transfers its heat to the fuel. The heat exchanger has a differential valve, which allows the by-pass of the oil if the heat exchanger is blocked (setting 80 kPa ; 11.6 PSI).

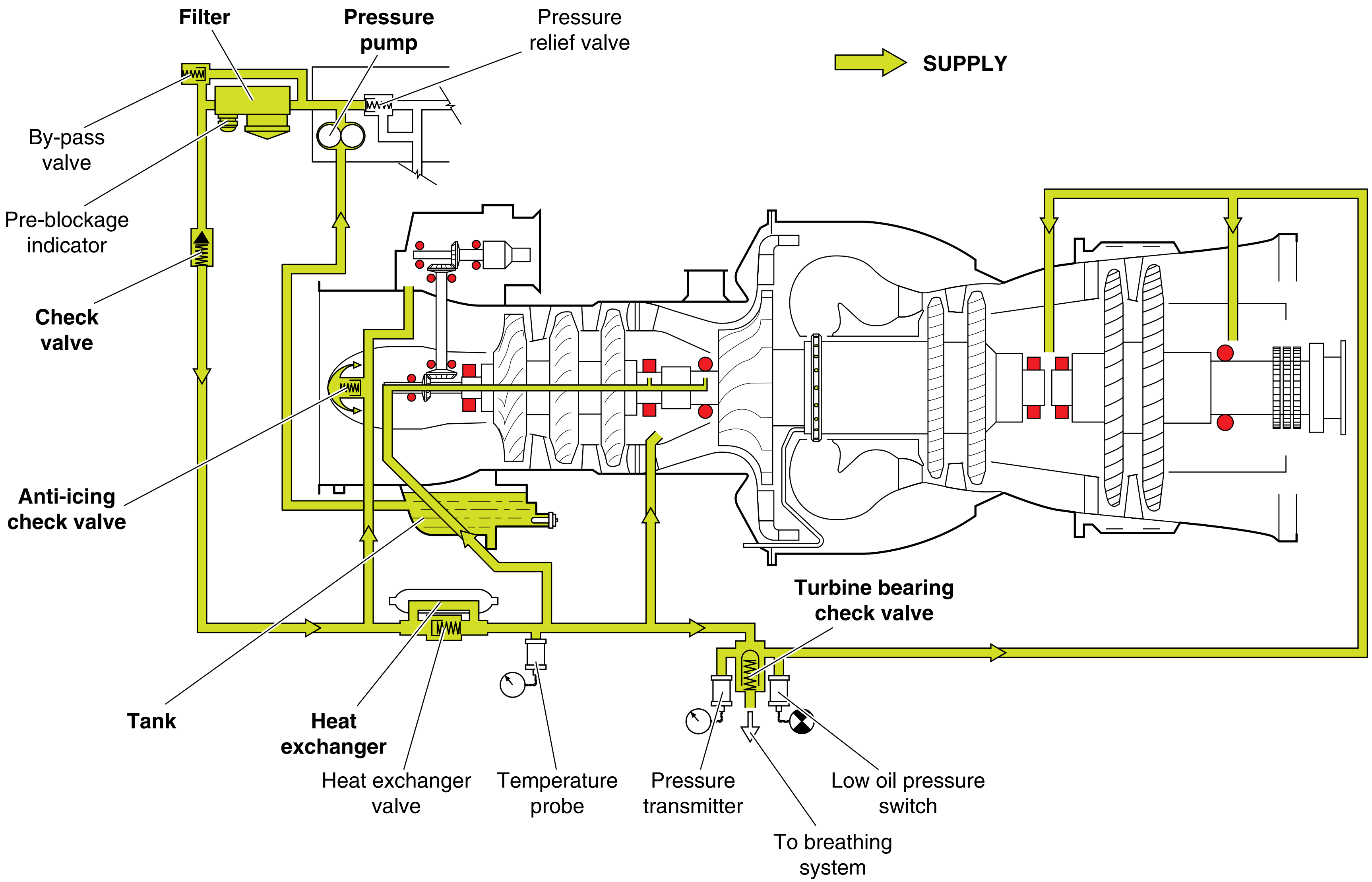
After cooling in the heat exchanger, the oil is delivered to the front section for the bevel gear lubrication, and, through an internal duct in the shaft for the lubrication of the axial compressor front bearing, the axial compressor rear bearing and the centrifugal compressor bearing and the muff coupling.

A certain quantity of oil is delivered through an external pipe in order to provide a second flow of lubrication to the centrifugal compressor bearing.

The oil is also delivered to the turbine bearings through a check valve (25 kPa ; 3.6 PSI) which prevents oil circulation at low pressure (same principle as the check valve located at the filter outlet, but here, it is used for the turbine bearings).

The bearings include the gas generator rear bearing, the power turbine front bearing and the power turbine rear bearing.

Indication is provided by a temperature probe, a pressure transmitter and a low pressure switch fitted at the heat exchanger outlet.



OIL SYSTEM - OPERATION - SUPPLY

OIL SYSTEM - OPERATION - SCAVENGE - BREATHING

Scavenge

The oil which has lubricated and cooled the different components, falls by gravity to the casing lower parts from where it is drawn by the four scavenge pumps (dry sump system). These pumps are spur gear type, driven by the same shaft as the pressure pump.

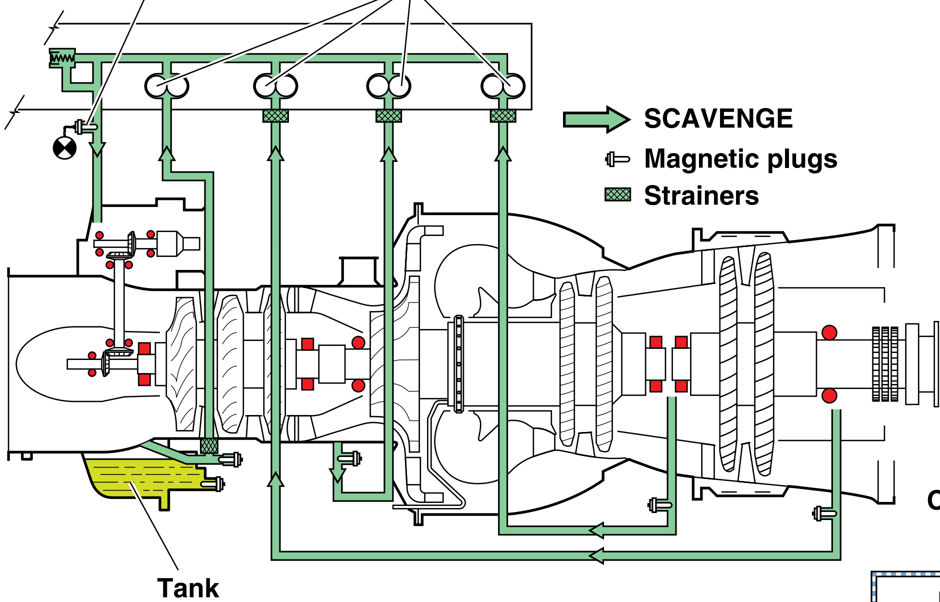
Each scavenge system includes a magnetic plug and a strainer.

The general return to the tank includes a chip detector.

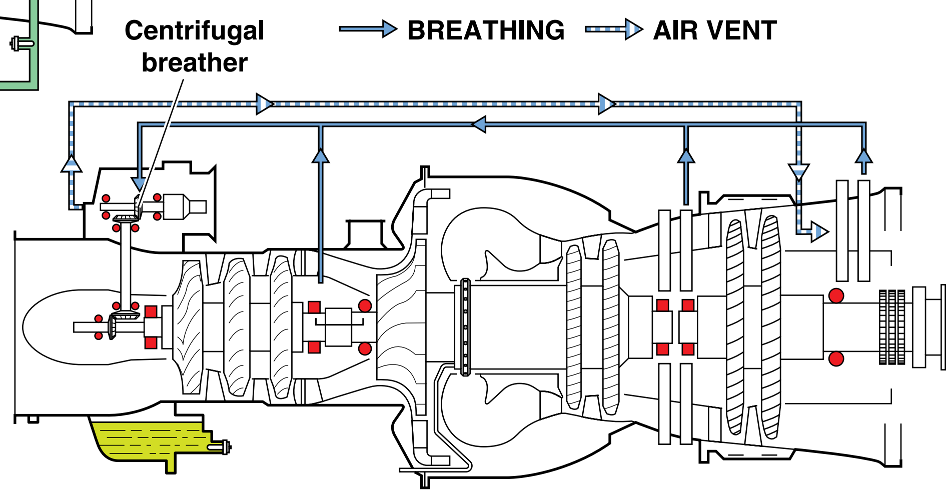
Breathing

The oil mist which results from the lubrication is returned to the front section, where the oil is separated from the air by a centrifugal breather (intermediate gear of the accessory drive train) and vents to the exhaust pipe through an external pipe.

Note *: Refer to each scavenge system in the section "LUBRICATION" (following pages).*



SCAVENGE



BREATHING

OIL SYSTEM - OPERATION - SCAVENGE - BREATHING

LUBRICATION (1) - FRONT SECTION

Supply

One outlet from the oil filter flows through the left hand strut to anti-ice the nose cone and lubricate the accessory drives.

The second outlet from the filter flows via the heat exchanger and up the lower strut and through an internal tube to lubricate the axial compressor front bearing and pass through the tie-bolt (refer to "LUBRICATION (2)").

The sealing is ensured by labyrinth seals.

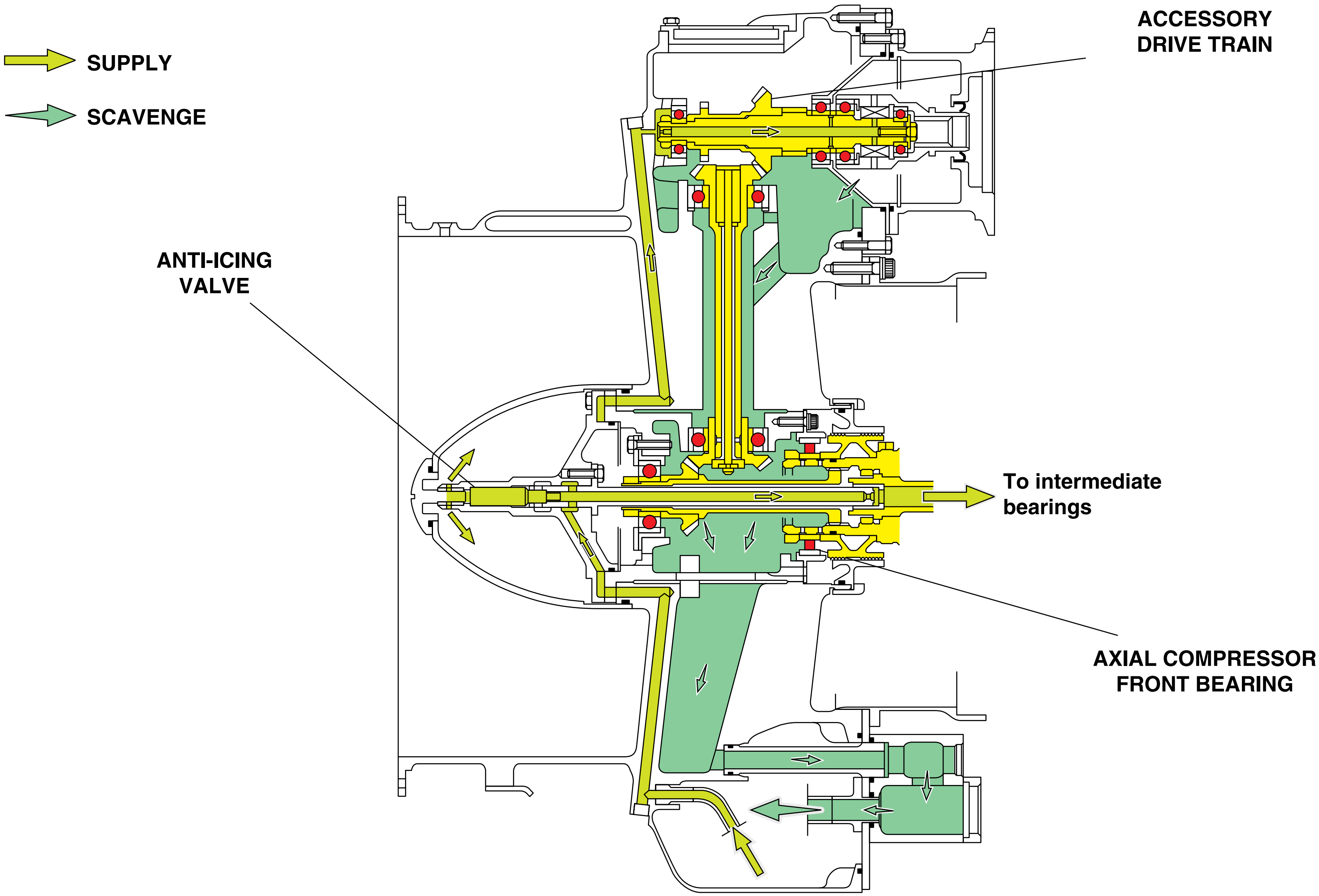
Note : *The air intake is also anti-iced by the oil contained in the tank, and by the oil flow in the casing struts.*

Scavenge

The oil falls by gravity to the casing lower strut, and is returned to the tank.

Breathing

The oil mist is drawn by the centrifugal breather in the accessory gearbox.



LUBRICATION (1) - FRONT SECTION

LUBRICATION (2) - INTERMEDIATE SECTION

Supply

The oil is supplied through the tie-bolt (from the air intake cone). Through drillings in the tie-bolt the oil is sprayed onto :

- The axial compressor rear bearing
- The coupling sleeve
- The centrifugal compressor bearing.

A second oil flow, through an external pipe, supplies :

- The jet for the centrifugal compressor bearing lubrication
- The squeeze film around the bearing cage.

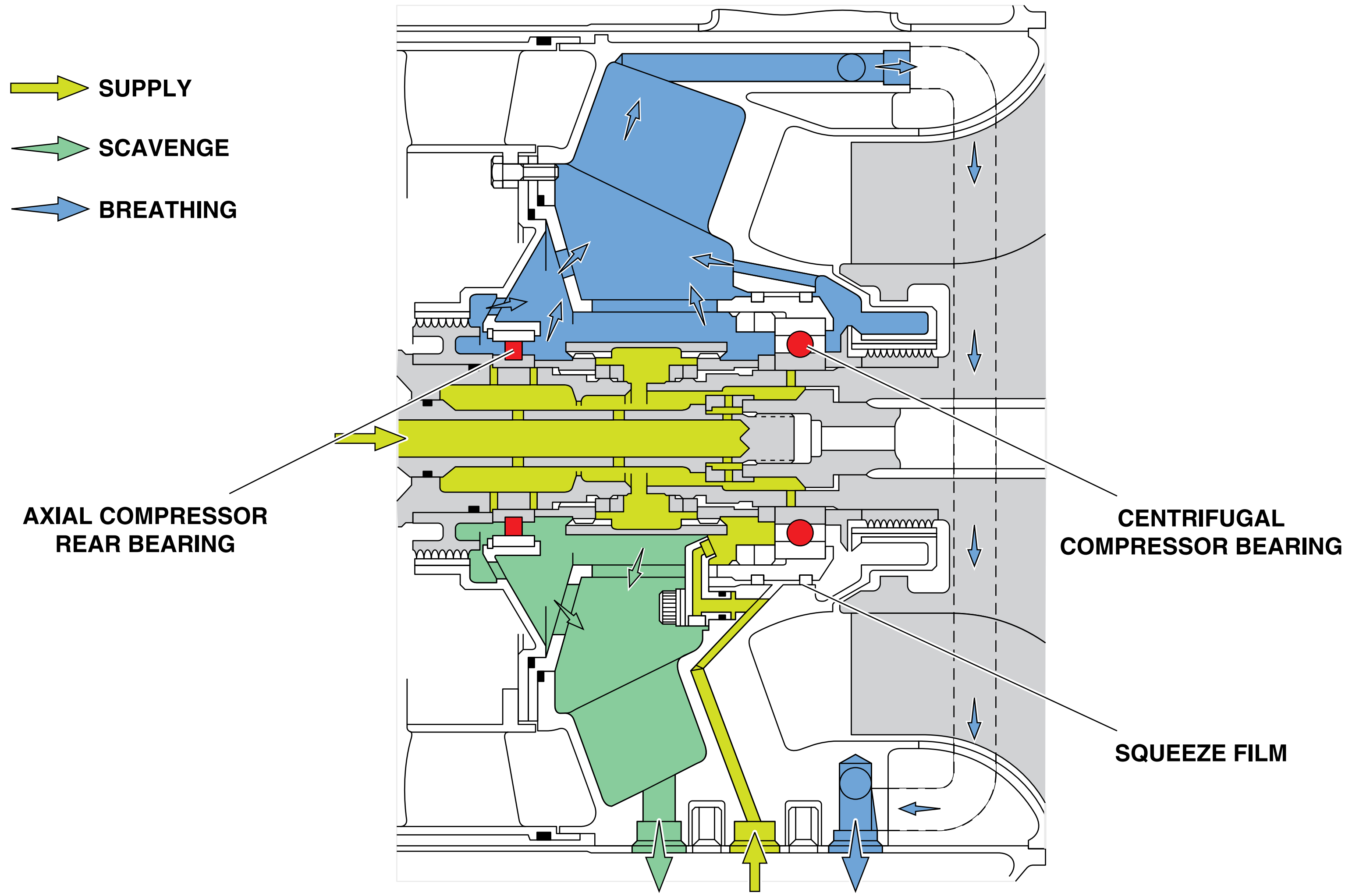
The sealing is ensured by pressurised labyrinth seals.

Scavenge

The oil falls by gravity to the bottom of the casing and is drawn by a scavenge pump through an external pipe.

Breathing

The oil mist which results from the lubrication is returned to the bottom of the casing through an internal duct, and passes to the centrifugal breather through an external pipe.



LUBRICATION (2) - INTERMEDIATE SECTION

LUBRICATION (3) - TURBINE BEARINGS

Supply

The oil is supplied through an external pipe, and then flows through the front tube located in the upper strut of the power turbine nozzle guide vane.

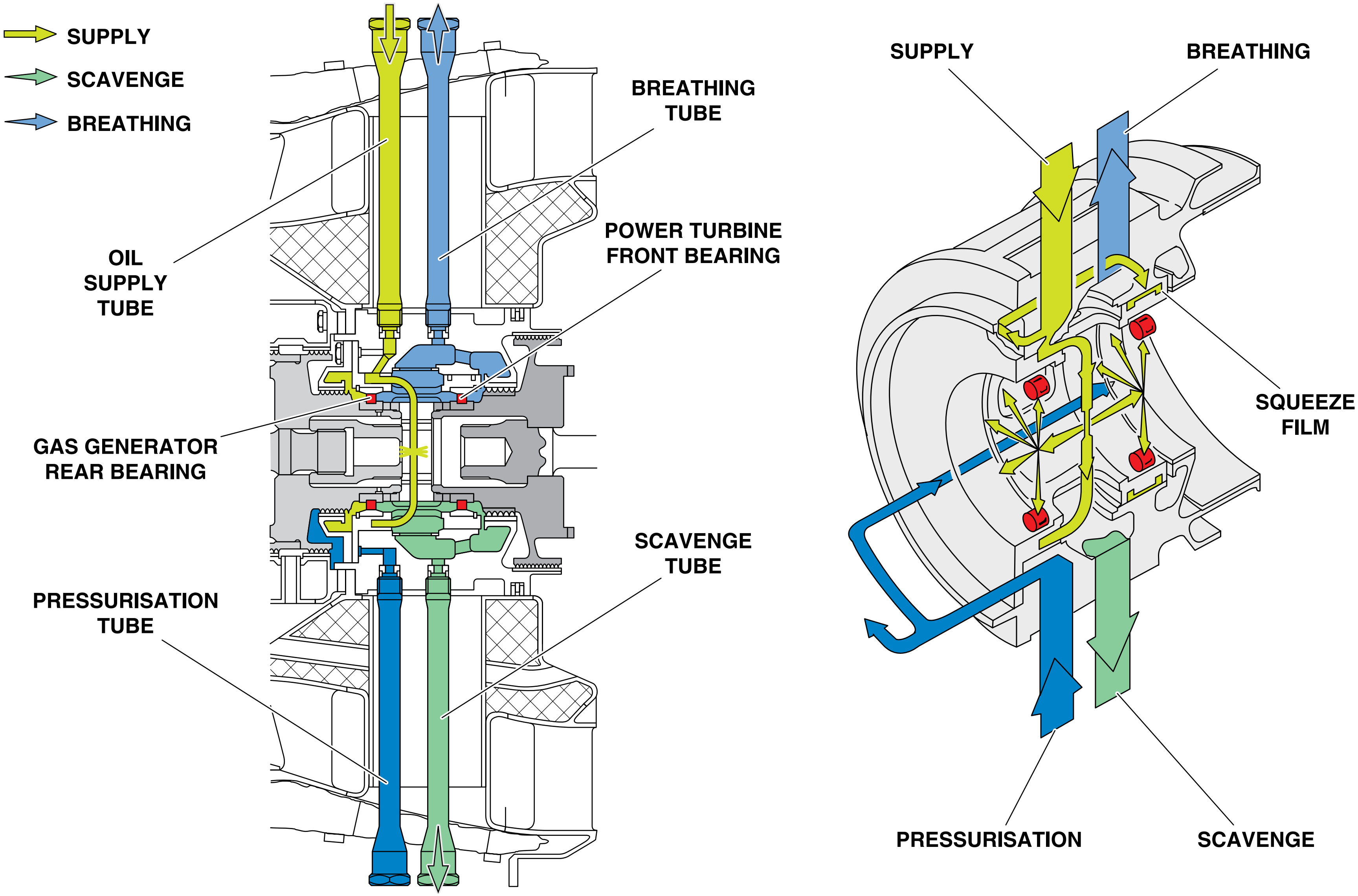
The oil is then directed through internal ducts and jets to the gas generator rear bearing and to the power turbine front bearing for the squeeze film and lubrication.

Scavenge

The oil falls by gravity to the bottom of the bearing support and is then drawn by a scavenge pump, through the rear tube located in the lower strut of the power turbine nozzle guide vane and through an external pipe.

Breathing

The oil mist which results from the lubrication is returned to the centrifugal breather through the rear tube located in the upper strut of the power turbine nozzle guide vane and through an external pipe.



LUBRICATION (3) - TURBINE BEARINGS

LUBRICATION (4) - POWER TURBINE REAR BEARING

Supply

The oil is supplied through an external pipe, and the rear tube, located in the upper strut of the exhaust diffuser.

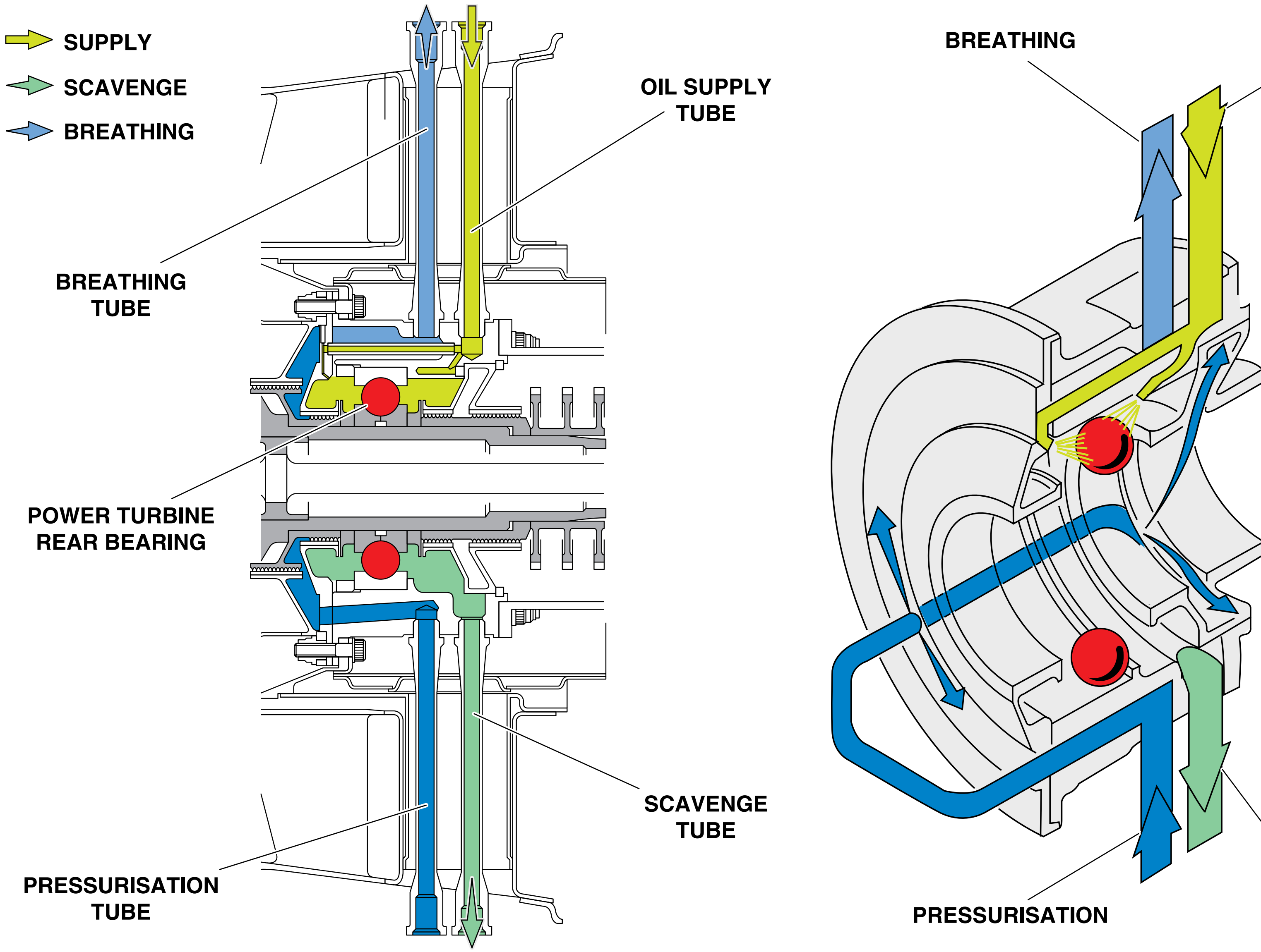
The oil is then directed through internal ducts and jets onto the front and rear faces of the power turbine rear bearing.

Scavenge

The oil falls by gravity to the bottom of the bearing housing and is then drawn by a scavenge pump, through the rear tube located in the lower strut of the exhaust diffuser, and through an external pipe.

Breathing

The oil mist which results from the lubrication is returned to the centrifugal breather through the front tube located in the upper strut of the exhaust diffuser and through an external pipe.



LUBRICATION (4) - POWER TURBINE REAR BEARING

OIL TANK

Function

The tank, integral with the intake, contains the necessary oil volume to lubricate the engine.

Position

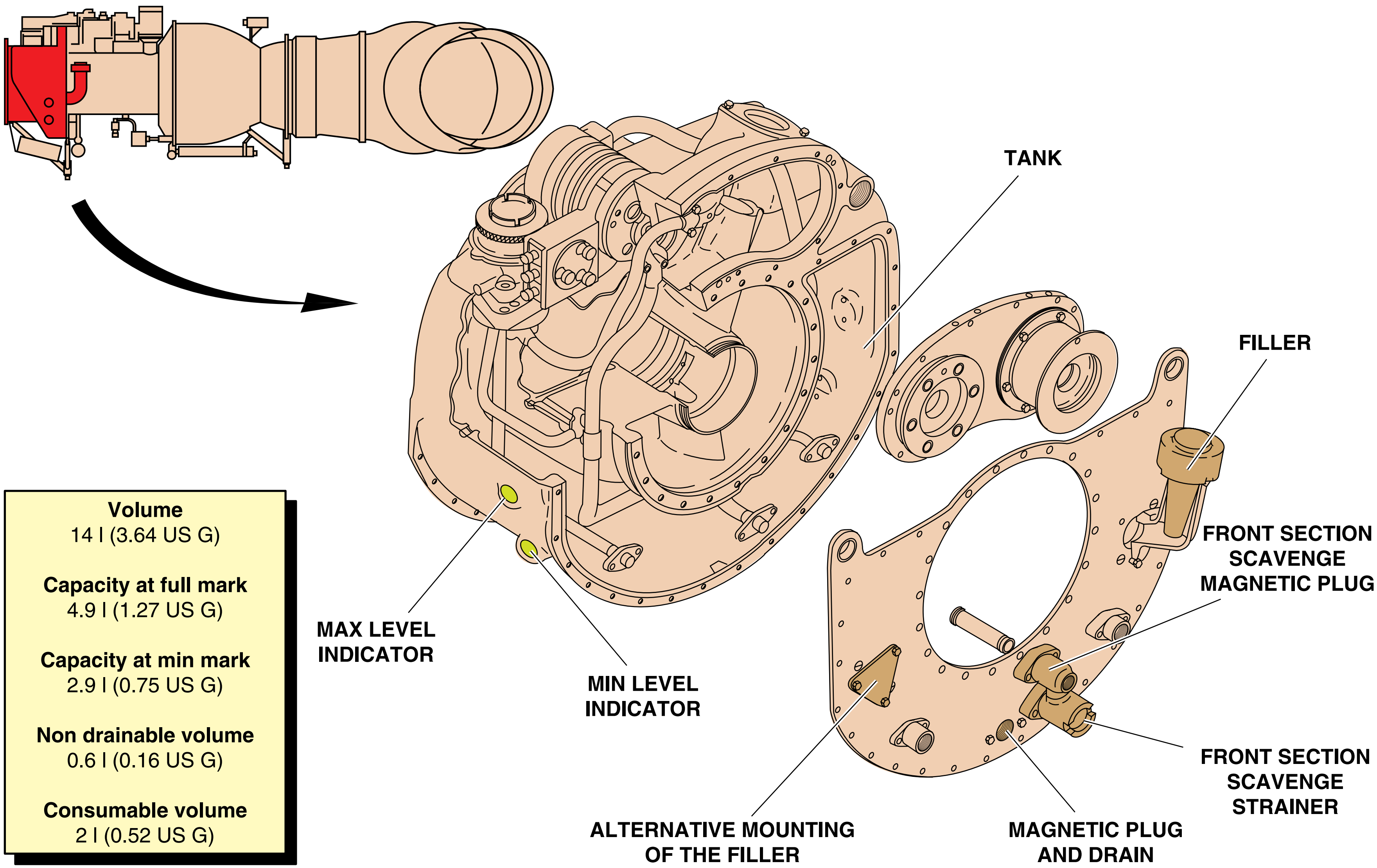
The oil tank is formed by the air intake casing.

Main characteristics

- Volume : 14 litres (3.64 US G)
- Capacity at full mark : 4.9 litres (1.27 US G)
- Capacity at min mark : 2.9 litres (0.75 US G)
- Non drainable volume : 0.6 litre (0.16 US G)
- Consumable volume : 2 litres (0.52 US G).

Main components

- Filler cap (location on the left or right of the oil tank casing ; depending on the engine position in the aircraft)
- Level indicators (max and min)
- Magnetic plug
- Drain plug
- Unions (supply, scavenge and breathing).



Volume
14 l (3.64 US G)

Capacity at full mark
4.9 l (1.27 US G)

Capacity at min mark
2.9 l (0.75 US G)

Non drainable volume
0.6 l (0.16 US G)

Consumable volume
2 l (0.52 US G)

OIL TANK

OIL PUMPS - GENERAL

Function

The pumps ensure oil circulation.

Position

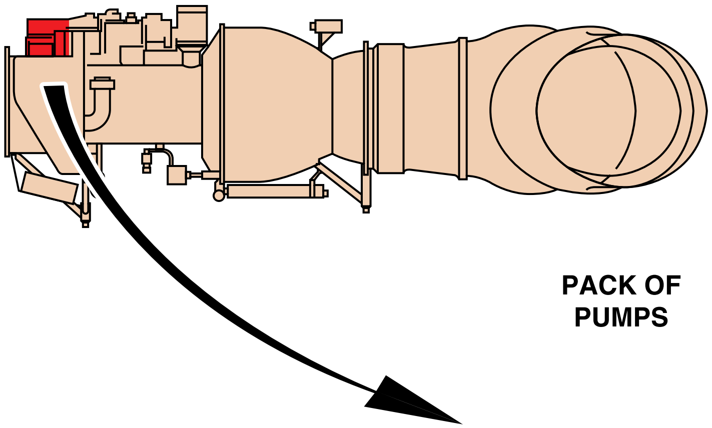
The pump pack is mounted on the front upper part of the air intake casing. It is part of module M01.

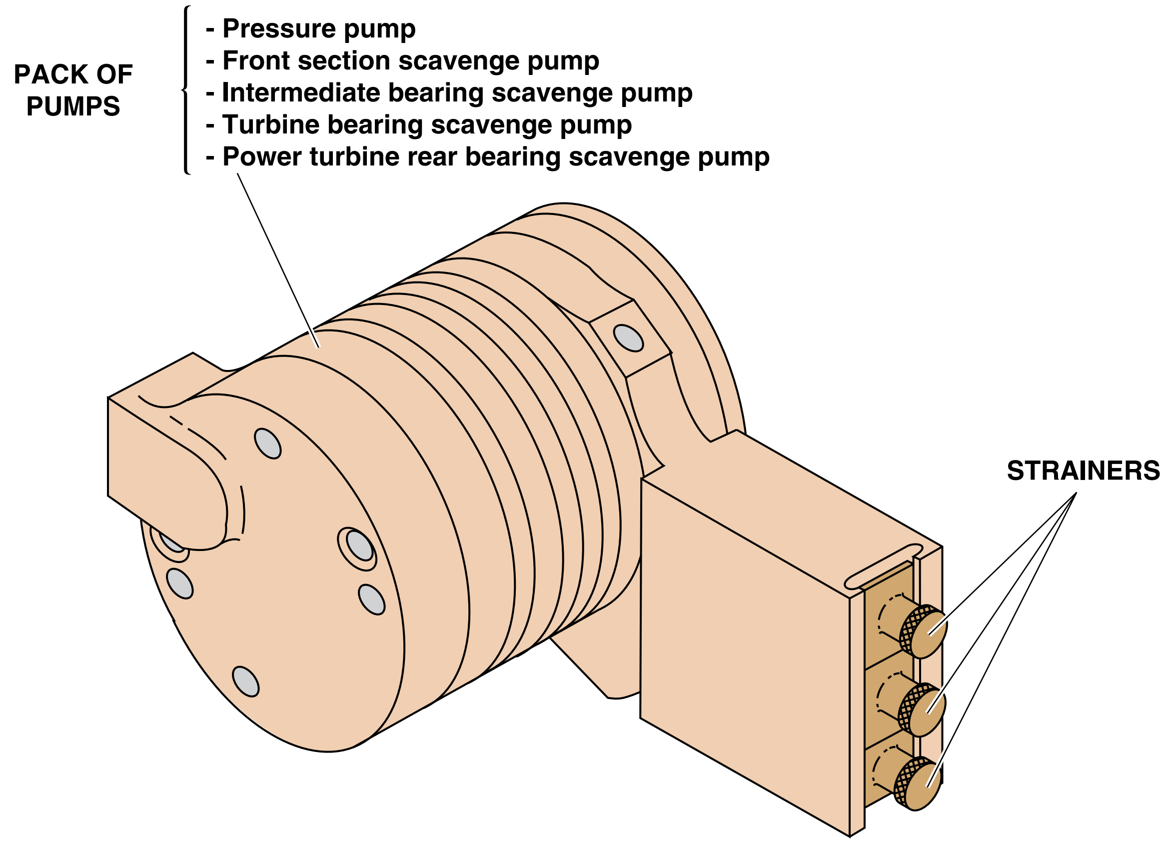
Main characteristics

- Type : spur gear
- Pressure pump outlet pressure : 170 kPa (24.7 PSI) < P < 600 kPa (87 PSI)
- Average pressure : 300 kPa (43.5 PSI)
- Full flow : 810 l/h (1782 lbs/hr)
- Pressure relief valve setting : 800 kPa (116 PSI).

Main components

- Drive shaft
- Pump body (pressure pump, scavenge pumps : front section, intermediate bearings, turbine bearings, power turbine rear bearing).





Type
Spur gear type

Pressure pump outlet pressure
170 kPa (24.7 PSI) < P
< 600 kPa (87 PSI)

Average pressure
300 kPa (43.5 PSI)

Full flow
810 l/h (1782 lbs/hr)

Pressure relief valve setting
800 kPa (116 PSI)

OIL PUMPS - GENERAL

OIL PUMPS - DESCRIPTION

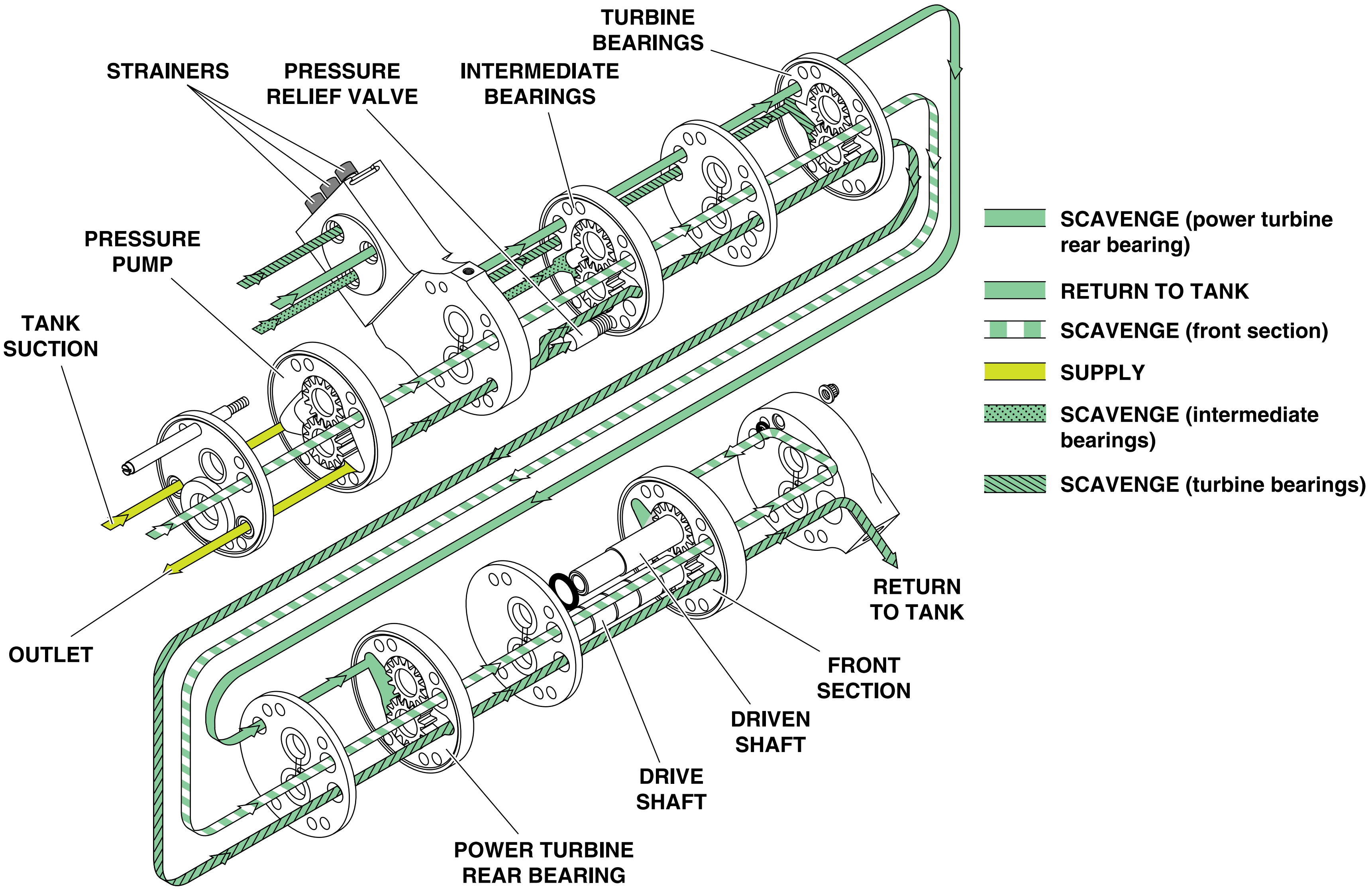
The pump pack, mounted on the front upper part of the air intake casing, is driven at a speed proportional to the gas generator speed N1.

The pump pack includes :

- The spur gear type pumps :
  - Pressure pump
  - Front section scavenge pump
  - Intermediate bearing scavenge pump
  - Turbine bearing scavenge pump
  - Power turbine rear bearing scavenge pump

- The pump body which includes the unions and orifices for oil inlet and outlet

- The pressure relief valve.



OIL PUMPS - DESCRIPTION

OIL PUMPS - OPERATION

General

The pressure pump draws the oil from the tank and delivers it to the filter.

The scavenge pumps draw the oil from the casings and deliver it to the tank.

Operating principle of the pumps

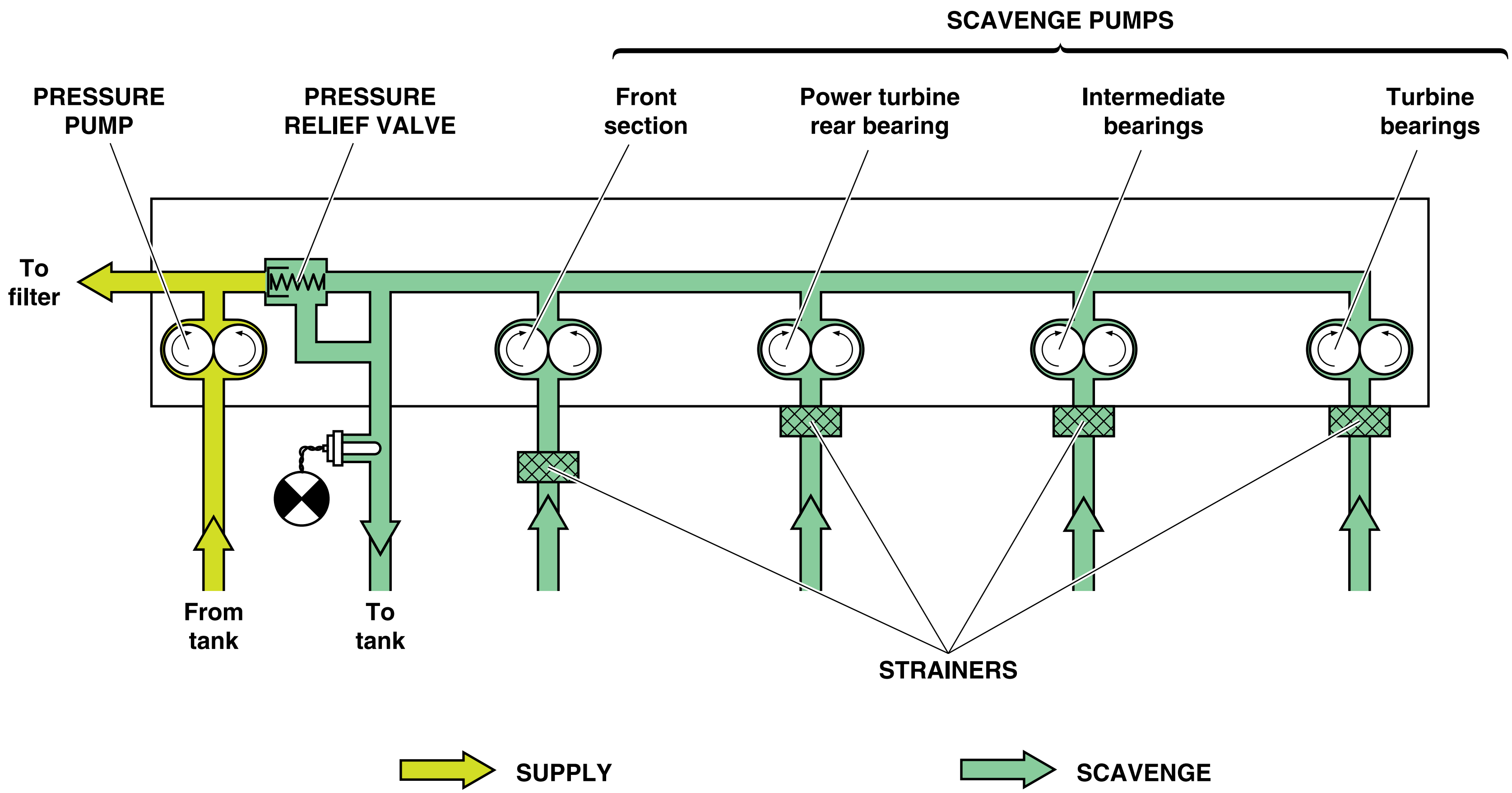
The pumps are spur gear type.

They are driven at a speed proportional to the gas generator speed through a common shaft.

The oil passes between the gears and the pump body. Then it is delivered at a flow and pressure which depend on the rotation speed and the oil viscosity.

Pressure relief valve operation

In case of overpressure, the valve opens and allows the oil to return to the tank. It is in fact a safety device and only opens exceptionally (starting at a very low temperature for example).



OIL PUMPS - OPERATION

OIL FILTER - GENERAL

Function

The filter retains particles that may be in the oil.

Position

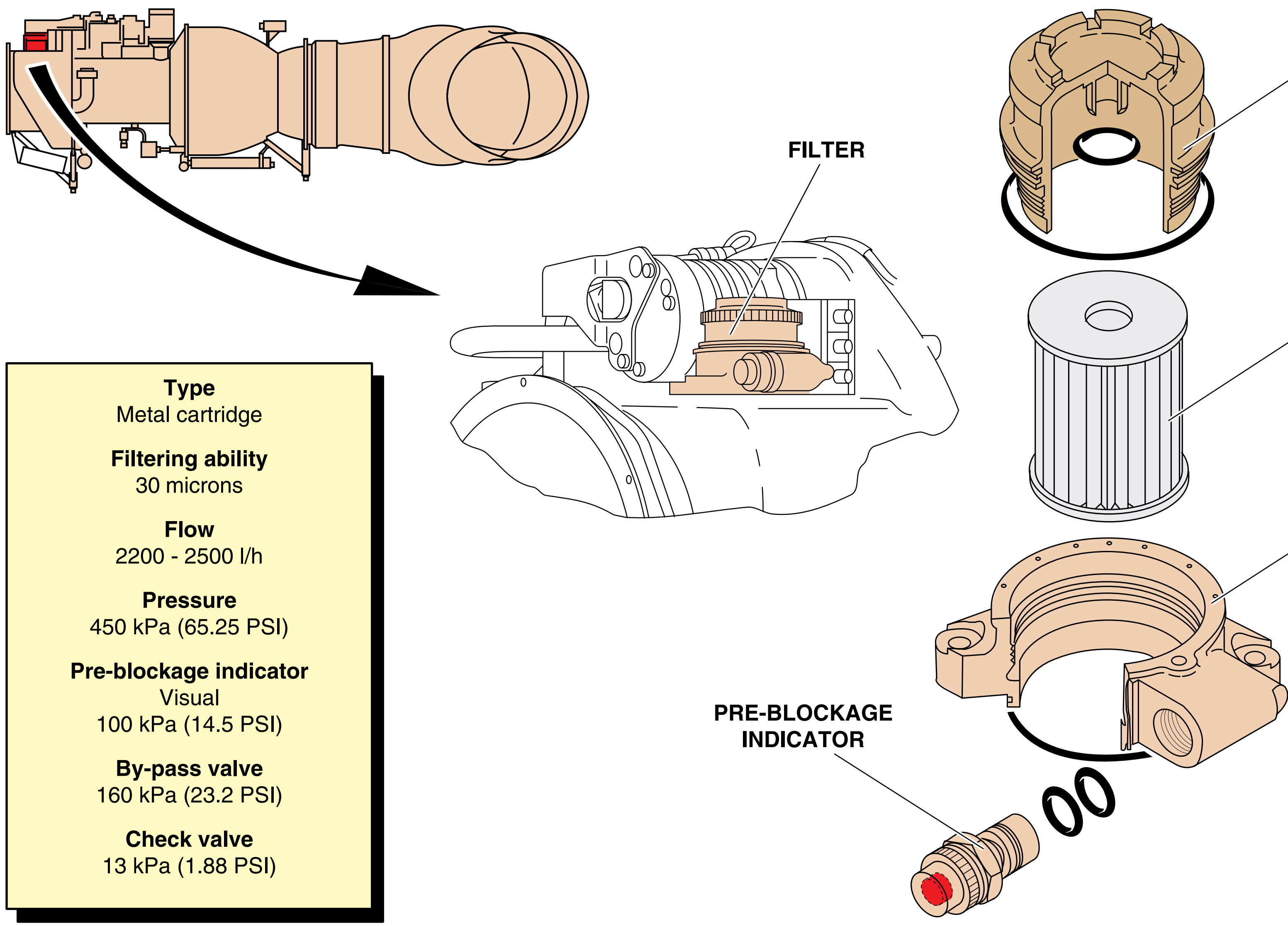
- In the system : downstream of the pressure pump
- On the engine : on the upper part of the air intake casing, on the left of the oil pump pack.

Main characteristics

- Type : metal cartridge
- Filtering ability : 30 microns
- Flow : 2200 - 2500 l/h
- Operating pressure : 450 kPa (65.25 PSI)
- Pre-blockage indicator : visual
  - Setting : 100 kPa (14.5 PSI)
- By-pass valve :
  - Setting : 160 kPa (23.2 PSI)
- Check valve :
  - Setting : 13 kPa (1.88 PSI).

Main components

- Filter base
- Filtering unit
- Filter cover
- Pre-blockage indicator
- By-pass valve
- Check valve.



Type
Metal cartridge

Filtering ability
30 microns

Flow
2200 - 2500 l/h

Pressure
450 kPa (65.25 PSI)

Pre-blockage indicator
Visual
100 kPa (14.5 PSI)

By-pass valve
160 kPa (23.2 PSI)

Check valve
13 kPa (1.88 PSI)

OIL FILTER - GENERAL

OIL FILTER - DESCRIPTION - OPERATION

Description

The main components of the filtering unit are the following :

- Filter base
- Metal cartridge (filtering unit)
- Visual pre-blockage indicator
- By-pass valve
- Check valve
- Filter cover.

The filter base includes :

- A mounting flange
- Mounting points for the following components :
  - Visual pre-blockage indicator
  - Supply union.

Operation

Filtering

The oil supplied by the pressure pump passes through the oil filter from outside to inside. The filtered oil is then delivered to the engine for lubrication.

Pre-blockage

If the filter begins to become blocked the pressure difference across the cartridge increases. At a given pressure difference, a red mechanical indicator pops out. The oil continues to flow through the filter.

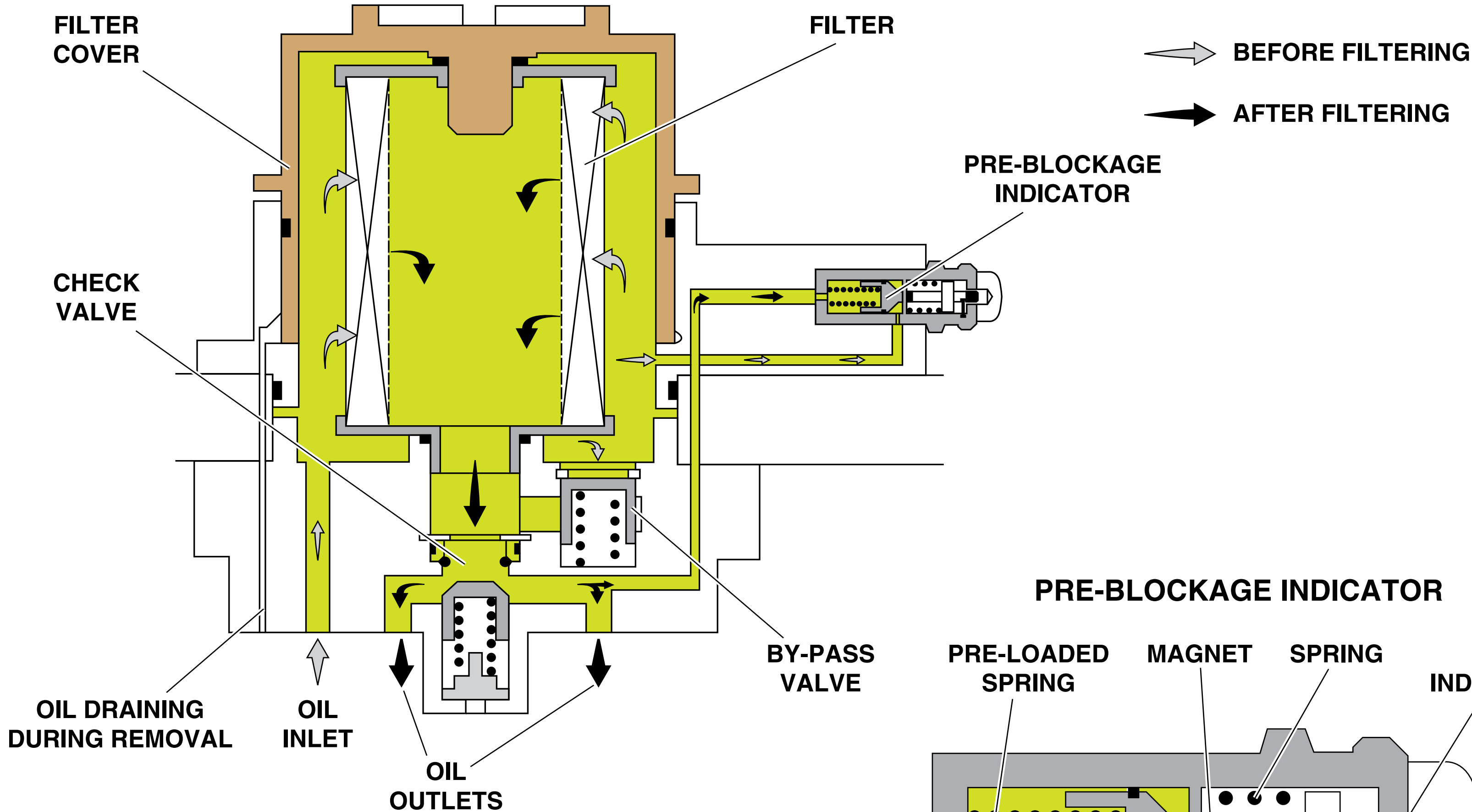
A thermal locking device constituted by a bi-metal strip locks the piston in cold condition, in order to avoid an untimely triggering of the clogging indicator.

Blockage

If the pressure difference exceeds 160 kPa (23.2 PSI), the by-pass valve opens and unfiltered oil passes to the system.

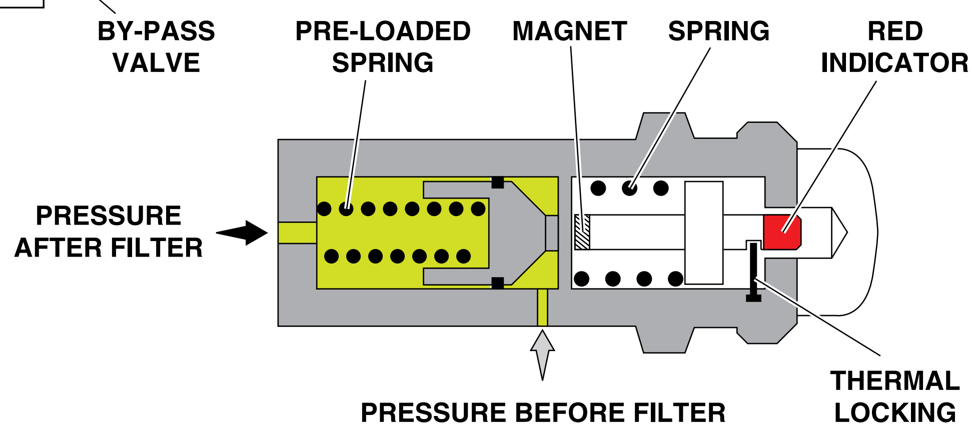
Check valve operation

The oil is delivered to the engine for lubrication when the pressure exceeds 13 kPa (1.88 PSI) to prevent leaks through the labyrinth seals which are not sufficiently pressurised.



OIL FILTER

PRE-BLOCKAGE INDICATOR



OIL FILTER - DESCRIPTION - OPERATION

OIL CHECK VALVE

Function

This valve prevents oil circulation to the engine at very low oil pressure encountered during engine shut-down. It prevents flooding and oil leaks through the labyrinth seals which are not very efficient at low speed.

Position

- In the system, the oil check valve is located at the oil filter outlet

- On the engine, the oil check valve is located inside the filter base.

Main characteristics

- Type : spring valve

- Oil check valve setting : 13 kPa (1.88 PSI).

Main components

- Valve seat

- Check valve

- Spring

- Guide

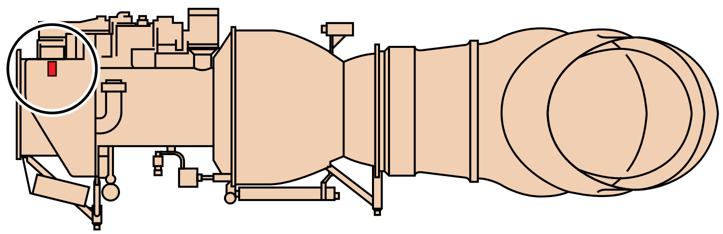
Operation

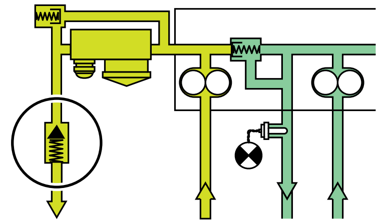
Engine shut-down

During engine shut-down, the oil pressure is lower than the check valve setting. The check valve is closed and prevents oil circulation to the engine. It prevents flooding and oil leaks through the labyrinth seals which are not very efficient at low speed.

Normal running

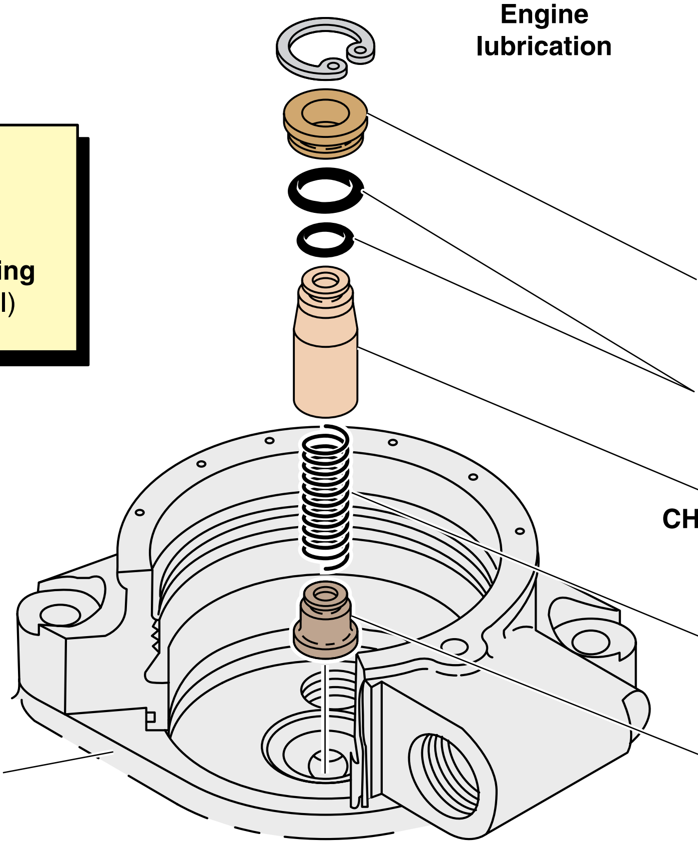
The oil pressure is higher than the check valve setting. The check valve is open and allows oil circulation to the engine parts which require lubrication.

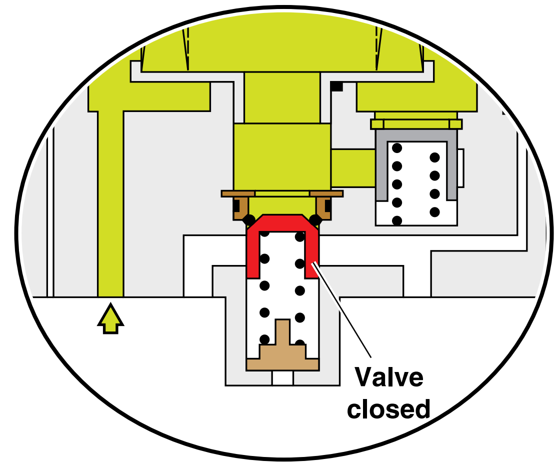




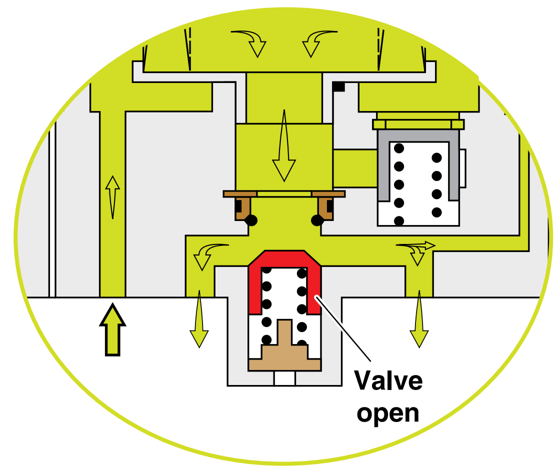
Type
Spring valve

Check valve setting
13 kPa (1.88 PSI)





ENGINE SHUT-DOWN
(pressure lower than 13 kPa / 1.88 PSI)



NORMAL RUNNING
(pressure higher than 13 kPa / 1.88 PSI)

OIL CHECK VALVE

HEAT EXCHANGER

Function

The heat exchanger cools the oil and heats the fuel.

Position

- In the system, the heat exchanger is located after the filter
- On the engine, the heat exchanger is mounted on the rear lower face of the air intake casing plate.

Main characteristics

- Type : tubular type
- By-pass valve setting : ΔP 80 kPa (11.6 PSID).

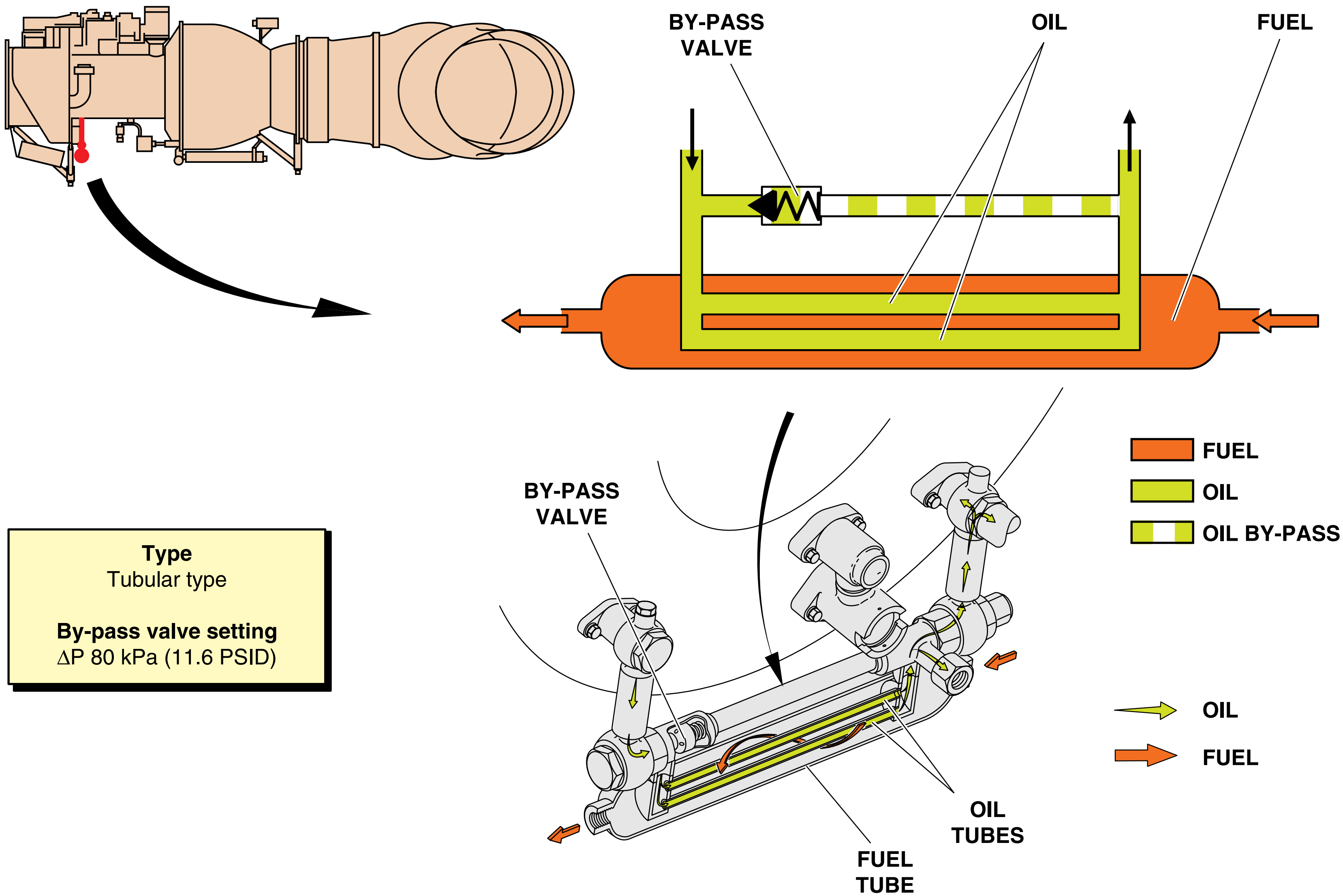
Main components

- Oil tubes
- Fuel tube
- By-pass valve.

Operation

The oil flows through a tube and heats by thermal exchange the fuel which flows around this tube.

In case of blockage of the oil tube the by-pass valve opens for a differential pressure higher than 80 kPa (11.6 PSID) : the oil is no longer cooled, but the engine lubrication continues.



Type
Tubular type

By-pass valve setting
ΔP 80 kPa (11.6 PSID)

HEAT EXCHANGER

TURBINE BEARING CHECK VALVE

Function

This valve prevents oil circulation to the turbine bearings at very low oil pressure encountered during engine shut-down. It prevents flooding and oil leaks through the turbine labyrinth seals which are not very efficient at low speed.

Position

- In the system, the turbine bearing check valve is located downstream of the heat exchanger
- On the engine, the turbine bearing check valve is located at the right rear part of the oil tank, above the low oil pressure switch.

Main characteristics

- Type : spring valve
- Check valve setting : 25 kPa (3.6 PSI).

Main components

- Body
- Check valve
- Spring
- Spring seat.

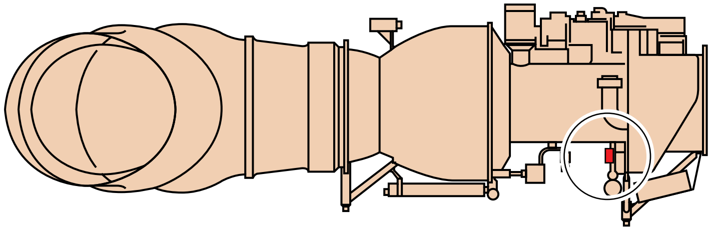
Operation

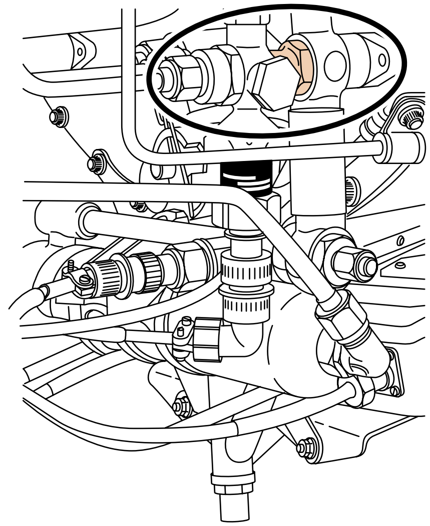
Engine shut-down

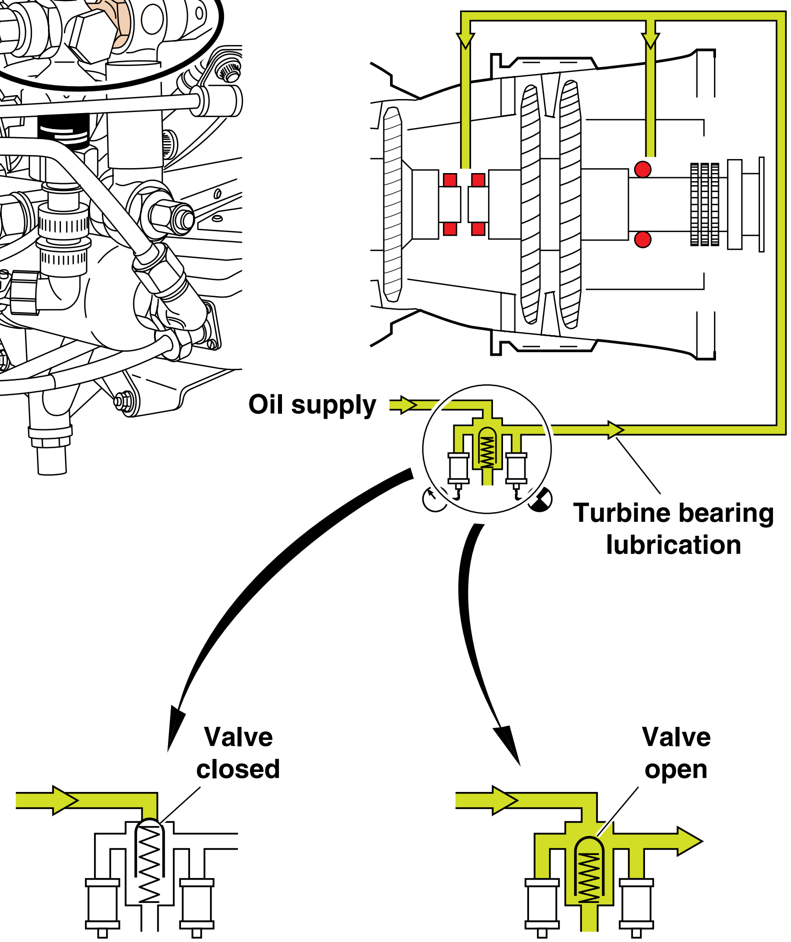
During engine shut-down, the oil pressure is lower than the check valve setting. The check valve is closed and prevents oil circulation to the turbine bearings. It prevents flooding and oil leaks through the turbine labyrinth seals which are not very efficient at low speed.

Normal running

The oil pressure is higher than the check valve setting. The check valve is open and allows oil circulation to the turbine bearings.

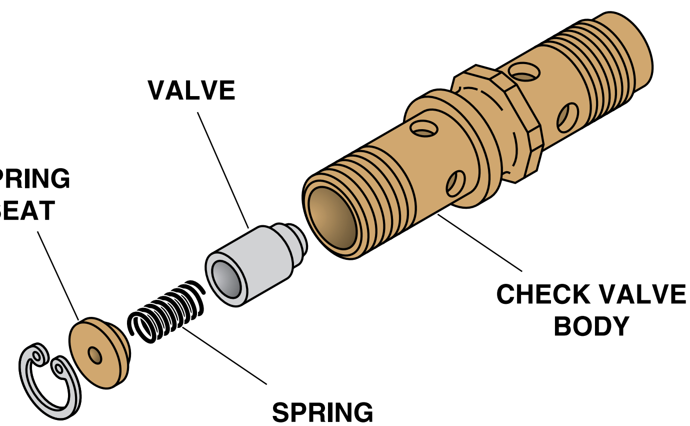






Type
Spring valve

Setting
25 kPa (3.6 PSI)



ENGINE SHUT-DOWN
(pressure < 25 kPa / 3.6 PSI)

NORMAL RUNNING
(pressure > 25 kPa / 3.6 PSI)

TURBINE BEARING CHECK VALVE

CENTRIFUGAL BREATHER

Function

The centrifugal breather separates the oil from the oil/air mist created by the lubrication.

Position

The centrifugal breather is formed by the intermediate gear of the accessory drive train.

Main characteristics

- Type : centrifugal
- Air vent : through the gear shaft.

Main components

- Gear with air passage holes
- Air vent.

Description

The centrifugal breather is formed by a hollow shaft which has radial drillings. It is part of the intermediate gear located in the accessory drive train.

The gear is supported by two ball bearings. The front bearing sealing is ensured by a graphite seal.

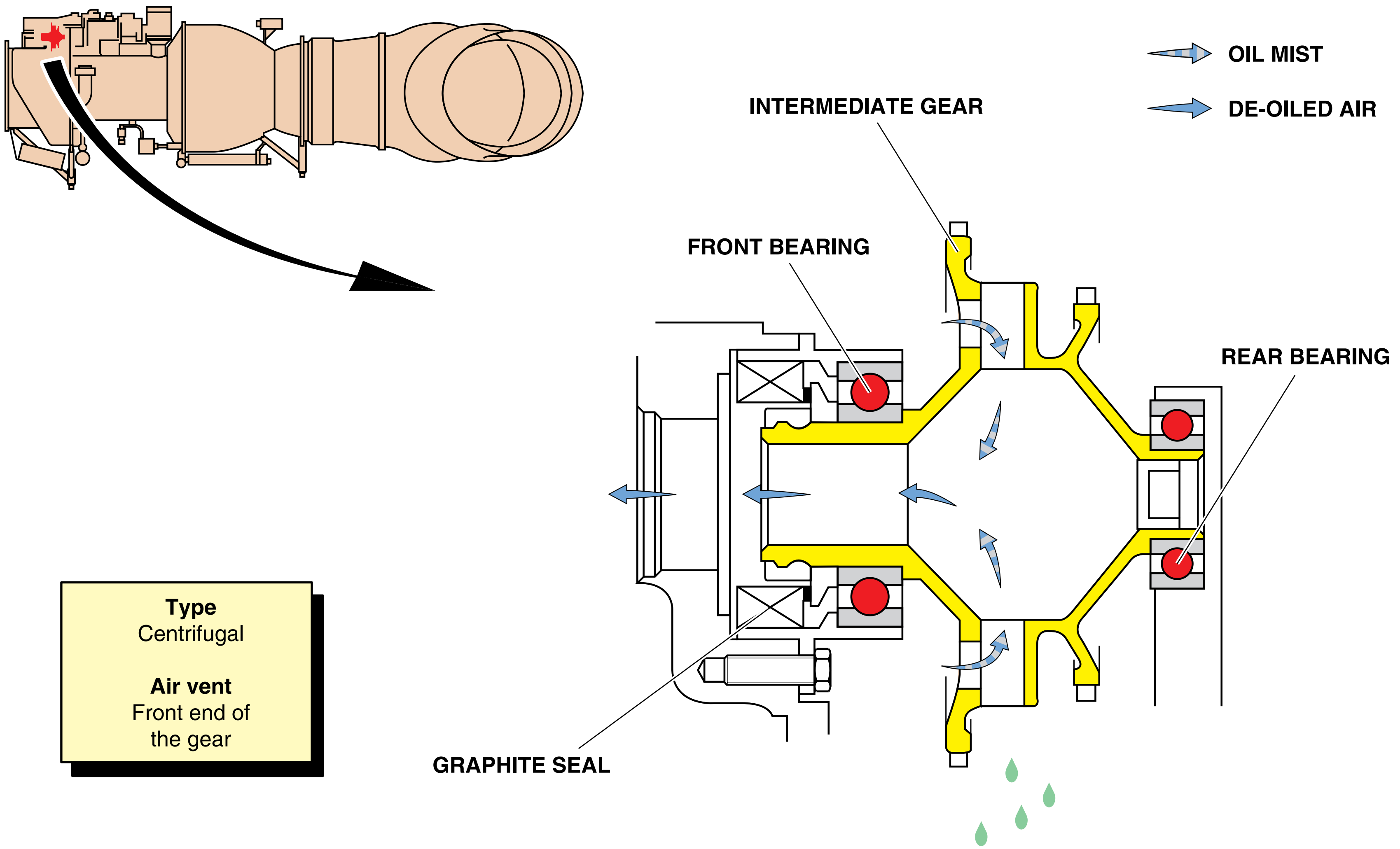
The centrifugal breather air outlet is at the front end of the hollow shaft and through a passage in the gearbox casing.

Operation

The centrifugal breather is the intermediate gear of the accessory drive train.

During operation, the oil mist which results from lubrication flows through the centrifugal breather.

- The oil is sprayed onto the internal walls of the gearbox, and falls by gravity to the lower part of the gearbox casing
- The de-oiled air is vented to the exhaust pipe through an external pipe.



Type
Centrifugal

Air vent
Front end of
the gear

CENTRIFUGAL BREATHER

STRAINERS

Function

The strainers protect the scavenge pumps.

Position

The strainers are fitted in each scavenge line upstream of the scavenge pumps.

Main characteristics

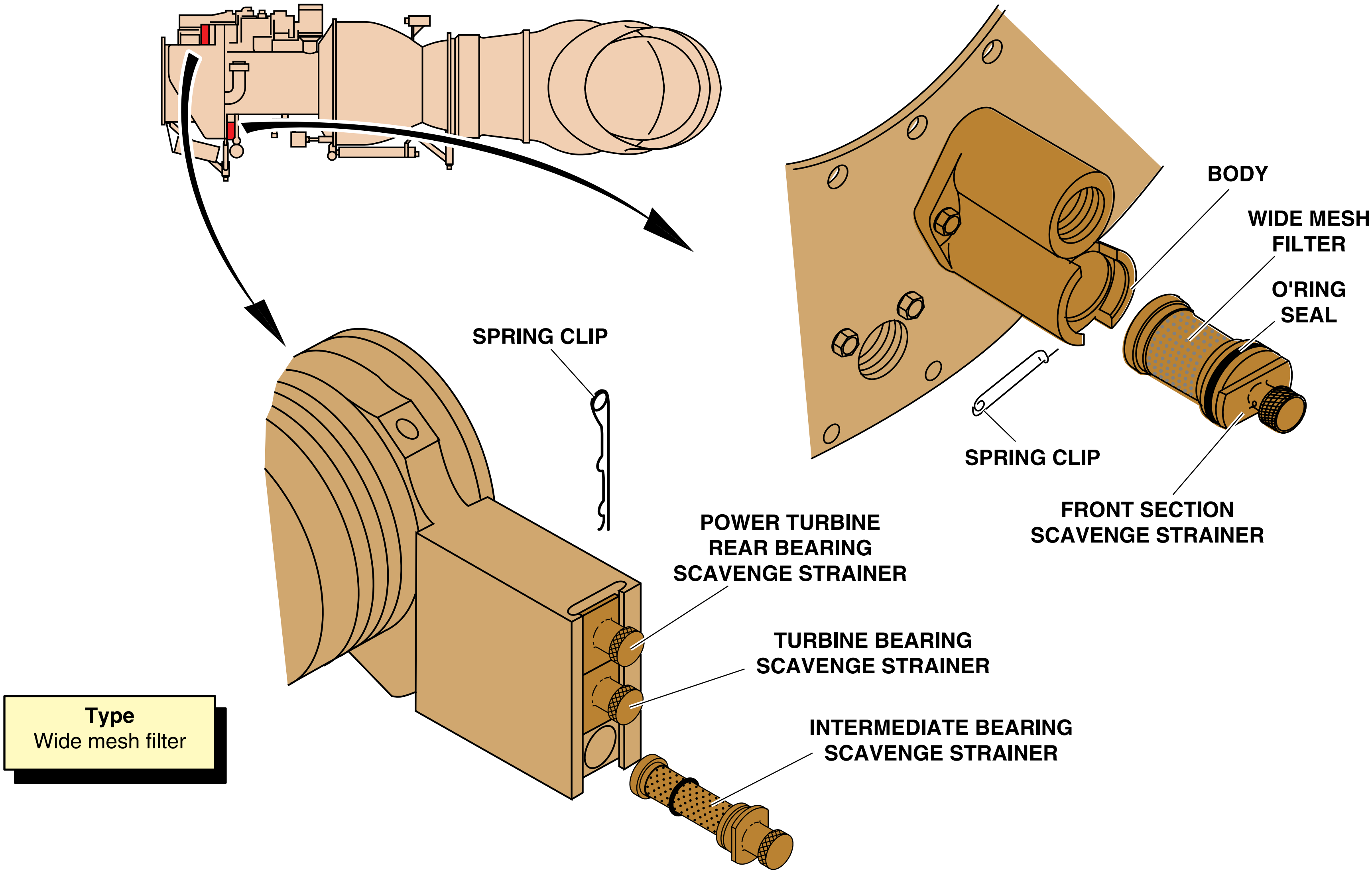
- Type : wide mesh filter.

Main components

- Strainer body
- Wide mesh filter
- Mounting flange
- O'ring seal
- Spring clip.

Functional description

A strainer is a wide mesh filter which retains any large particles which may be present in the oil in order to protect the scavenge pumps.


BODY
WIDE MESH FILTER
O'RING SEAL
SPRING CLIP
SPRING CLIP
FRONT SECTION SCAVENGE STRAINER
POWER TURBINE REAR BEARING SCAVENGE STRAINER
TURBINE BEARING SCAVENGE STRAINER
INTERMEDIATE BEARING SCAVENGE STRAINER
Type
Wide mesh filter

STRAINERS

MAGNETIC PLUGS

Function

The magnetic plugs permit a frequent and quick check of the engine internal condition.

Position

In the oil system, the magnetic plugs are located :

- On the front section scavenge system
- At the lower part of the tank
- On the scavenge pipes :
  - Of the intermediate gears
  - Of the turbine bearings
  - Of the power turbine rear bearing.

Main characteristics

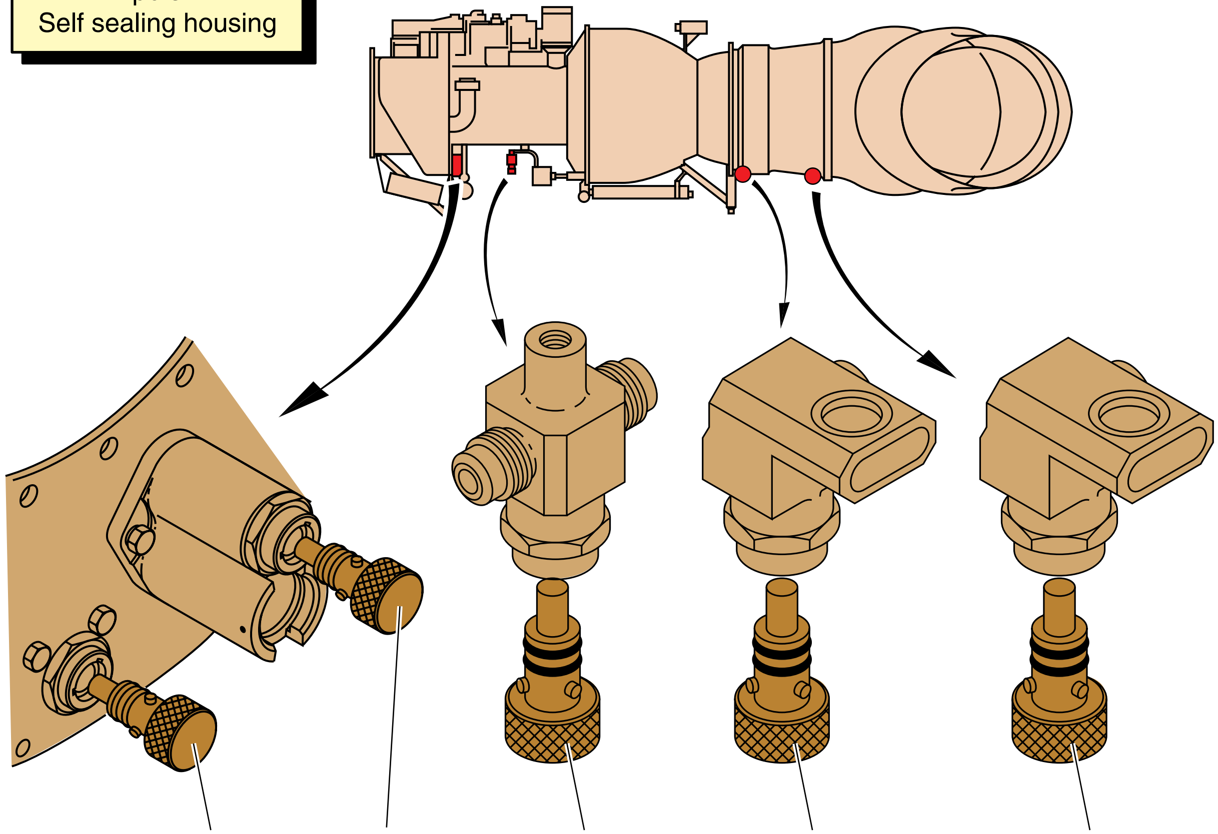
- Type : single magnetic pole. Self sealing housing.

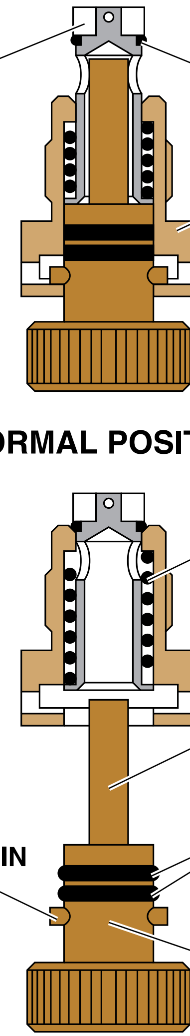
Main components

- Valve
- O'ring seal
- Housing
- Magnetic rod
- Locating pin.

Note *: The oil tank magnetic plug is different from the other one. It provides the connection with a drain pipe allowing the tank drainage.*

Type
Single magnetic pole
Self sealing housing





MAGNETIC PLUGS

INDICATING DEVICES - GENERAL

Function

The indicating devices enable the monitoring of oil system operation (pressure, temperature…).

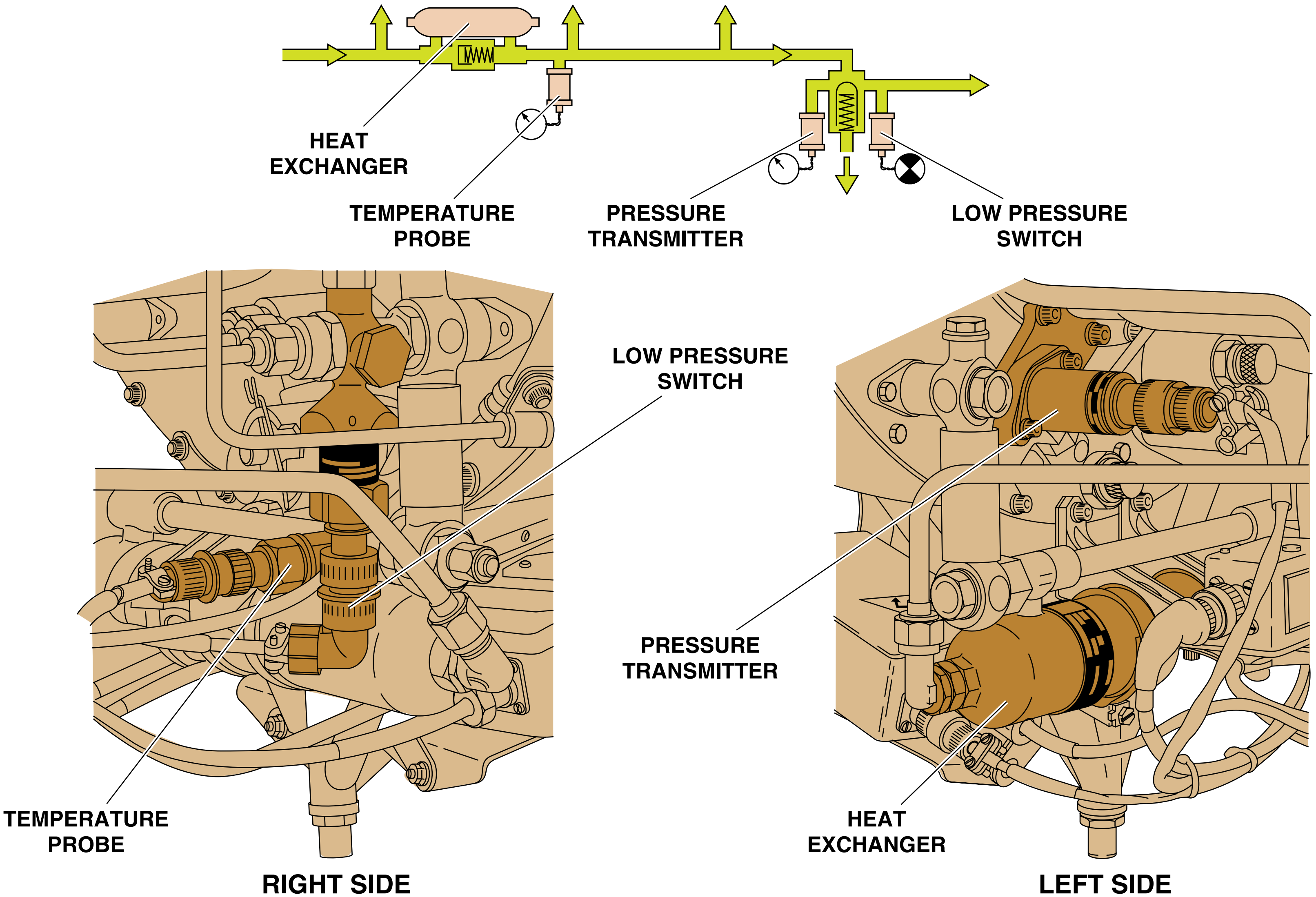
Position

- In the system :
  - Downstream of the heat exchanger for the pressure and temperature indicating devices
  - Downstream of the scavenge pumps for the chip detector

- On the engine :
  - At the lower rear part of the air intake casing for the pressure and temperature indicating devices
  - On the pump scavenge outlet pipe for the chip detector.

Main components

- Low oil pressure switch
- Oil pressure transmitter
- Oil temperature probe
- Chip detector.



INDICATING DEVICES - GENERAL

LOW OIL PRESSURE SWITCH

Function

The low oil pressure switch detects low oil system pressure.

Position

- In the system : downstream of the heat exchanger
- On the engine : at the heat exchanger outlet on a special union.

Main characteristics

- Type : diaphragm pressure switch
- Setting : 170 kPa (24.65 PSI)
- Indication : warning light on instrument panel.

Main components

- Switch base
- Mounting union
- Electrical connector.

Description

The pressure switch includes the following components :

- A diaphragm subjected to the oil pressure downstream the heat exchanger
- A plunger fixed to the diaphragm to operate the microswitch
- A microswitch connected to a warning light on the instrument panel.

Operation

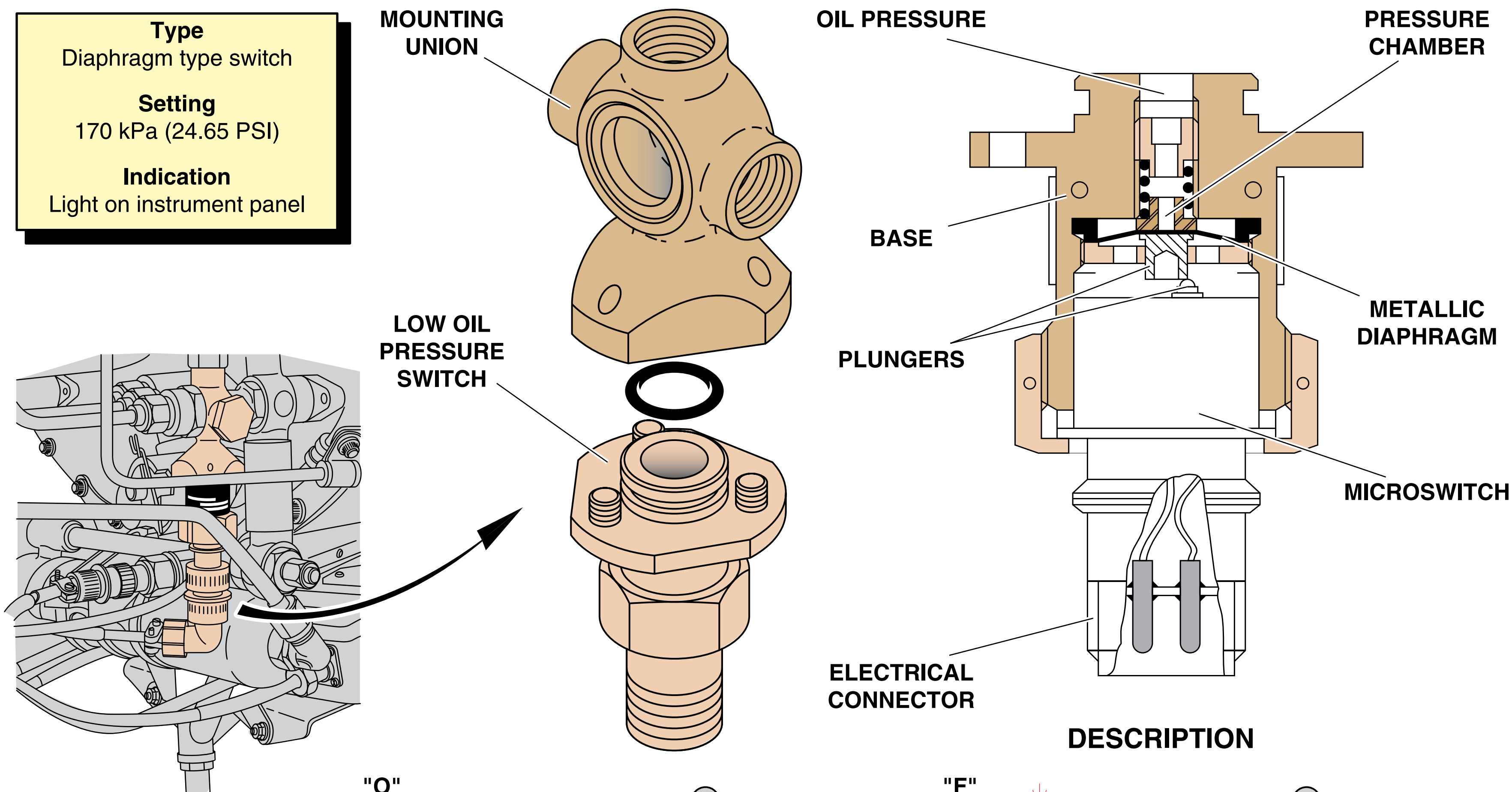
The pressure switch microswitch is open in normal engine operation.

If the oil pressure downstream of the heat exchanger reduces to less than 170 kPa (24.65 PSI), the diaphragm moves down. This causes the microswitch to close, completing the circuit of the low oil pressure warning light.

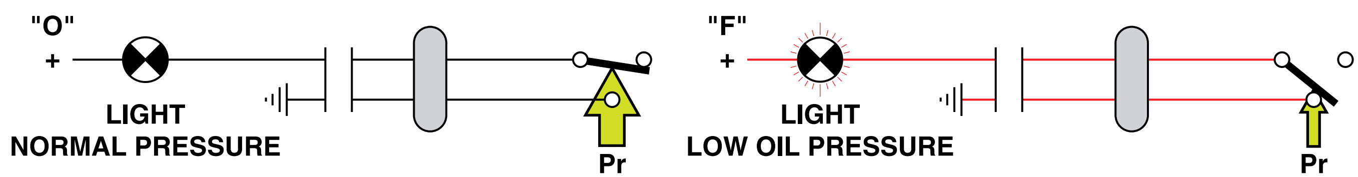
Type
Diaphragm type switch

Setting
170 kPa (24.65 PSI)

Indication
Light on instrument panel



DESCRIPTION



OPERATION

LOW OIL PRESSURE SWITCH

OIL PRESSURE TRANSMITTER

Function

The transmitter provides a signal of oil pressure to the instrument panel.

Position

- In the system : downstream of the heat exchanger
- On the engine : on the oil tank rear cover.

Main characteristics

- Type : resistive
- Output signal : electrical voltage proportional to the oil pressure ("Vs" = 0 to 100 mV)
- Input voltage :"Ve" = 10 VDC.

Description

The transmitter includes :

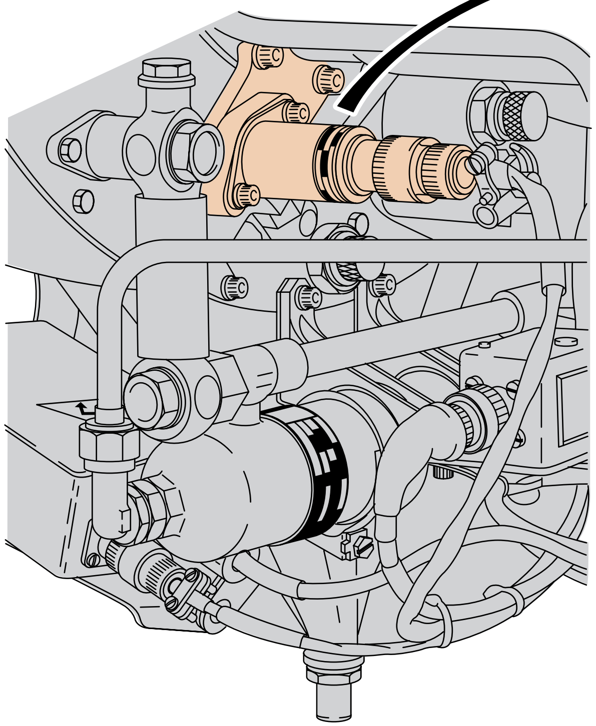
- The transmitter body
- A mounting flange (attachment on a mounting base)
- An electrical connector.

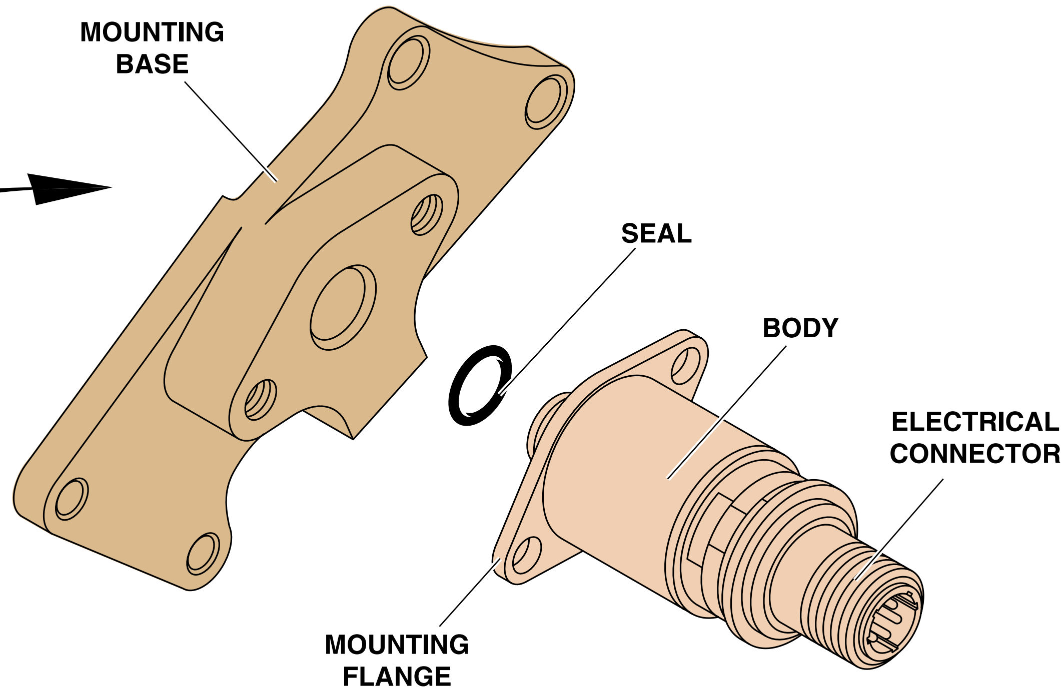
Operation

It is a resistive type transmitter. It incorporates a bridge of resistors printed on a flexible support.

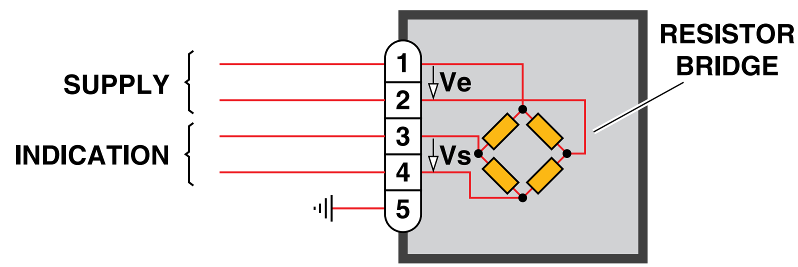
The deformation of the support produces an output voltage proportional to the oil pressure for a constant input voltage.

Type
Resistive strain gauge





DESCRIPTION



Ve : Constant input voltage ; Ve = 10 VDC
Vs : Output voltage proportional to the oil pressure ; Vs = 0 to 100 mV

OPERATION

OIL PRESSURE TRANSMITTER

OIL TEMPERATURE PROBE

Function

The probe measures the oil temperature at the heat exchanger outlet.

Position

- In the system : downstream of the heat exchanger
- On the engine : at the heat exchanger outlet on the engine right-hand side.

Main characteristics

- Type : nickel wire resistor.

Main components

The oil temperature probe includes the following components :

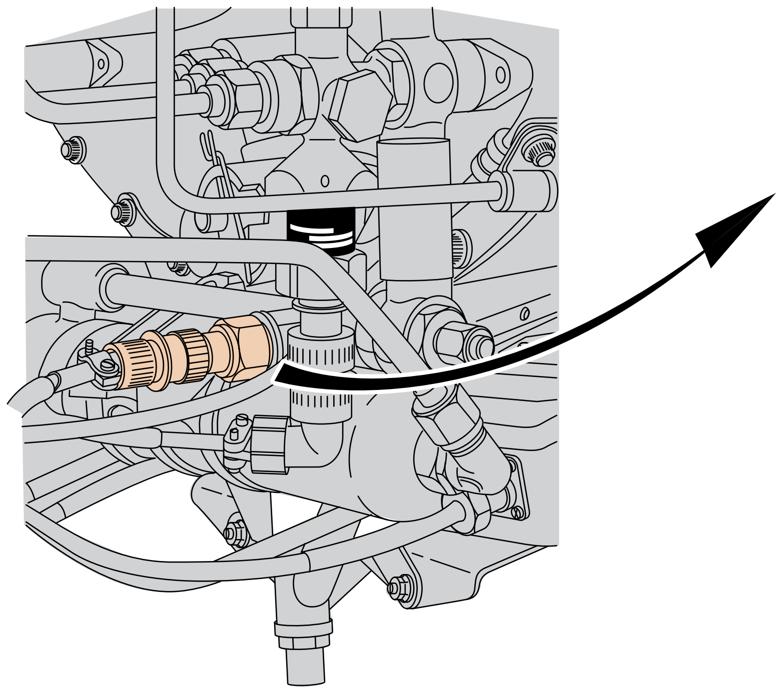
- Bulb (houses the resistance)
- Body
- Electrical connector.

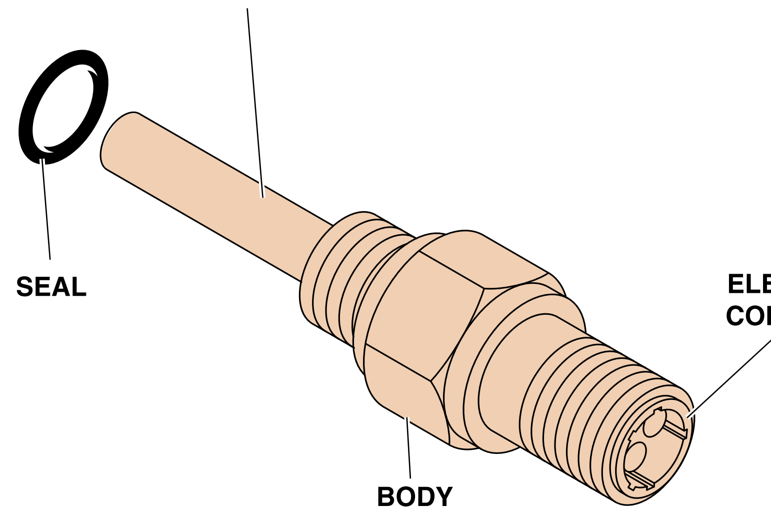
Functional description

The oil temperature variations induce variations in the probe resistance.

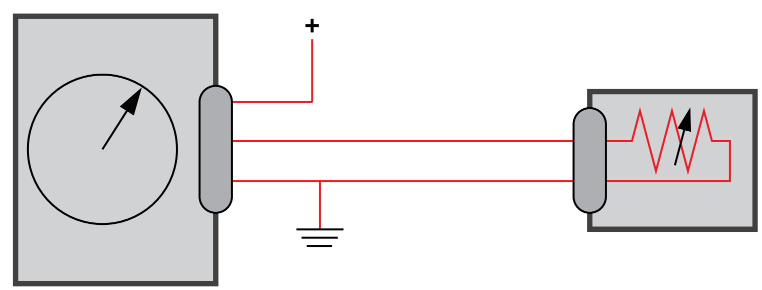
The probe is electrically installed in a Wheatstone-bridge circuit including a galvanometer to which the probe imparts variations which are proportional to the temperature measured.

Type
Nickel wire resistor





DESCRIPTION



OPERATION

OIL TEMPERATURE PROBE

CHIP DETECTOR

Function

The chip detector indicates, by means of a warning light in the instrument panel, a build-up of particles in the oil.

Position

- In the system : downstream of the scavenge pumps
- On the engine : on the scavenge pump outlet pipe.

Main characteristics

- Type :
  - Magnetic with electrical indication
  - Self sealing housing.

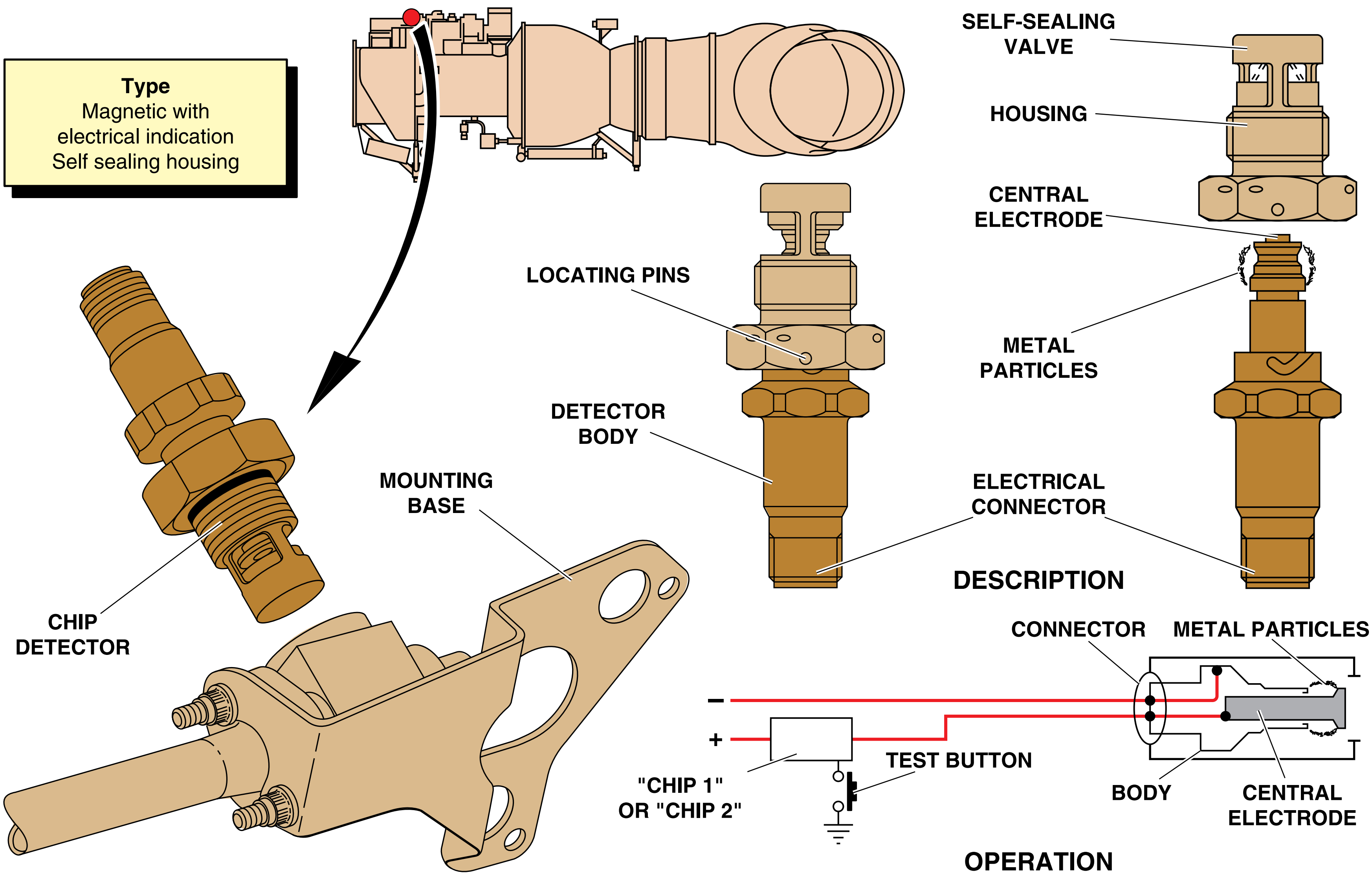
Main components

- Detector body
- Electrical connector
- Housing
- Locating pins.

Functional description

The magnetic particles, contained in the scavenge oil, accumulate around the central electrode. When the quantity of magnetic particles is enough to create electrical continuity between the central electrode and the body, a warning light illuminates on the instrument panel via the control and monitoring harness.

Type
Magnetic with
electrical indication
Self sealing housing



CHIP DETECTOR

OIL PIPES (1) - PRESSURE SYSTEM

This description includes external pipes and internal ducts of the pressure system.

Tank to pressure pump

- Internal pipe (in the air intake casing)
- Union on pressure pump.

Pressure pump to filter

- Internal pipe (in the air intake casing).

Filter to check valve

- Internal duct
- Check valve located in the filtering unit.

Check valve to anti-icing

- Internal pipe (in the air intake casing).

Check valve to heat exchanger

- Internal pipe (in the air intake casing) and external pipe (engine left lower part).

Heat exchanger to compressor bearings

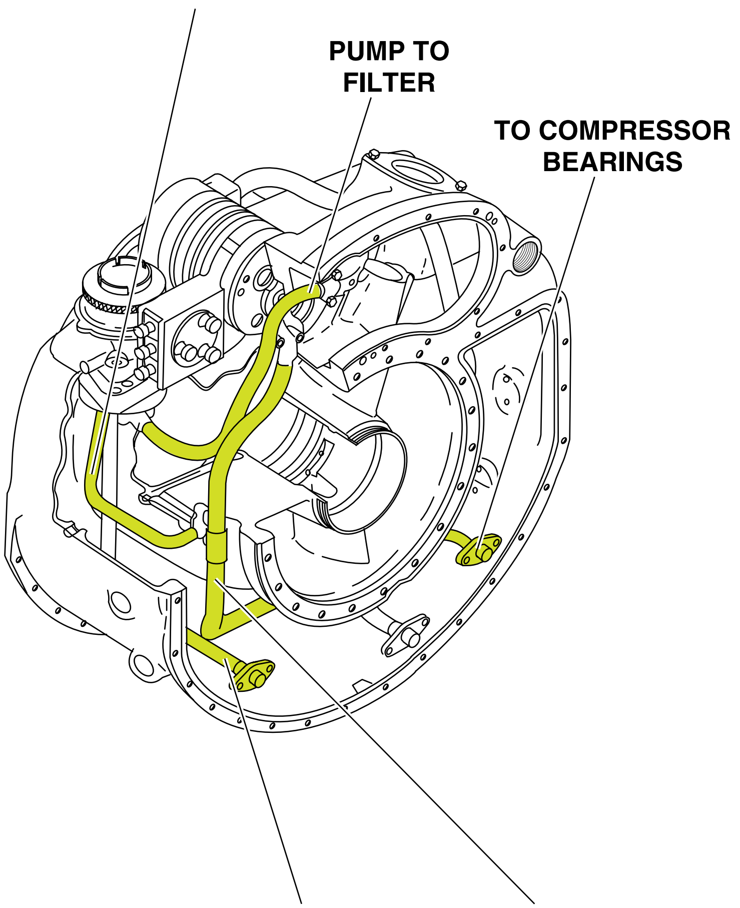
- External pipe (engine right lower part)
- Internal pipe (in the air intake casing, to central shaft).

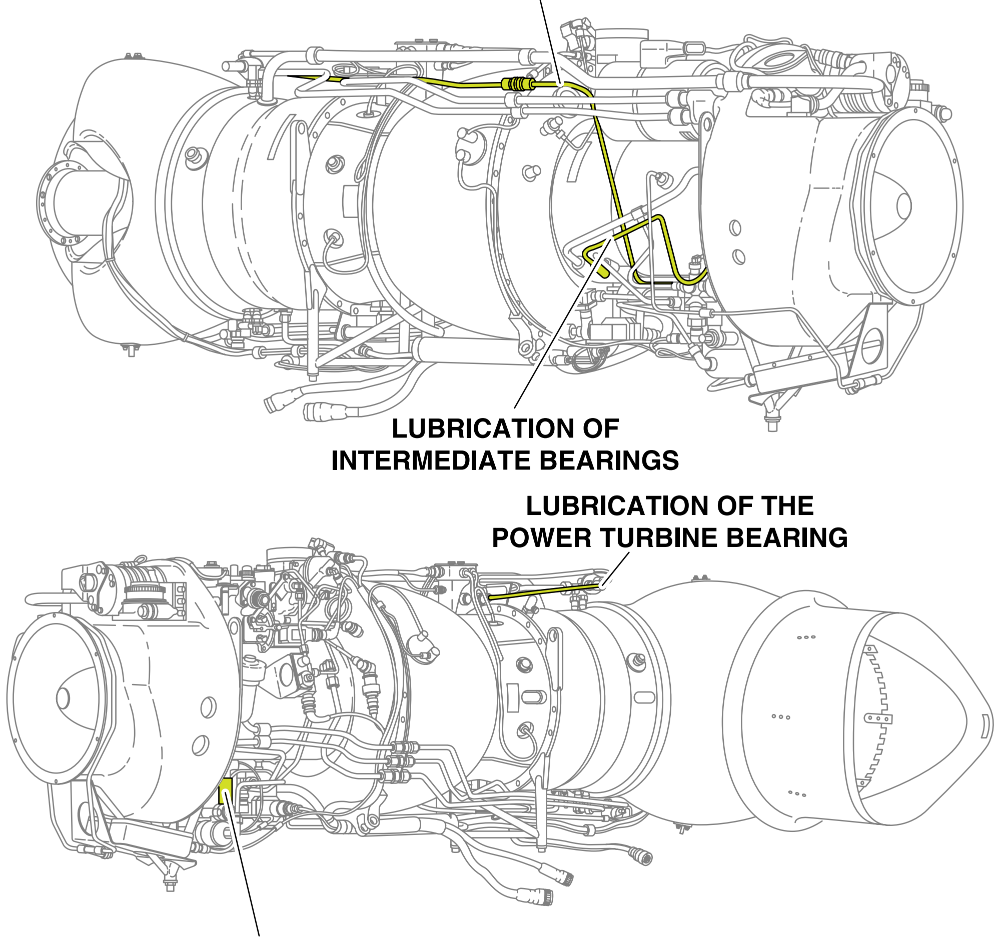
Heat exchanger to turbine bearings

- External pipe (engine right upper part).

Turbine bearings to power turbine rear bearing

- External pipe (engine right upper part).





OIL PIPES (1) - PRESSURE SYSTEM

OIL PIPES (2) - SCAVENGE, BREATHING SYSTEMS

This description includes external pipes and internal ducts of the scavenge and breathing systems.

Scavenge of front section (accessory gearbox and anti-icing)

- Internal duct (in the air intake casing).

Scavenge of intermediate bearings

- External pipe (engine front lower part).

Scavenge of turbine bearings

- Internal tube and external pipe (engine left-hand side).

Scavenge of power turbine rear bearing

- Internal tube and external pipe (engine left-hand side).

Breathing of front section

- Internal (direct).

Breathing of intermediate bearings

- Internal duct and external pipe (engine front right part).

Breathing of turbine bearings

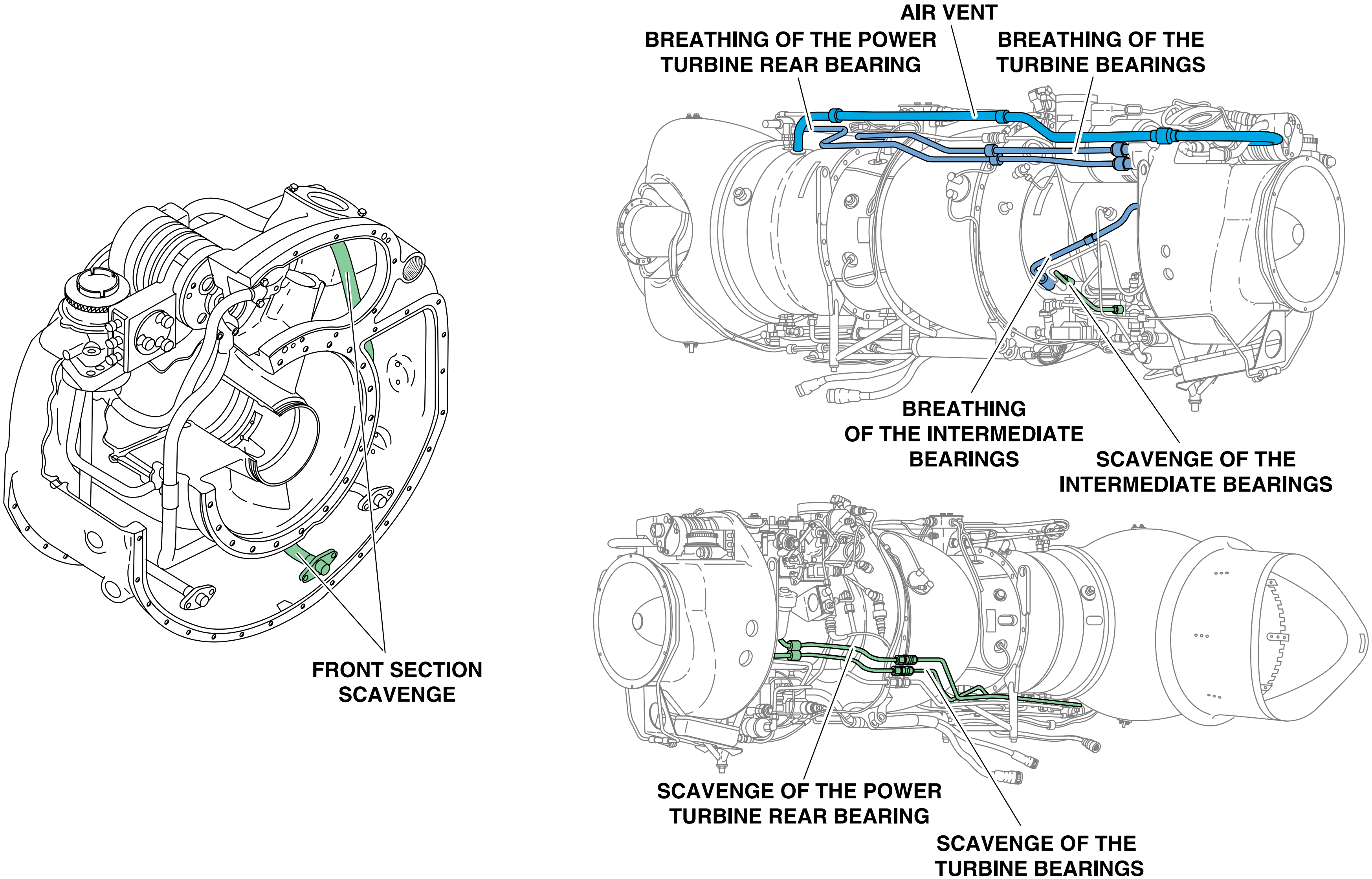
- Internal tube and external pipe (engine right upper part).

Breathing of power turbine rear bearing

- Internal tube and external pipe (engine right upper part).

Air vent

- External pipe (engine right upper part) from centrifugal breather to exhaust pipe.



OIL PIPES (2) - SCAVENGE, BREATHING SYSTEMS

5 - AIR SYSTEM

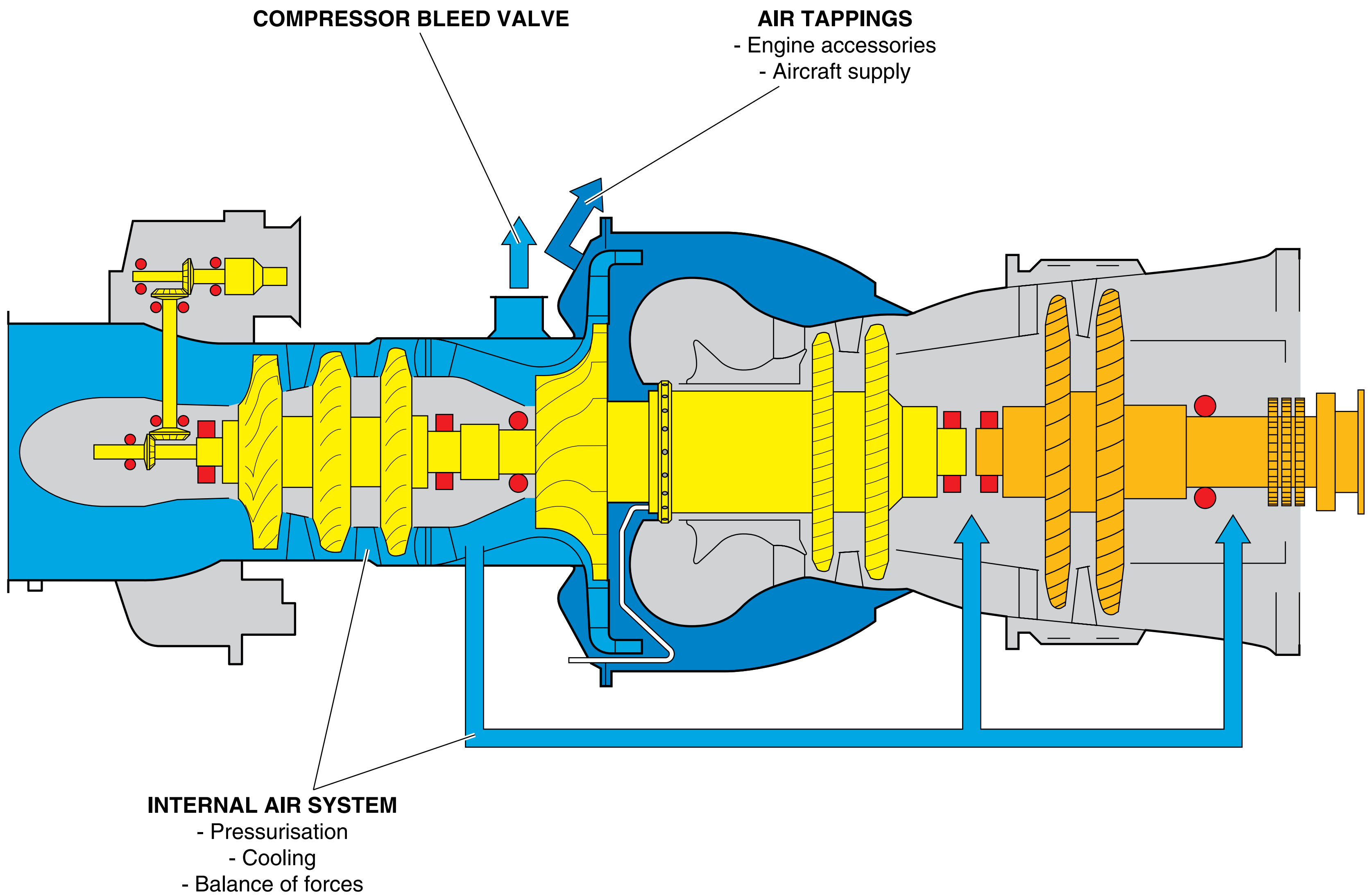
AIR SYSTEM

Function

The engine air system comprises several functions :

- Internal air system for pressurisation, cooling and balance of forces
- Air tappings for engine accessory supply and aircraft services
- Compressor bleed valve.

Note : *Refer to the various systems for the position, characteristics, description and operation.*


COMPRESSOR BLEED VALVE
AIR TAPPINGS
- Engine accessories
- Aircraft supply
INTERNAL AIR SYSTEM
- Pressurisation
- Cooling
- Balance of forces

AIR SYSTEM

INTERNAL AIR SYSTEM - GENERAL

Function

The "internal" or "secondary" air system pressurises the labyrinth seals, cools certain parts and provides a balancing of forces.

Position

All the parts of the system are internal except the pressurisation of the labyrinths of the turbine bearings which are supplied by external pipes.

Main characteristics

- Type : air pressure tapping with a calibrated flow
- Axial compressor outlet pressure : 340 kPa (49.3 PSI)
- Centrifugal compressor outlet pressure : 1040 kPa (150.8 PSI)
- Flow : ≈ 2 % of total flow.

Main components

- Internal ducts
- Passages and calibrated orifices
- External pipes.

Note *: The following systems are considered :*

- front section
- hot sections
- turbine bearings.

INTERNAL AIR SYSTEM

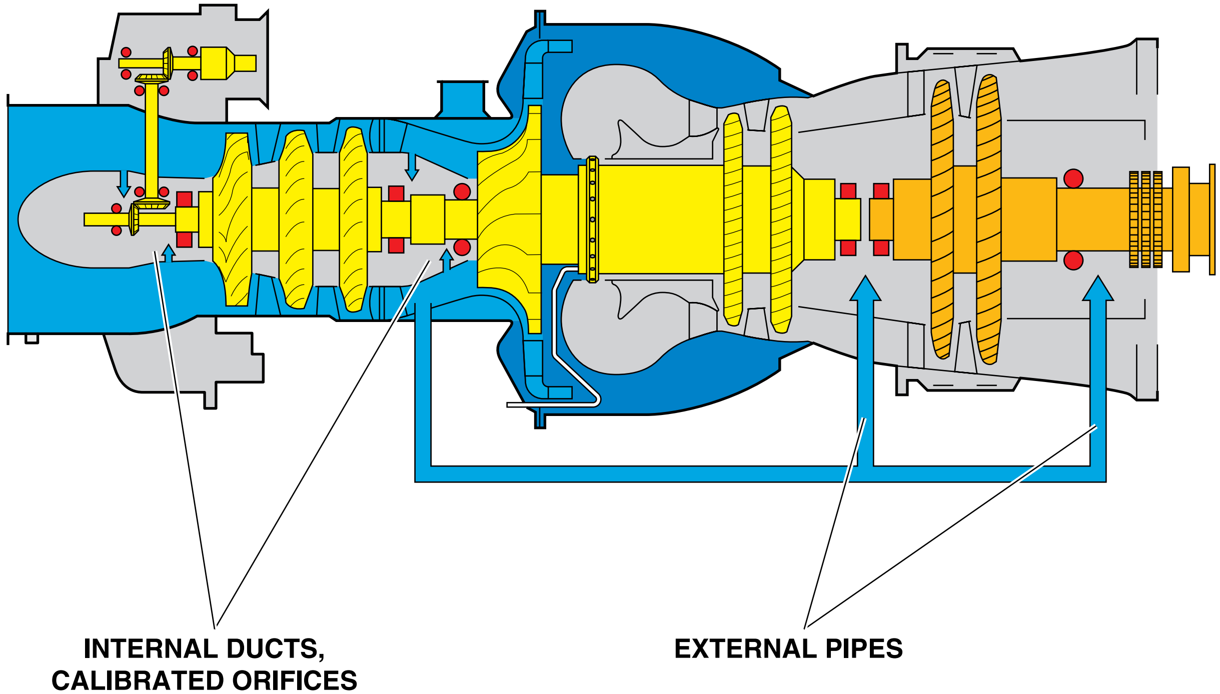
- Internal ducts
- Passages and calibrated orifices

Type
Air pressure tapping with a calibrated flow

Axial compressor outlet pressure
340 kPa (49.3 PSI)

Centrifugal compressor outlet pressure
1040 kPa (150.8 PSI)

Internal system flow
≈ 2 % of engine total flow



INTERNAL AIR SYSTEM - GENERAL

INTERNAL AIR SYSTEM - FRONT SECTION

The air is tapped to pressurise the labyrinth seals of the compressor bearings.

Inter-stage air

The air is tapped from the axial compressor 2nd stage wheel outlet. It flows through drilled orifices in the compressor shaft, to pressurise the labyrinth seal of the axial compressor front bearing.

A certain air leak (between the labyrinth and the abradable deposit) goes to the oil enclosure.

Axial compressor outlet air

The air is tapped from the 3rd stage wheel of the axial compressor. It directly pressurises the axial compressor rear bearing.

A certain air leak (between the labyrinth and the abradable deposit) goes to the oil enclosure.

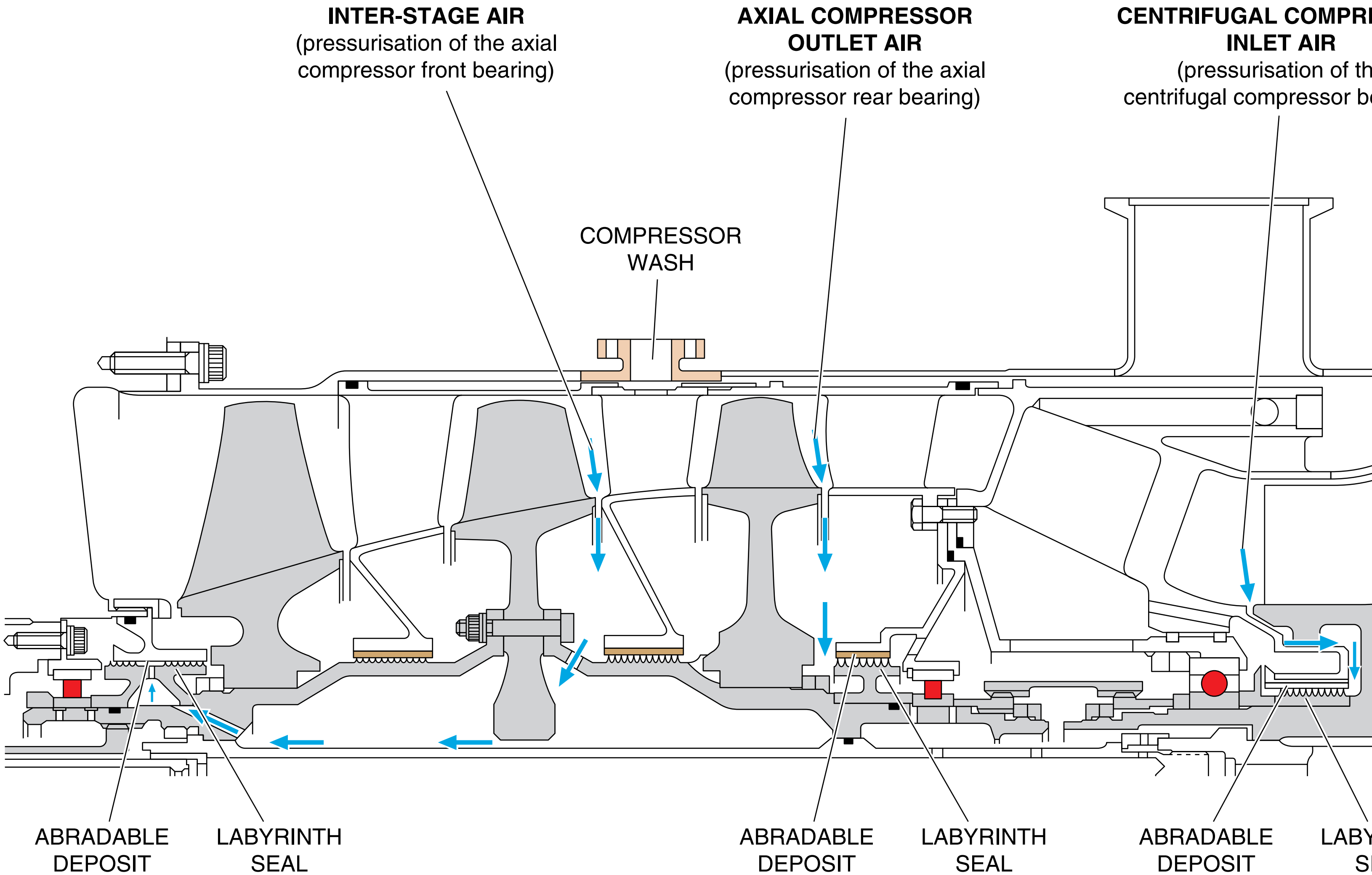
Centrifugal compressor inlet air

The air is tapped from the centrifugal compressor wheel inlet.

It flows through the front hole, and pressurises the centrifugal compressor bearing. As with the two other bearings, a certain air leak goes to the oil enclosure.

Note *: The casing includes a mounting pad with a union, allowing the spraying of the cleaning product, between the second and the third compressor stage.*

For training purposes only



INTERNAL AIR SYSTEM - FRONT SECTION

INTERNAL AIR SYSTEM - HOT SECTIONS

In addition to the air flow for the combustion, a certain quantity of air is tapped for the pressurisation, the cooling and the balance of forces.

Combustion chamber flow

The air which comes from the compressor is divided in two flows : a primary air flow for the combustion and a secondary air flow for the dilution (refer to chapter 3 for more details).

Pressurisation of labyrinth seals

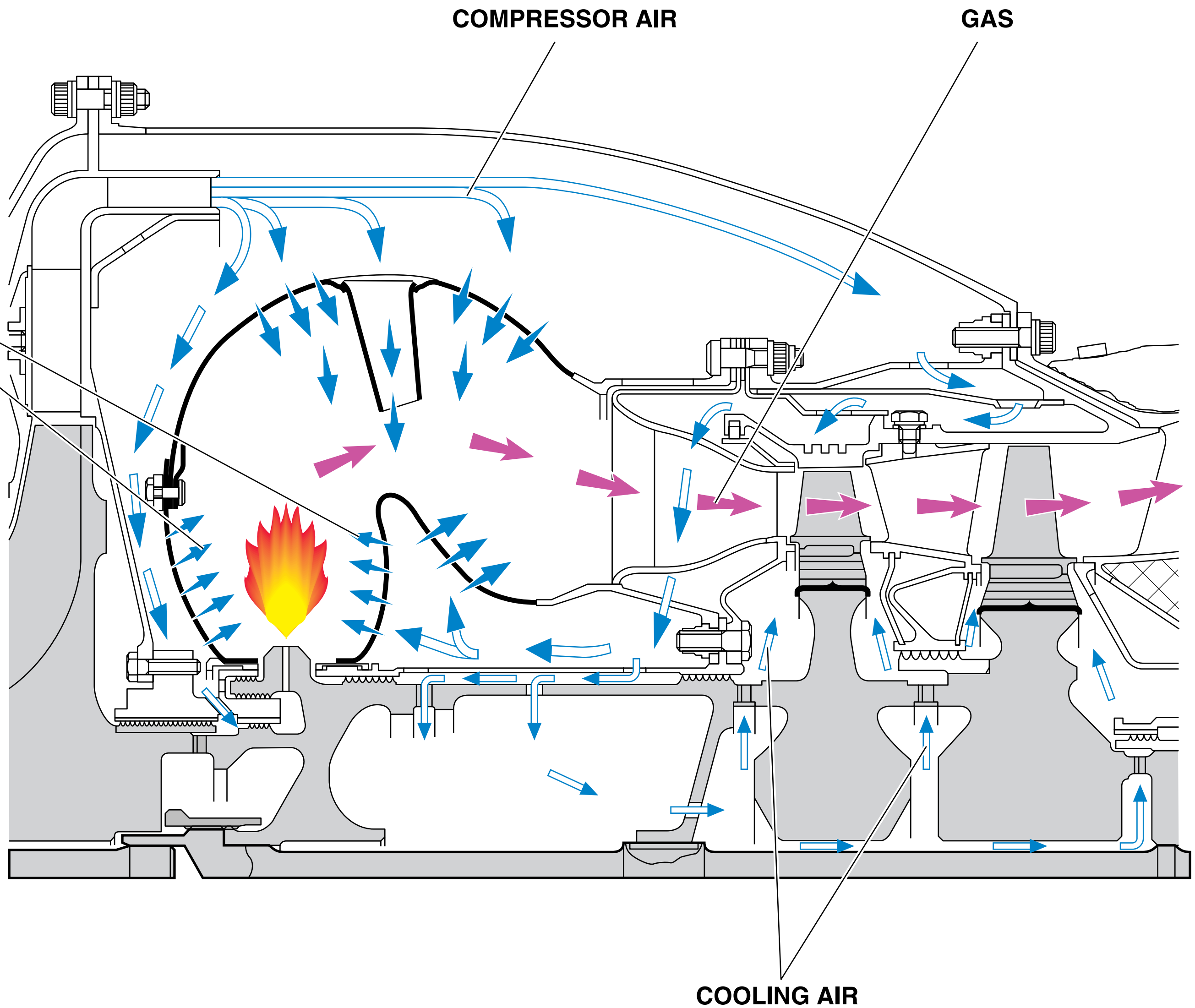
A certain quantity of air is tapped from the primary air flow (air which flows between the diffuser holder plate and the combustion chamber front swirl plate).

This air pressurises the labyrinth seals of the shaft and of the fuel centrifugal injection wheel.

Cooling and balance of forces

A certain quantity of air is tapped from the primary air flow (air which flows through the hollow vanes of the turbine nozzle guide vane).

This air flows through the curvic-couplings. It cools the turbine discs, the blade roots and establishes a certain balance of axial forces.



INTERNAL AIR SYSTEM - HOT SECTIONS

INTERNAL AIR SYSTEM - TURBINE BEARINGS

The air is tapped to pressurise the gas generator turbine rear bearing and the power turbine bearings.

Tapping and air flow

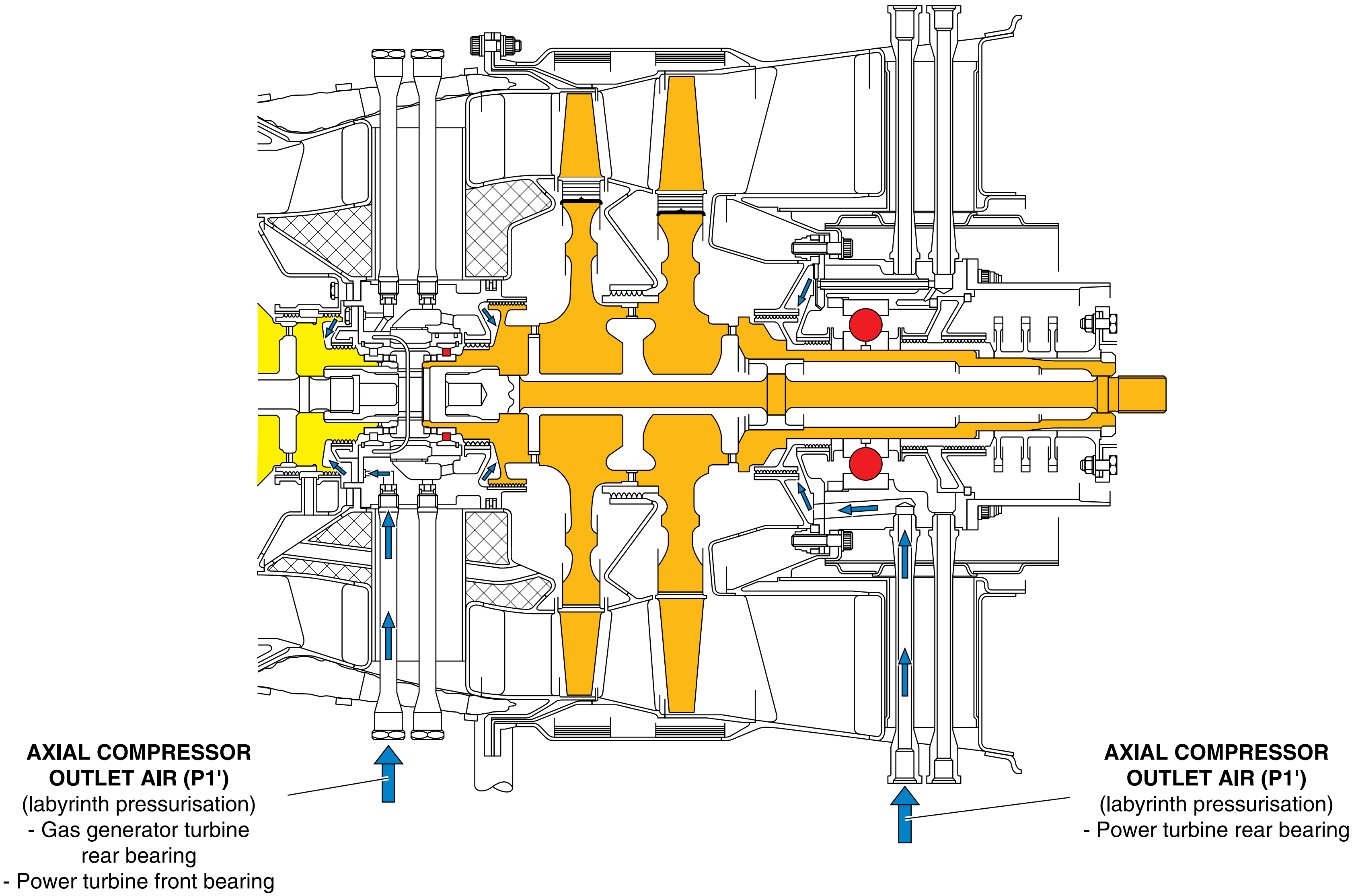
The air tapped from the axial compressor outlet is delivered to the turbines through external pipes and tubes screwed into the bearing housings.

The bearing labyrinth seals are pressurised. There is a small leak to the oil enclosure, and to the gas flow.

Pressurisation

We can distinguish :

- The pressurisation of the gas generator rear bearing and the power turbine front bearing
- The pressurisation of the power turbine rear bearing.



INTERNAL AIR SYSTEM - TURBINE BEARINGS

AIR TAPPINGS

Function

Air tappings are used for :

- Start injector ventilation
- Fuel control
- Aircraft services.

Start injector ventilation

The air tapped from the centrifugal compressor outlet is used to ventilate the start injectors to avoid blockage by the carbonisation of unburnt fuel.

The system comprises a tapping union and a pipe connected to the start electro-valve.

Note *: Refer to chapter "FUEL SYSTEM" for the system operation.*

Fuel control

The air pressure at the centrifugal compressor outlet is used for the fuel control (acceleration controller).

The system comprises a tapping union and a pipe connected to the hydromechanical control unit.

Note *: Refer to chapter "FUEL SYSTEM" for the system operation.*

Aircraft services

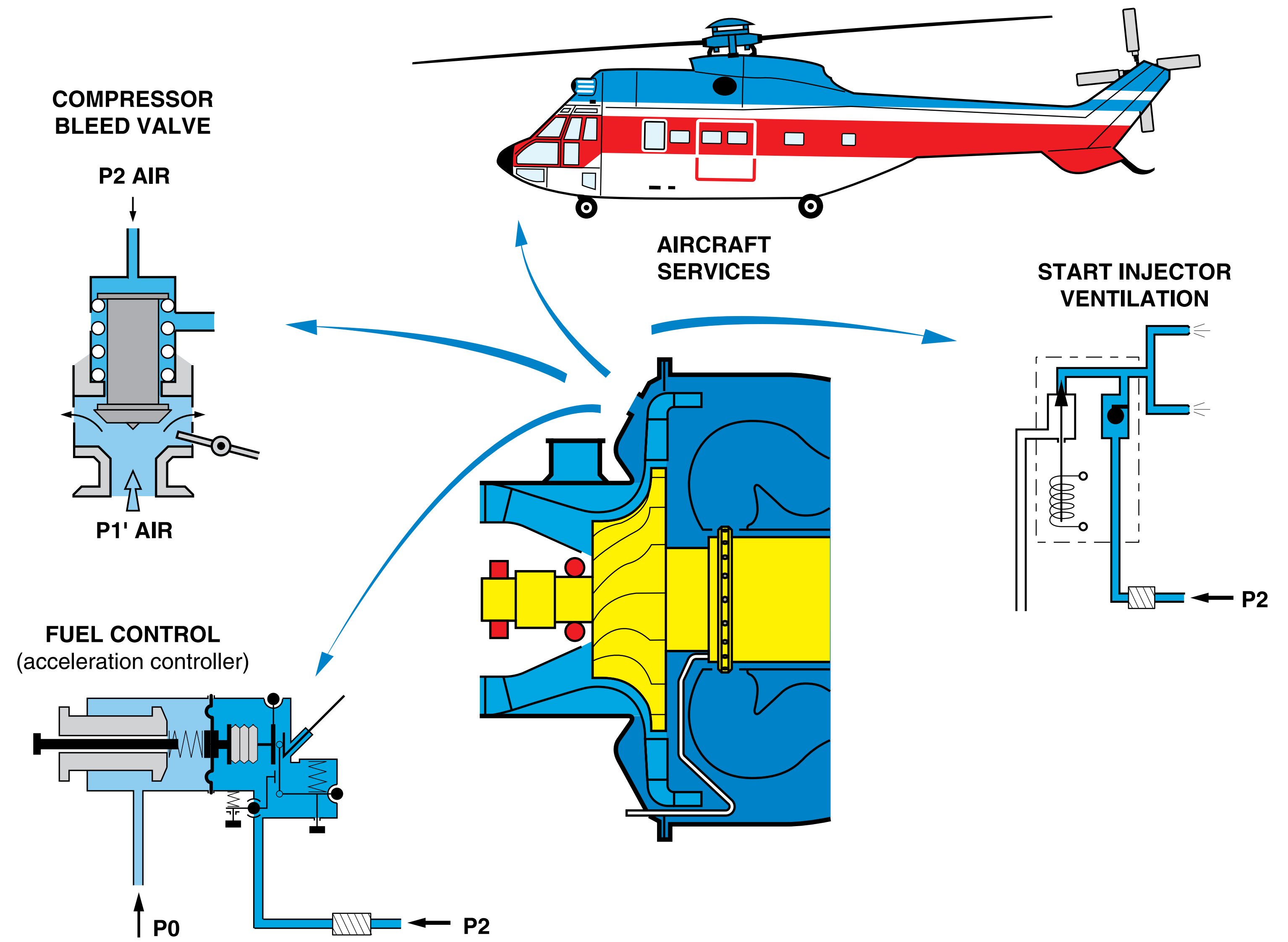
The air tapped from the centrifugal compressor is used in various aircraft systems.

The engine comprises a tapping point located on each side of the counter casing for aircraft use.

Sensors

The engine control system uses air temperature and pressure signals for :

- Ambient air temperature of the aircraft air data computer
- Temperature sensor of the engine air intake.



AIR TAPPINGS

COMPRESSOR BLEED VALVE - GENERAL

Function

The compressor bleed valve prevents axial compressor surge.

Position

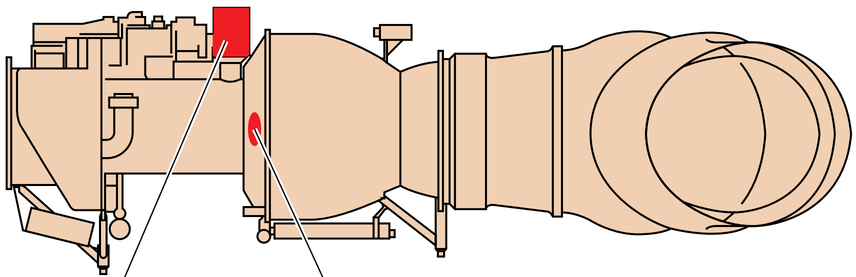
- In the system : between the axial and centrifugal compressors
- On the engine : at the top of the counter casing.

Main characteristics

- Type : pneumatic, with piston
- Control :
  - As a function of P2/P0
  - By the DECU in off-set mode
- Setting : as a function of P2/P0 : ≈ 600 kPa (87 PSI)
- Discharge flow : 200 g/s (0.44 lb/sec.)
- Power loss when the valve is open : ≈ 12 %.

Main components

- Pneumatic control system (compressor outlet air tapping and pipe)
- Bleed valve assembly
- Off-set threshold solenoid valve.



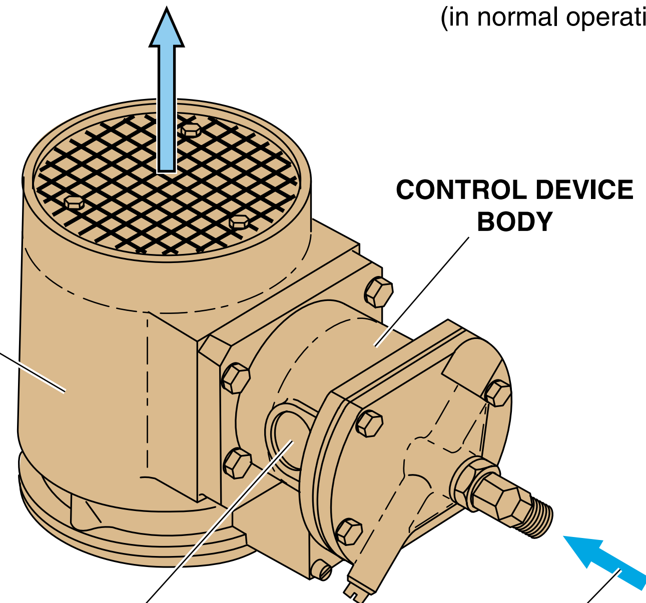
Type
Pneumatic, with piston

Control
- As a function of P2/P0
- By the DECU in off-set mode

Setting
Function of P2/P0
≈ 600 kPa (87 PSI)

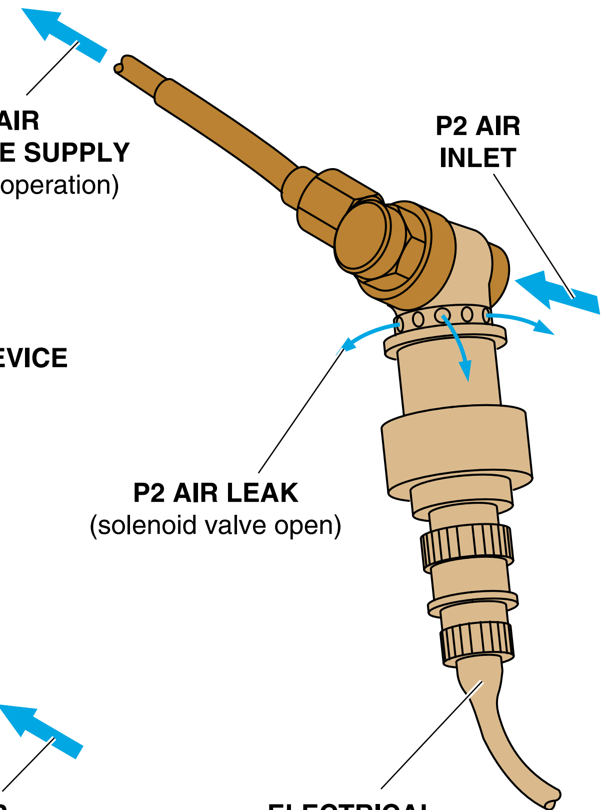
Discharge flow
200 g/s (0.44 lb/sec.)

Power loss
≈ 12 %



COMPRESSOR BLEED VALVE

OFFSET THRESHOLD SOLENOID VALVE



COMPRESSOR BLEED VALVE - GENERAL

COMPRESSOR BLEED VALVE - DESCRIPTION

The system includes the pneumatic control system, the bleed valve and the off-set threshold solenoid valve.

Pneumatic control system

The system includes the compressor air pressure tapping (fitted with sand trap) and a pipe connected to the bleed valve.

Compressor bleed valve

Main components :

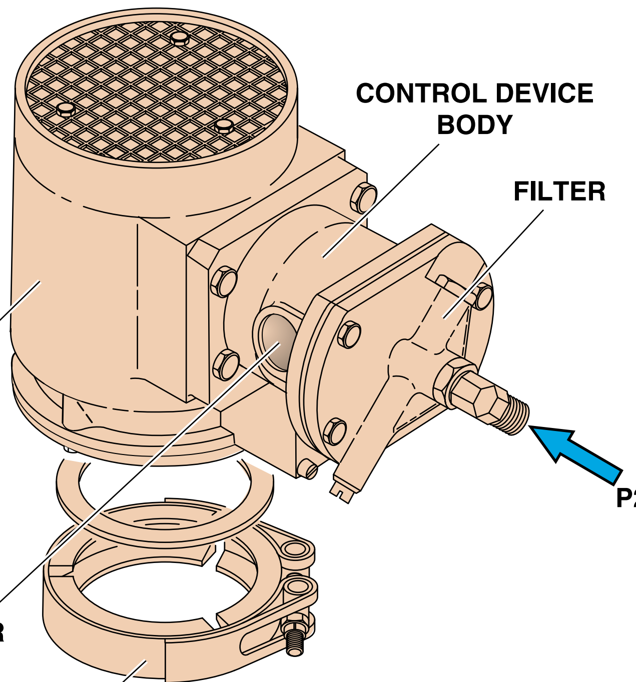
- Valve body (includes a valve, a release spring and a microswitch)

- Pneumatic control body (includes a P2 air inlet fitted with filter, a P0 air inlet and capsules).

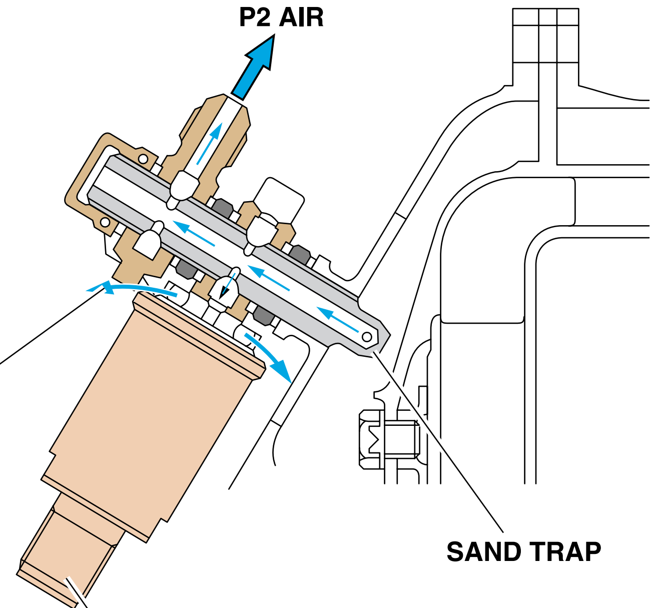
The valve is secured on the counter casing flange with a securing clamp.

Off-set threshold solenoid valve

The solenoid valve is mounted on the left of the centrifugal compressor casing. It includes a P2 air outlet pipe. Its electrical connector is connected to the DECU.



COMPRESSOR BLEED VALVE



OFF-SET THRESHOLD SOLENOID VALVE

COMPRESSOR BLEED VALVE - DESCRIPTION

COMPRESSOR BLEED VALVE - OPERATION

Principle

The valve prevents compressor surge by bleeding off a certain quantity of air tapped from the axial compressor outlet. When the valve is open, the discharge of air causes the air flow through the axial compressor to increase thus moving the operating line away from the surge line. The operation of this valve is controlled at a N1 speed value which depends on the P2/P0 compression ratio. In certain conditions the threshold is off-set.

Open position

The P2/P0 pressure is not sufficient to activate the capsules and there is an air leak downstream of the calibrated orifices. The valve is open under the action of its spring and P1' air pressure. A certain quantity of air is expelled overboard.

The microswitch then supplies the valve indicating light.

Note *: Min opening threshold in standard condition 81.3 %.*

Valve closing

When the gas generator rotation speed N1 increases, the compression ratio P2/P0 increases and beyond a certain value (value which is independent of the N1 speed) :

- The pressure becomes sufficient to deform the detection capsule which closes the leak
- The pressure downstream of the calibrated orifice B increases
- The diaphragm of the intermediate stage closes the leak
- The pressure downstream of the calibrated orifice A increases
- The valve closes under P2 pressure, the indicating light turns off.

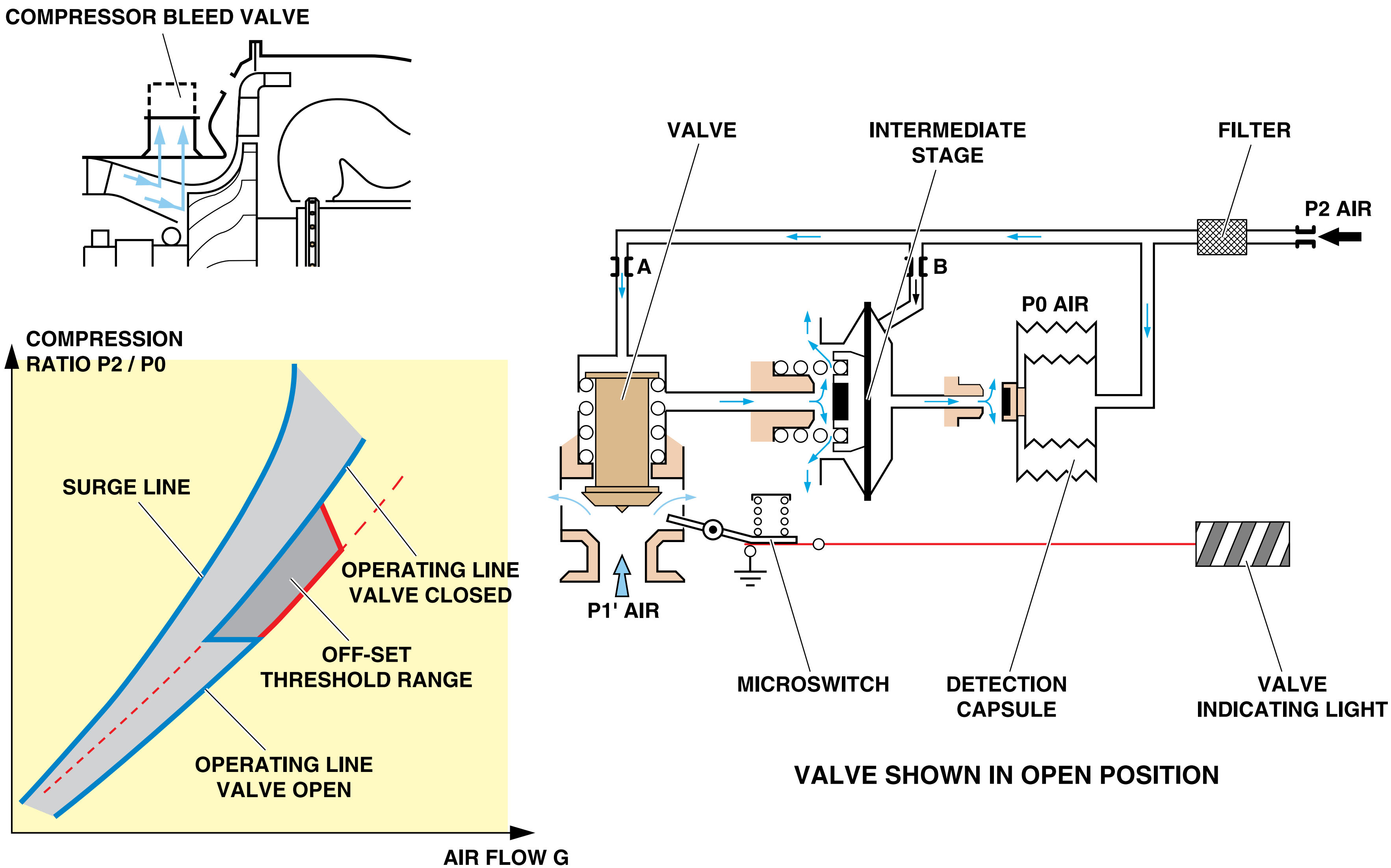
Note *: Min closing threshold 0.6 % above the opening threshold.*

Operation in "off-set threshold" mode

This device prevents engine surge which is liable to occur during hovering with ground effect, with a strong tail wind (more than 20 knots).

When the off-set mode is selected, the DECU controls the electrical supply of the solenoid valve as a function of N1 rotation speed, it closes at 98 % and opens at 95 %.

Note *: Refer to the flight manual for operating procedure.*



COMPRESSOR BLEED VALVE - OPERATION

OFF-SET THRESHOLD SOLENOID VALVE

Function

The solenoid valve creates a leak off the bleed valve control air, and modifies the bleed valve setting.

Position

On the left front of the centrifugal compressor casing.

Main characteristics

- Type : electro-magnetic valve
- Voltage : 14 to 32 Volts
- Setting : by the DECU (valve closing at 98 % N1, valve opening at 95 % N1).

Main components

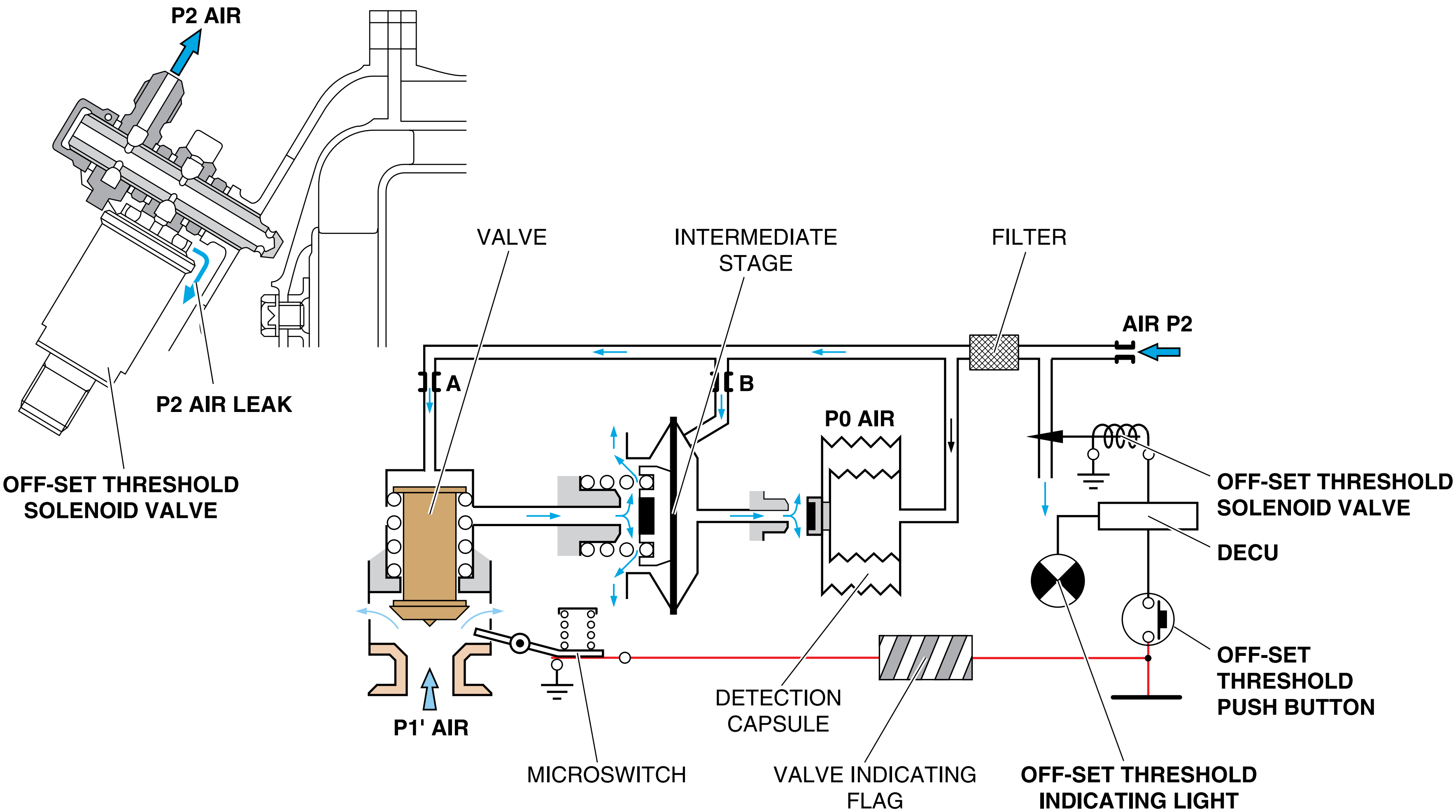
Beyond the solenoid valve, we can note the control system with :

- The Digital Engine Control Unit
- The push button
- The indicating light (blue light on push-button).

Operation

Let's remember that this device prevents engine surge which is liable to occur during hovering with ground effect, with a strong tail wind of more than 20 knots.

In these conditions, when the push-button is activated, the DECU is also activated and supplies the solenoid valve as a function of N1 speed. When the solenoid valve is open, it causes a leak of the P2 control pressure, which modifies the bleed valve setting. The valve no longer works as a function of P2/P0 ratio but works as a function of speed with a certain hysteresis determined by the DECU.



OFF-SET THRESHOLD SOLENOID VALVE

AIR TAPPING UNIONS

This part summarises the tappings of the various air systems.

Internal air system

(Pressurisation of the turbine bearing labyrinth seals)

- P1' air tapping and pipes.

P2 air tappings

The P2 air is tapped from a zone which is not in the main air stream (P2 air considered clean as it contains very little debris). But some air tappings are fitted with sand traps which are probes screwed into the counter casing mounting pads. A probe comprises a P2 air inlet which is orientated in the opposite direction to the air flow.

Compressor bleed valve

- Control P2 air tapping and pipe

- P0 air tapping on the valve.

Off-set threshold solenoid valve

- P2 air tapping and leak.

Start injector ventilation

- Air tapping and pipe.

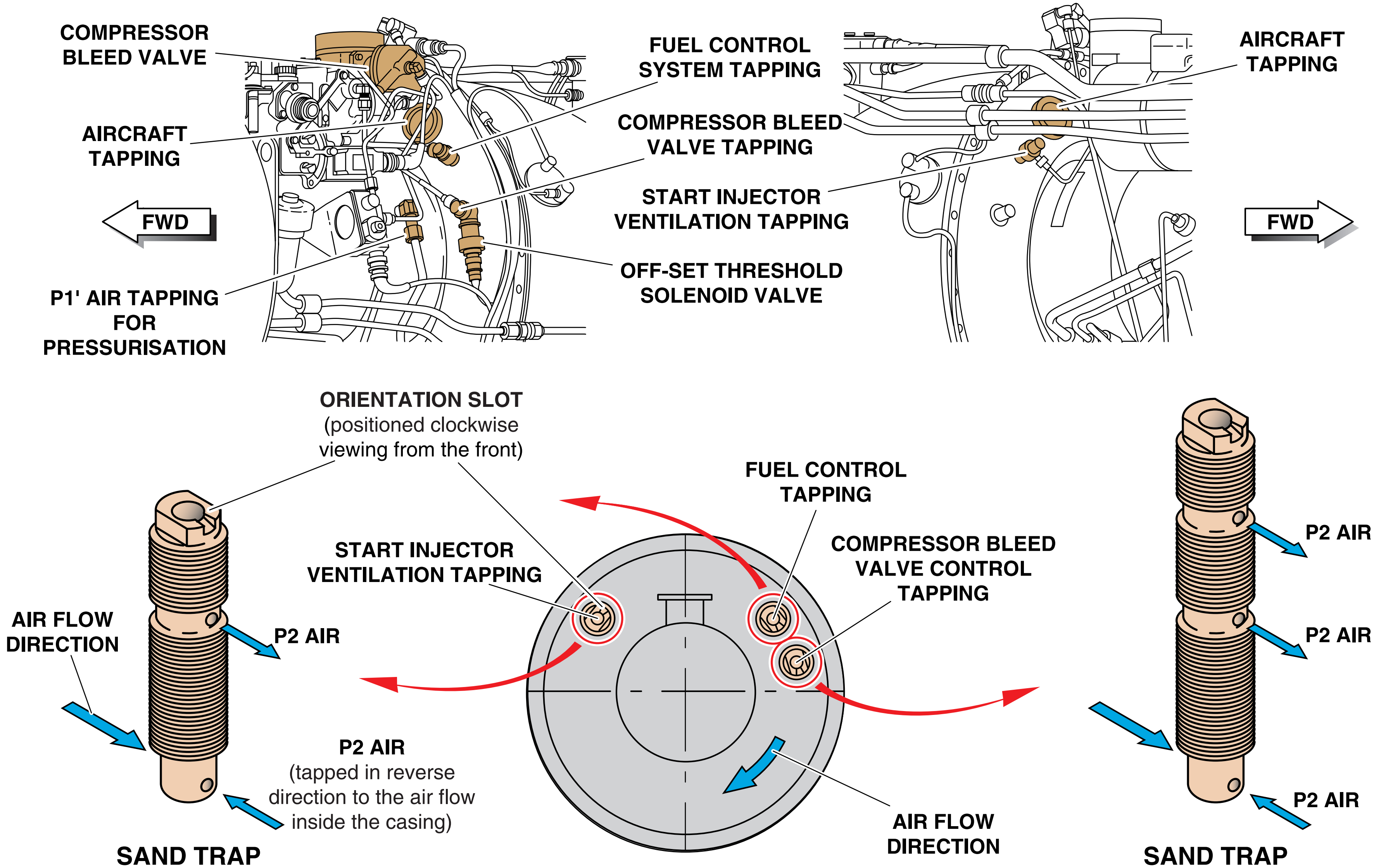
Fuel Control supply

(P2 air for the acceleration controller)

- P2 air tapping and pipe.

Aircraft services

- Two air tappings for the aircraft manufacturer's use.



AIR TAPPING UNIONS

AIR PIPES

This part considers the external air pipes of the air system.

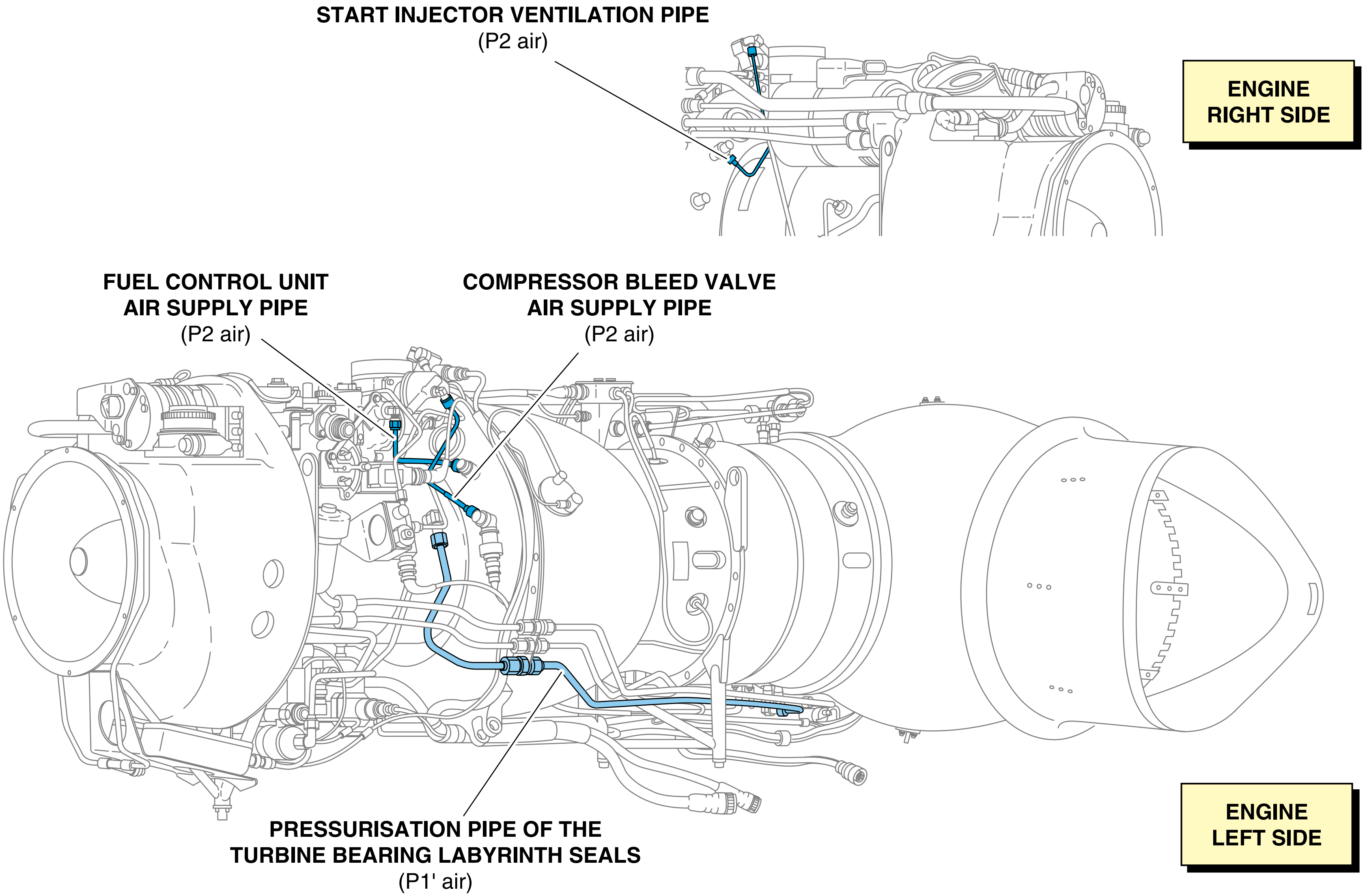
Function

The air pipes ensure the air supply from/to the various system components

Description

The air system uses the following external pipes :

- P2 air pipe to supply the compressor bleed valve
- P2 air pipe for the ventilation of the start injectors
- P2 air pipe to supply the Fuel Control Unit
- P1' air pipe for the pressurisation of the turbine bearing labyrinth seals.


START INJECTOR VENTILATION PIPE
(P2 air)
ENGINE RIGHT SIDE
FUEL CONTROL UNIT AIR SUPPLY PIPE
(P2 air)
COMPRESSOR BLEED VALVE AIR SUPPLY PIPE
(P2 air)
PRESSURISATION PIPE OF THE TURBINE BEARING LABYRINTH SEALS
(P1' air)
ENGINE LEFT SIDE

AIR PIPES

6 - FUEL SYSTEM

FUEL SYSTEM - GENERAL

Function

The fuel system ensures fuel supply, injection, control and metering.

Position

All the system components are mounted on the engine except the aircraft system components and the DECU.

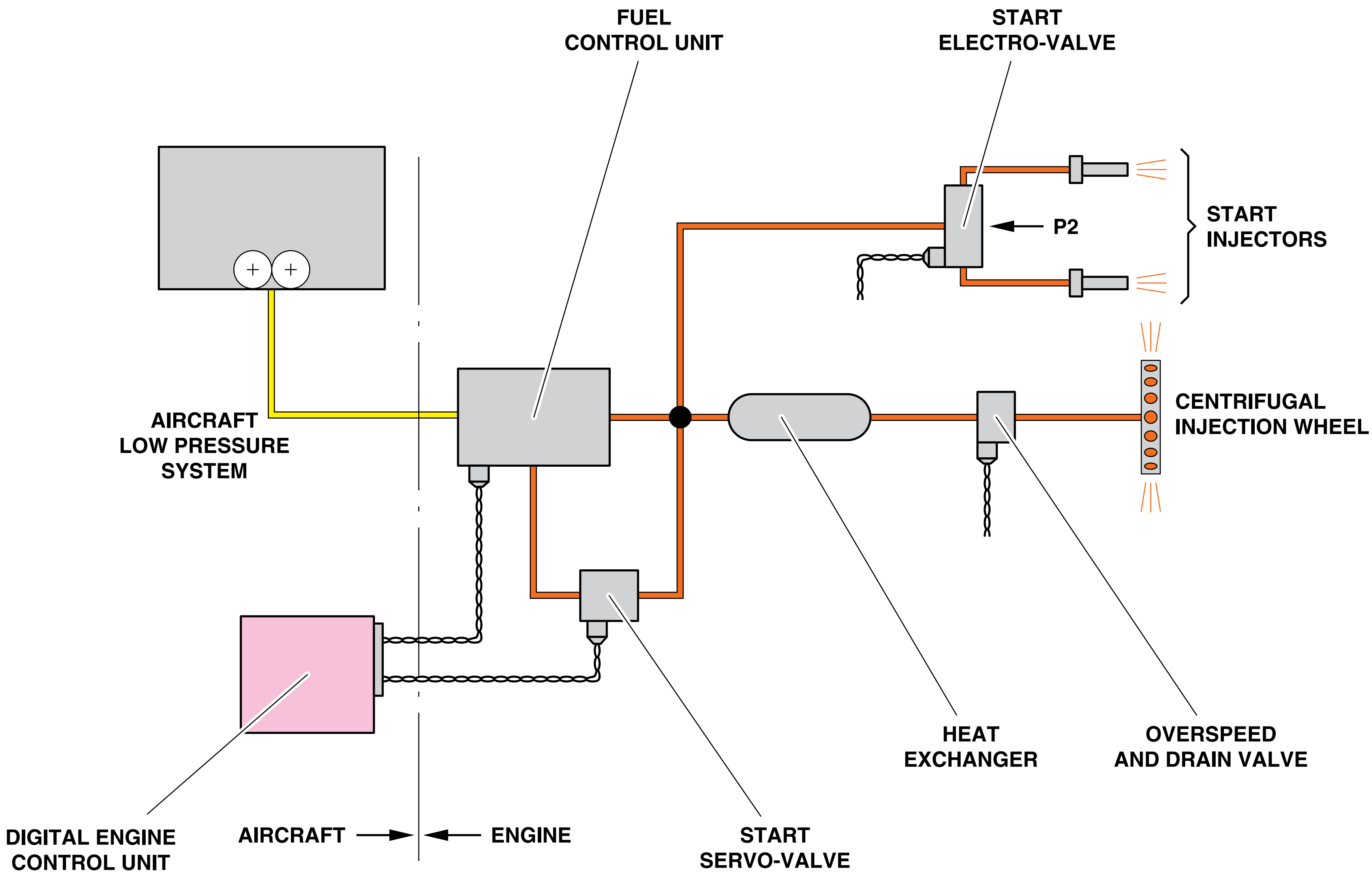
Main characteristics

- Supply from the aircraft system and the engine pump
- Centrifugal main injection and start injection by injectors
- Manual control of the emergency valve
- Fuel control : Digital Engine Control Unit and hydromechanical Fuel Control Unit.

Main components

- Fuel Control Unit
  - Fuel pump
  - Filter
  - Metering unit
- Start servo-valve
- Start electro-valve
- Overspeed and drain valve
- Heat exchanger
- Start injectors
- Centrifugal injection wheel
- Digital Engine Control Unit.

Note *: The control part is treated in the chapter "CONTROL SYSTEM". The heat exchanger is treated in the chapter "OIL SYSTEM".*



FUEL SYSTEM - GENERAL

FUEL SYSTEM - DESCRIPTION

This part shows the main components of the fuel system.

Fuel Control Unit

Pump

Spur gear type pump which provides the pressure supply. It is fitted with a pressure relief valve.

Filter

Filtering at the pump outlet. The filter includes a pre-blockage indicator and a by-pass valve.

Valves

- Main valve
- Manual valve (or emergency valve).

Metering unit

- Automatic control (pressure-reducing valve, speed control units, acceleration controller, metering valve, constant ΔP valve)
- Manual control (valves and cam).

Start servo-valve

Fuel metering required to start the engine.

Start injector electro-valve

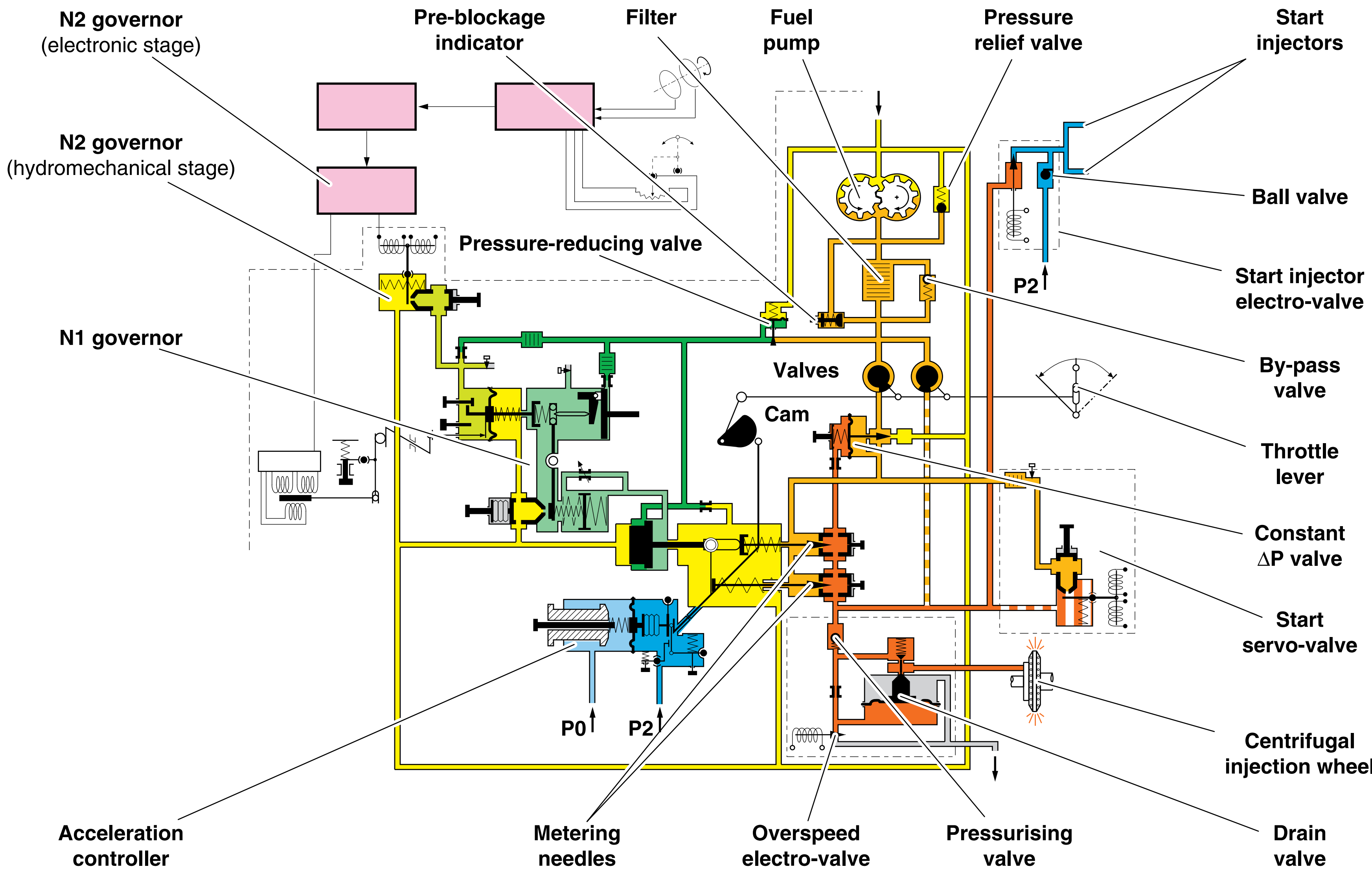
Electro-valve and ventilation valve.

Overspeed and drain valve

Pressurising valve, drain valve, and overspeed drain valve.

Fuel injection system

- Start injectors (2)
- Main injection system (centrifugal wheel).



FUEL SYSTEM - DESCRIPTION

FUEL SYSTEM - OPERATION

This part deals with the following operating phases : pre-start, starting, normal operation, manual control and stop.

Pre-start

There is no pressure in the system, and no electrical supply to the accessories.

- The throttle lever is in the stop position (the two valves are closed)
- The pump is not operating (its by-pass valve is closed)
- The overspeed and drain valve is in the drain position.

Starting

When start is selected (throttle lever to the start position and push-button activated) :

- The start injector electro-valve is energised
- The starter drives the gas generator
- The ignition system operates (sparks at the igniter plugs).

The pump pressure increases and the fuel flows to the start injectors. As soon as the pressure is sufficient to open the pressurising valve, fuel flows to the injection wheel through the overspeed and drain valve.

The ignition occurs (temperature and speed of gases increase) : at self-sustaining speed, the starter and the ignition are de-energised and P2 air ventilates the start injectors.

The engine is stabilised at idle speed, controlled by the starting device (servo-valve which receives a DECU signal in order to obtain a rapid acceleration without surge or overheat).

Manual control

The servo-valve can be manually or automatically isolated, to enable the pilot to carry out a manual engine start by means of the throttle lever.

Acceleration to nominal speed is achieved by moving the throttle lever to the flight position.

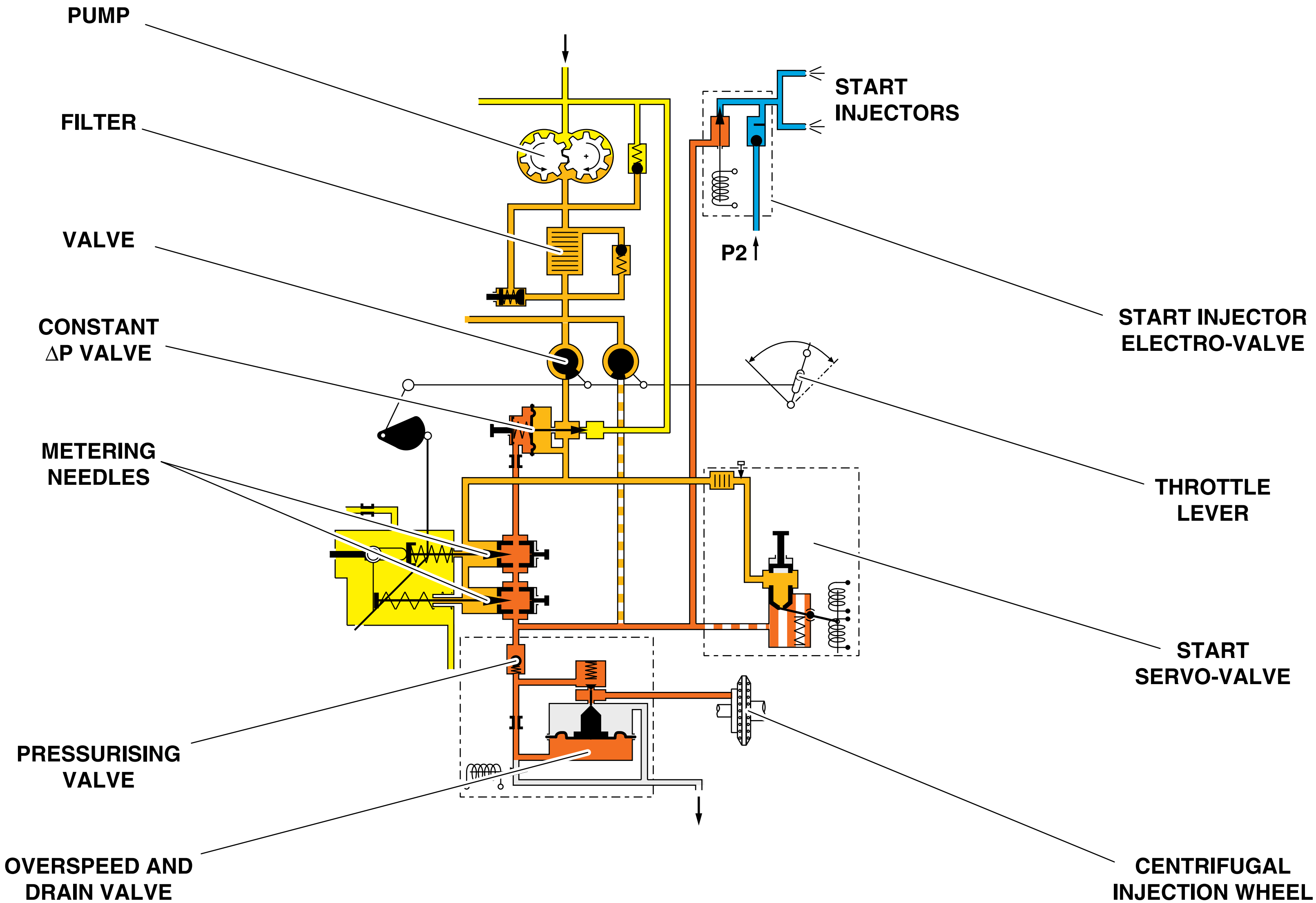
"Normal operation"

The pump supplies fuel under pressure, at a flow which is always higher than the engine requirements. The fuel is metered by the control system (refer to the following chapter) ; the excess fuel is returned to the pump inlet.

Engine shut-down

The pilot brings the throttle lever back to the "stop", fully closed position. The fuel is shut-off, and the engine stops.

During the shut-down phase, the drain valve opens to drain the fuel which remains in the injection wheel.



FUEL SYSTEM - OPERATION

FUEL CONTROL UNIT - GENERAL

Function

The FCU ensures the supply and control of the fuel.

Position

- On the left front face of the accessory gearbox.

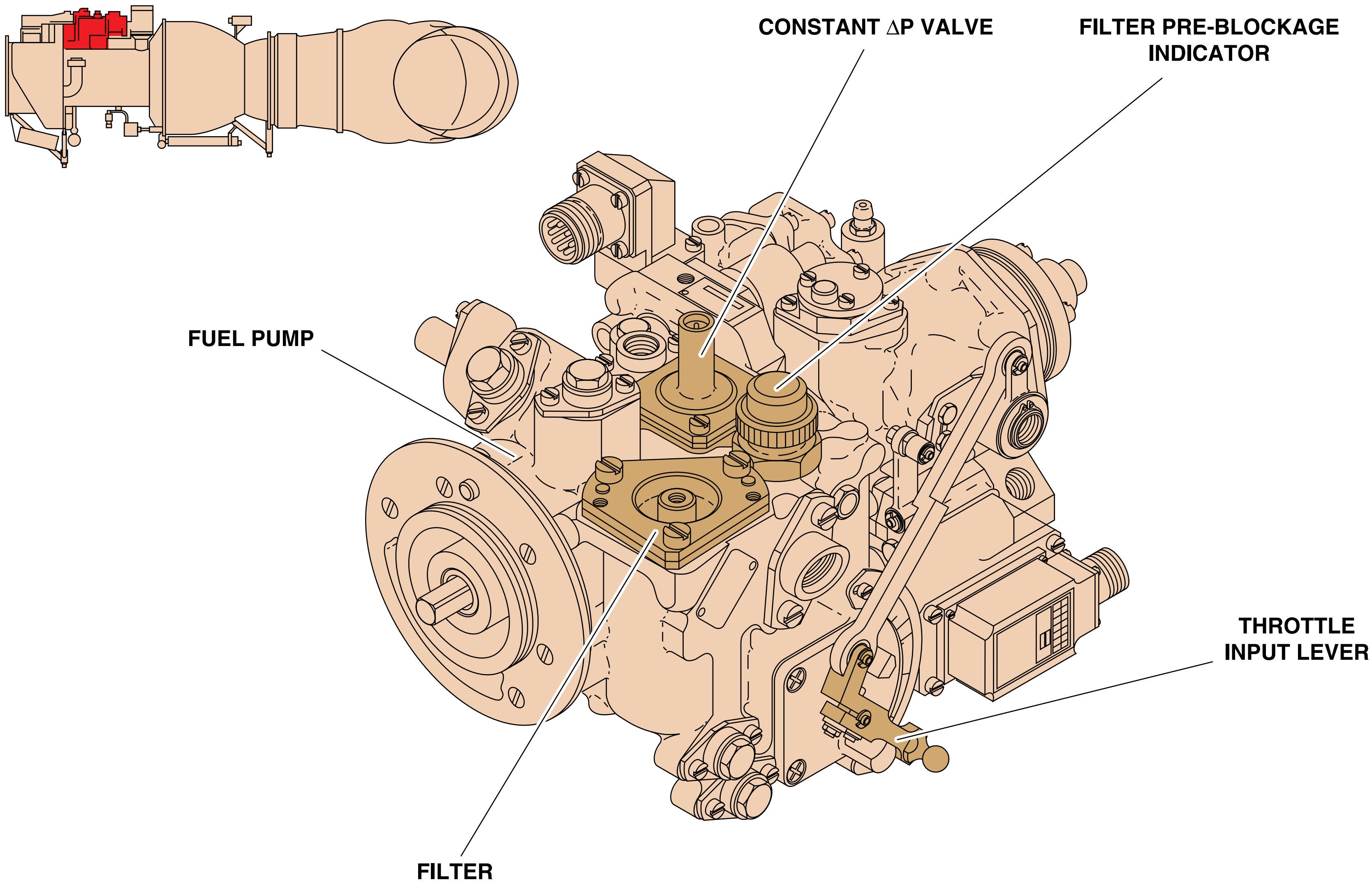
Main characteristics

- Type : hydro-mechanical
- Mounting : clamping ring
- Replaceable components :
  - Filter
  - Pre-blockage indicator.

Main components

- Fuel pump
- Filter and pre-blockage indicator
- Valves (actuated by the throttle lever)
- Constant ΔP valve
- Control devices (N2 governor, N1 governor, acceleration controller, metering device…).

Note *: This part gives a simple presentation of the Fuel Control Unit. It is treated in more detail in the "CONTROL SYSTEM" chapter.*



FUEL CONTROL UNIT - GENERAL

START SERVO-VALVE - GENERAL

Function

The start servo-valve meters the fuel required to start the engine. It is controlled by the DECU according to certain signals, and to specific "fuel control" laws.

Position

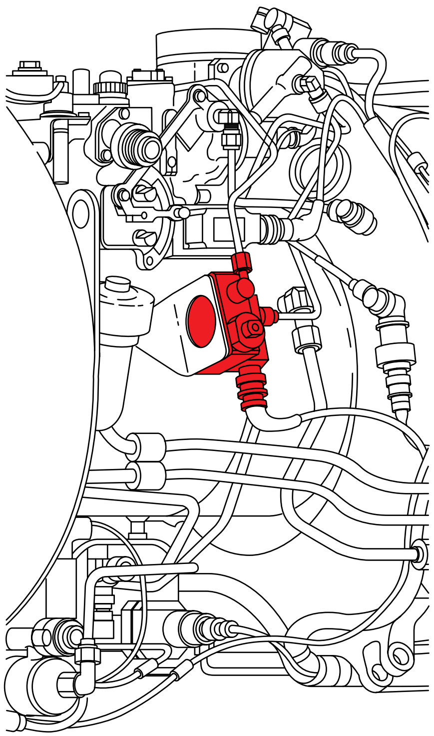
- In the system : in by-pass of the metering needles
- On the engine : on the left side of the compressor counter casing.

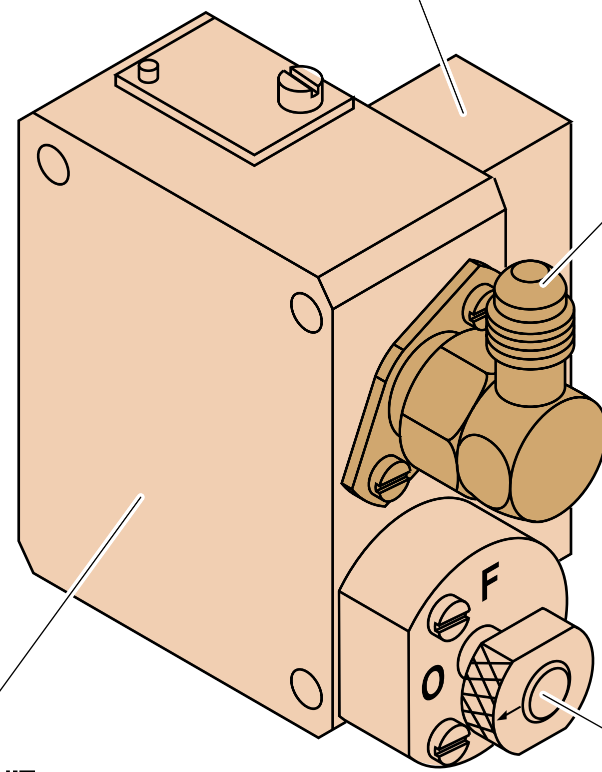
Main characteristics

- Type : servo-valve with two windings
- Max Q : 120 l/h (264 lbs/hr) for 30 mA
- Min Q : ≈ 0 l/h (0 lbs/hr) for 0 mA
- Basic Q : 25 l/h (55 lbs/hr) for 2 mA.

Main components

- Electrical servo-valve (with the electrical connector for the connection to the DECU)
- Metering unit with fuel inlet and outlet unions
- Manual shut-off valve.





Type
Servo-valve with 2 windings

Max Q
120 l/h for 30 mA (264 lbs/hr)

Min Q
0 l/h for 0 mA (0 lbs/hr)

Basic Q
25 l/h for 2 mA (55 lbs/hr)

START SERVO-VALVE - GENERAL

START SERVO-VALVE - DESCRIPTION

The assembly includes an electrical part and a mechanical part.

Electrical part

The electrical part includes a servo-valve with two windings. It receives from the DECU a current of variable intensity (0 to 30 mA).

The magnetic forces cause the flap valve to move.

Mechanical part

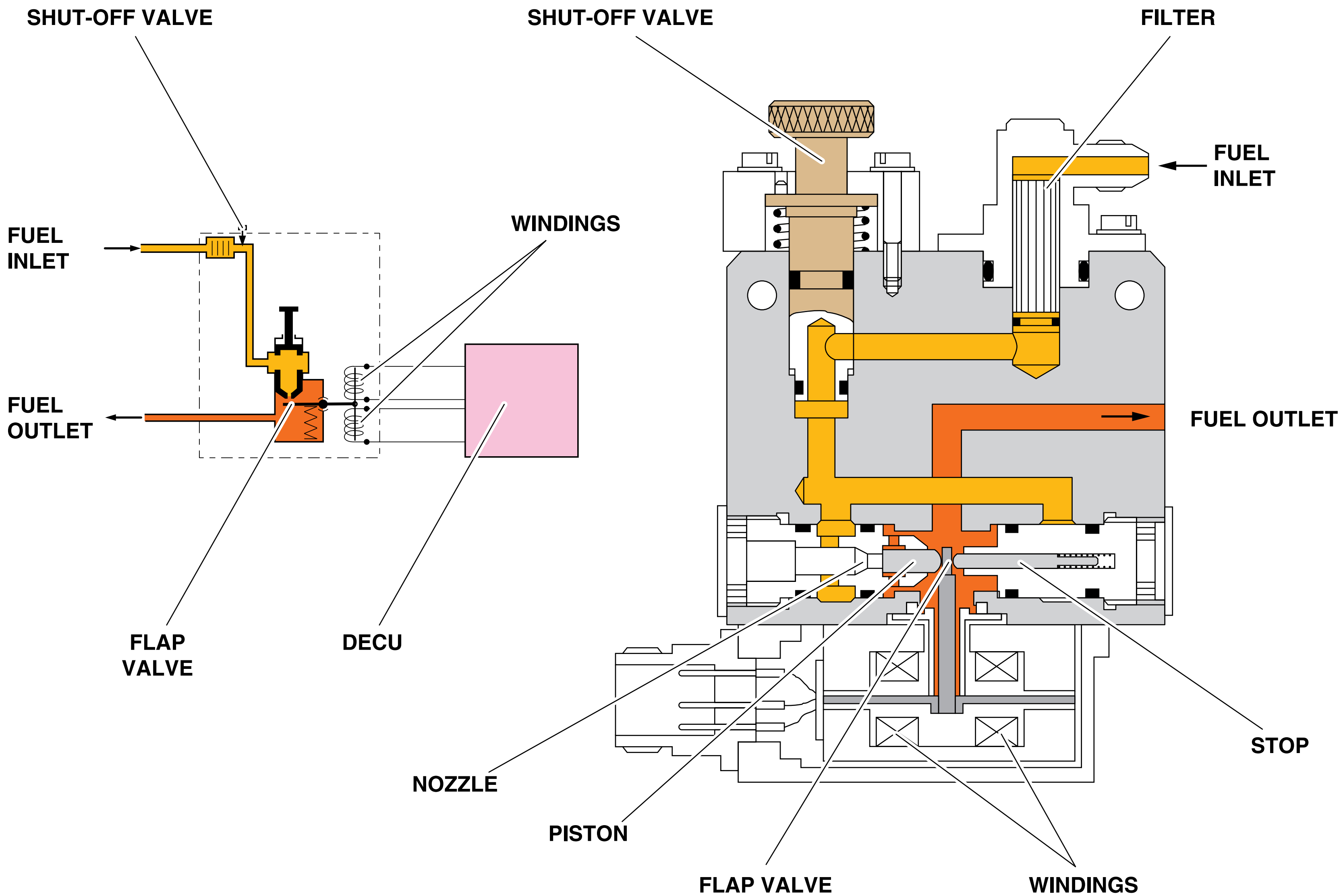
The mechanical part comprises mainly the fuel flow metering unit.

This involves a flap valve which moves a piston in a potentiometric jet. The movement of the flap valve is controlled by the electrical part. The maximum travel of the valve is limited by a spring loaded mechanical stop.

There is a filter at the fuel inlet.

A manually operated cock is fitted at the fuel inlet to allow the servo-valve to be isolated for manual starting.

It is provided with a knurled knob which must be pushed and turned to operate.



START SERVO-VALVE - DESCRIPTION

START SERVO-VALVE - OPERATION

The servo-valve (connected to the DECU) meters the fuel flow necessary to obtain a rapid start without overheat in all conditions.

The operation is considered during pre-start, starting, idle speed, acceleration from idle to flight idle and manual emergency starting.

Engine stopped

The servo-valve is receiving 0 mA and is therefore closed. The leak flow is negligible.

Starting

When start is selected, the servo-valve receives a basic current of 2 mA which determines a fuel flow of about 25 l/h (55 lbs/hr). This flow in addition to the flow determined by the main valve (leak), constitutes the basic flow necessary for ignition in the combustion chamber.

During starting, the current progressively increases (from 2 to 30 mA) and induces the flap valve displacement and the progressive increase of flow. The current is supplied by the DECU according to a N1 speed law corrected by a t4 temperature law (refer to chapter "CONTROL SYSTEM" for more details).

Idle speed

At the end of starting, the flow is metered so as to stabilise the speed at a value of about 65 % N1. The idle law (elaborated by the DECU) is of proportional type ; that is to say with a static droop between 65 % of N1 (30 mA) and 71 % of N1 (0 mA).

Acceleration from idle to flight idle

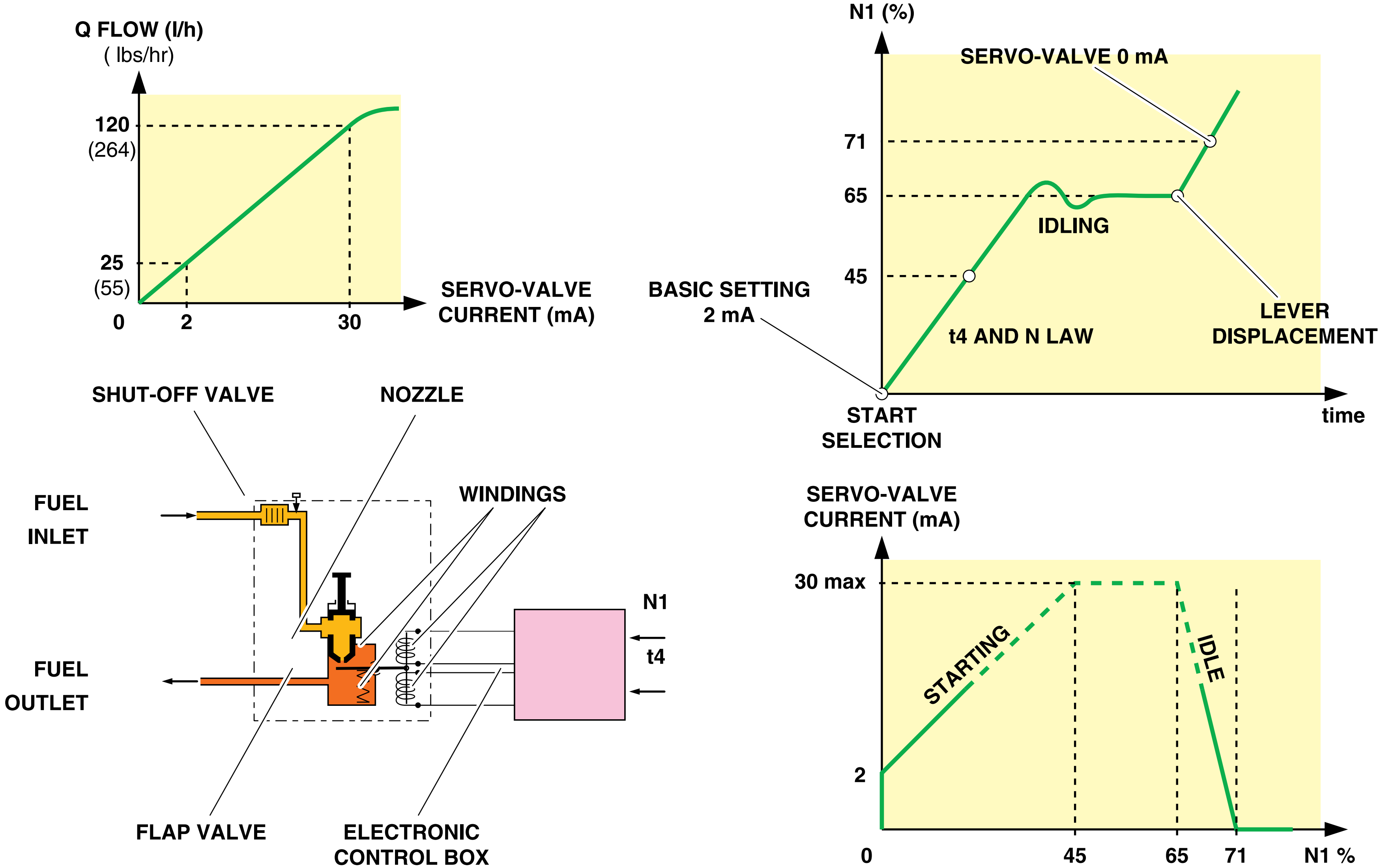
This acceleration is selected by moving the throttle lever. The flow is then determined by the FCU. But, as the N1 speed passes 71 %, the intensity is fixed at 0 mA, which corresponds to the servo-valve closing ; this is to prevent interference between the idle control and the min N1 control. The acceleration is considered complete when the lever is fully open in the flight position.

Manual emergency starting

In case of failure of the automatic metering system, the servo-valve can be isolated by actuating the shut-off valve.

Furthermore, in case of major failure, the start servo-valve is automatically closed (I = 0 mA).

The start fuel flow is then controlled by movement of the throttle lever.



START SERVO-VALVE - OPERATION

START ELECTRO-VALVE - GENERAL

Function

The start electro-valve ensures the fuel supply of the two start injectors during starting and their ventilation during normal engine operation.

Position

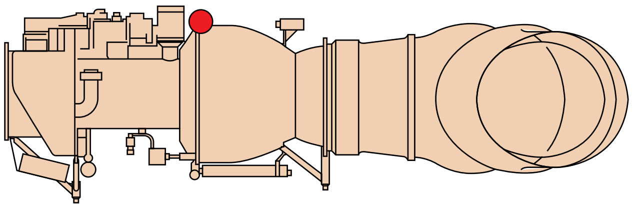
- In the fuel system : at the metering unit outlet
- On the engine : at the upper part, at the junction of the counter casing and the turbine casing.

Main characteristics

- Type : electro-valve
- Voltage : 28 VDC
- Energised : open
- Ventilation valve : ball type.

Main components

- Electro-magnet
- Valve
- Ventilation valve.

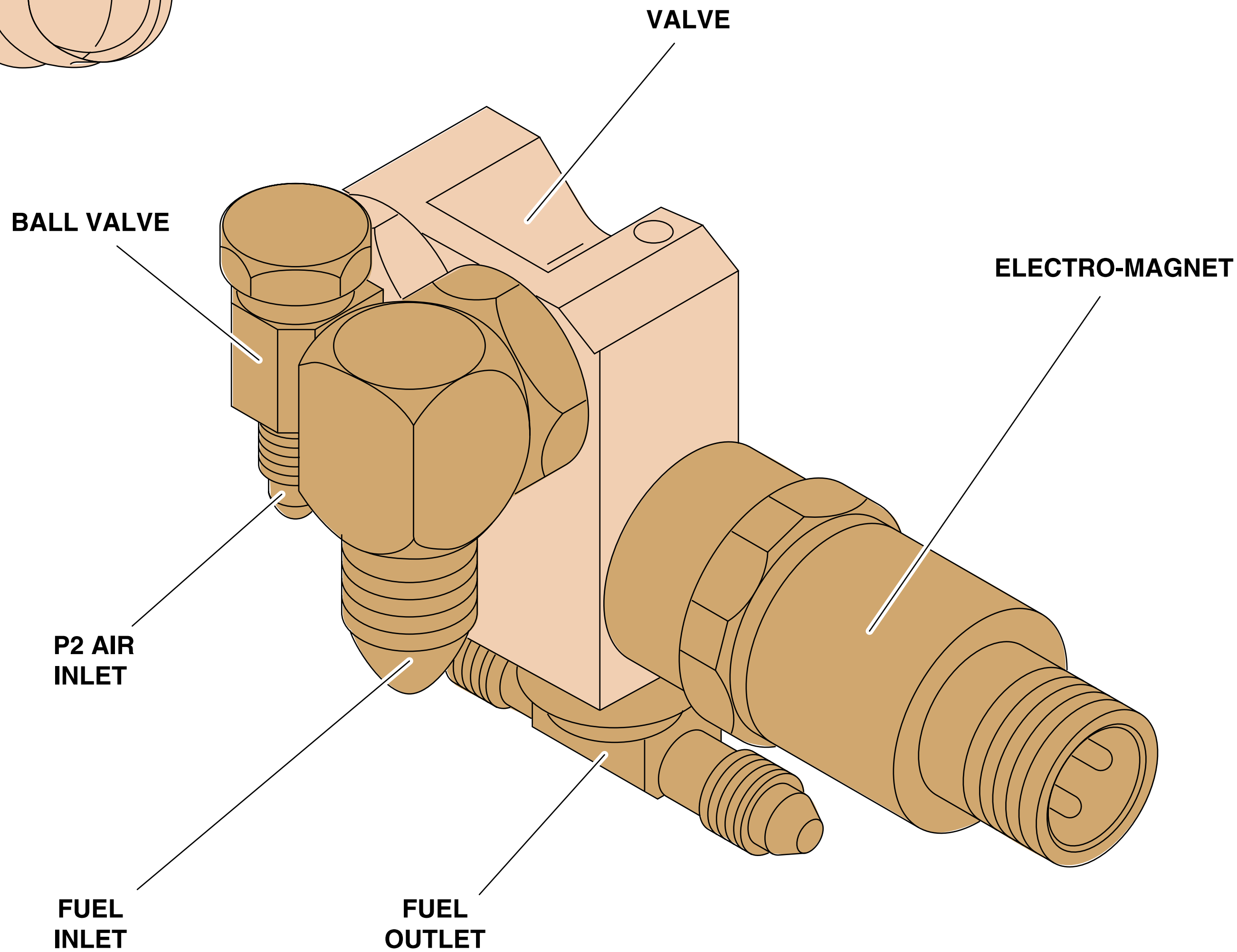


Type
Electro-valve

Voltage
28 VDC

Energised
Open

Ventilation valve
Ball type



START ELECTRO-VALVE - GENERAL

For training purposes only

START ELECTRO-VALVE - DESCRIPTION - OPERATION

Description

The electro-valve is secured by means of two screws at the upper front part of the turbine casing.

The assembly includes :

- An electro-magnet supplied with direct current
- A valve body which includes the valve and its release spring
- Unions screwed into the valve body (fuel inlet union, fuel outlet union to the injectors and P2 air inlet union).

The P2 air inlet union includes the injector ventilation valve (ball, seals and plug for ball access).

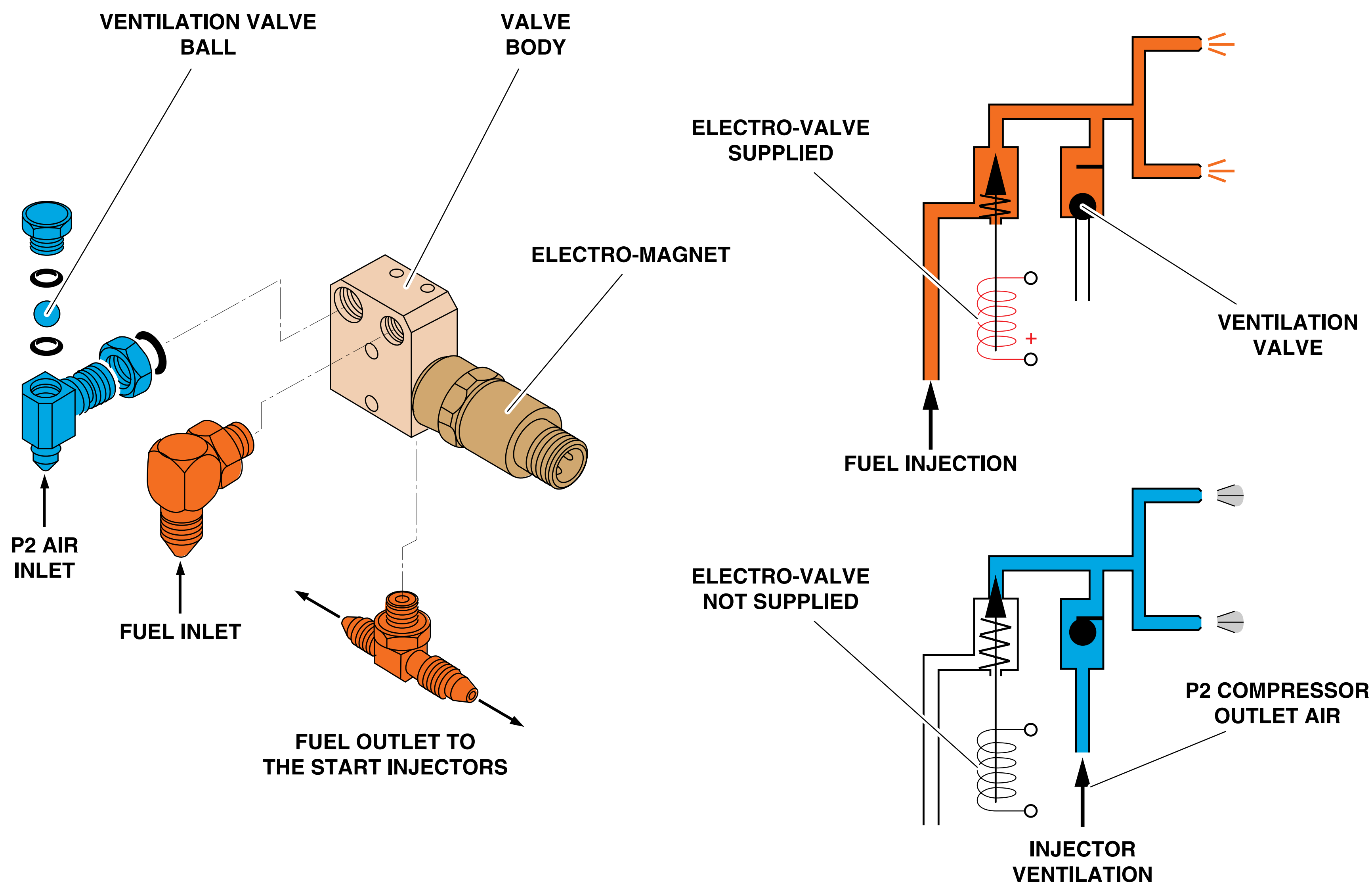
Operation

Fuel injection

When start is selected, the electro-valve is supplied and the fuel provided by the pump is directed to the two injectors which spray the fuel into the combustion chamber. The fuel is then ignited by the sparks produced by the igniter plugs.

Injector ventilation

When self-sustaining speed is reached, the electrical supply of the start electro-valve is cut-off and the valve closes. The P2 air pressure from the compressor (which has built up in the meantime) lifts the ball and ventilates the injectors. This ventilation operates continuously during engine operation to prevent blockage of the injectors by carbonisation.



START ELECTRO-VALVE - DESCRIPTION - OPERATION

PRESSURISING VALVE

Function

During starting, the pressurising valve ensures priority of fuel flow to the start injectors.

Position

- In the system : upstream of the overspeed and drain valve
- On the engine : at the right lower part of the engine.

Main characteristics

- Type : spring valve
- Setting : 220 kPa (32 PSI).

Main components

- Fuel inlet union
- Flat seal
- Valve body
- Fuel outlet union.

Operation

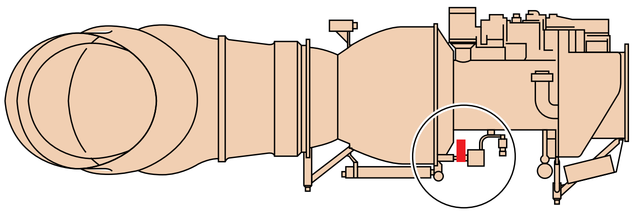
The pressurising valve has two stable positions : "open" position and "closed "position".

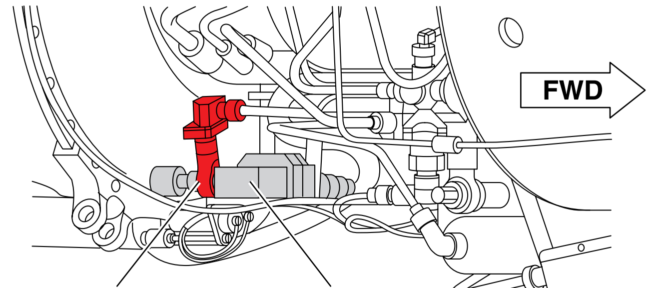
"Open" position

When the fuel pressure becomes higher than the pressurising valve setting, the pressurising valve opens and supplies fuel to the centrifugal injection wheel.

"Closed" position

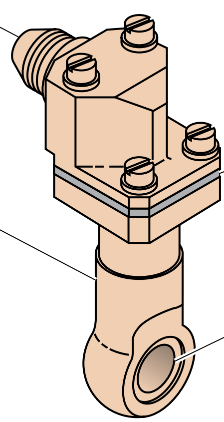
During starting, as the fuel pressure is lower than the pressurising valve setting, the pressurising valve is closed. It prevents fuel supply to the centrifugal injection wheel and ensures priority of fuel flow to the start injectors.

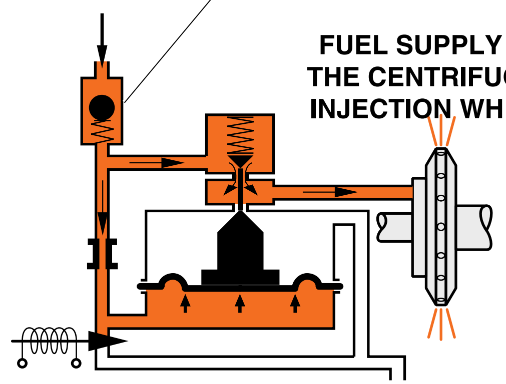




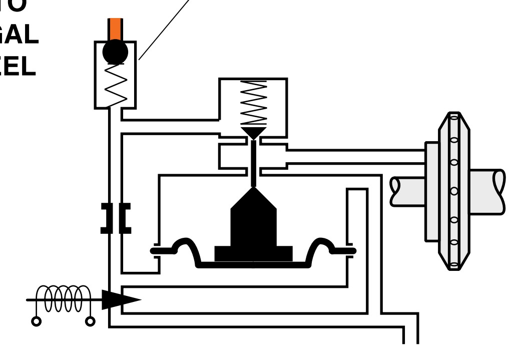
Type
Spring valve

Setting
220 kPa (32 PSI)





"OPEN" POSITION
(pressure > 220 kPa / 32PSI)



"CLOSED" POSITION
(pressure < 220 kPa / 32PSI)

PRESSURISING VALVE

OVERSPEED AND DRAIN VALVE - GENERAL

Function

The valve controls the supply to the injection wheel :

- Fuel supply during starting and normal operation
- Fuel shut-off during engine shut-down.

The assembly includes :

- A check valve which ensures priority supply to the start injectors during starting
- An overspeed electro-valve supplied by the DECU in case of power turbine overspeed.

Position

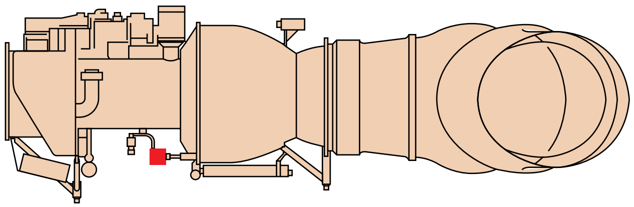
- In the system : between the Fuel Control Unit and the engine fuel inlet
- On the engine : at the lower right part of the engine.

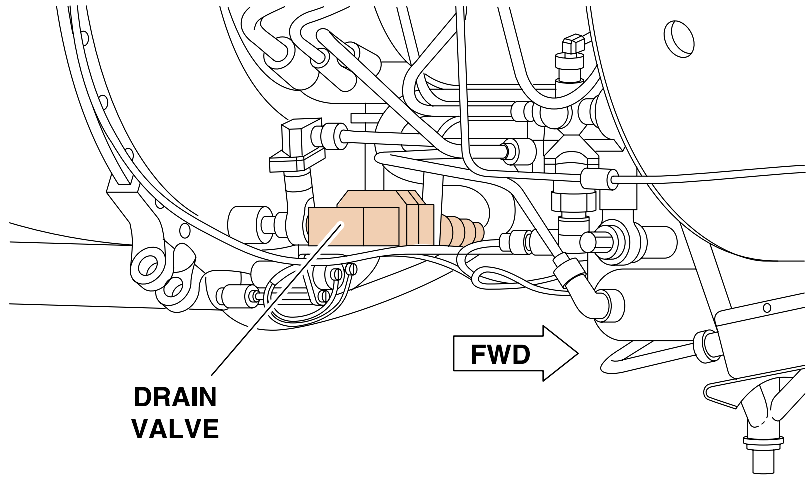
Main characteristics

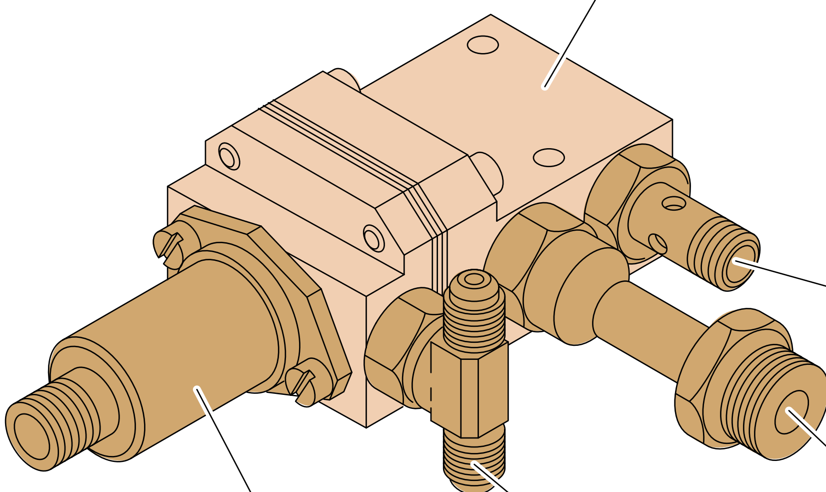
- Dual drain valve controlled by a diaphragm
- Overspeed electro-valve supplied with direct current by the DECU.

Main components

- Drain valve
  - Diaphragm
  - Dual valve
  - Unions
- Overspeed electro-valve
  - Electro-valve
  - Valve).







OVERSPEED AND DRAIN VALVE - GENERAL

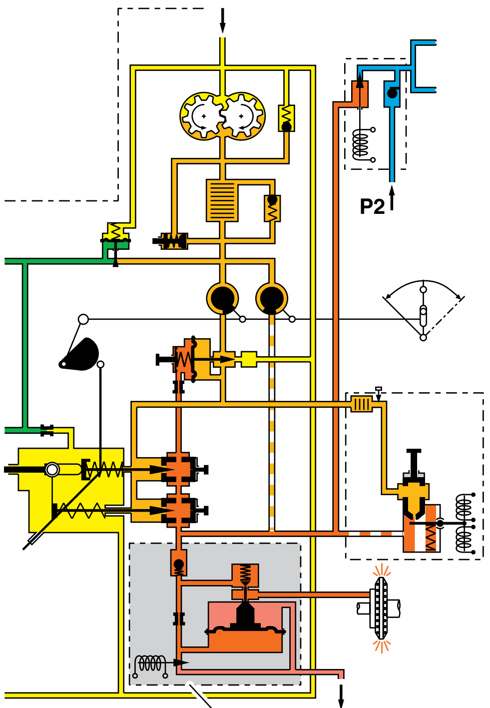
OVERSPEED AND DRAIN VALVE - DESCRIPTION

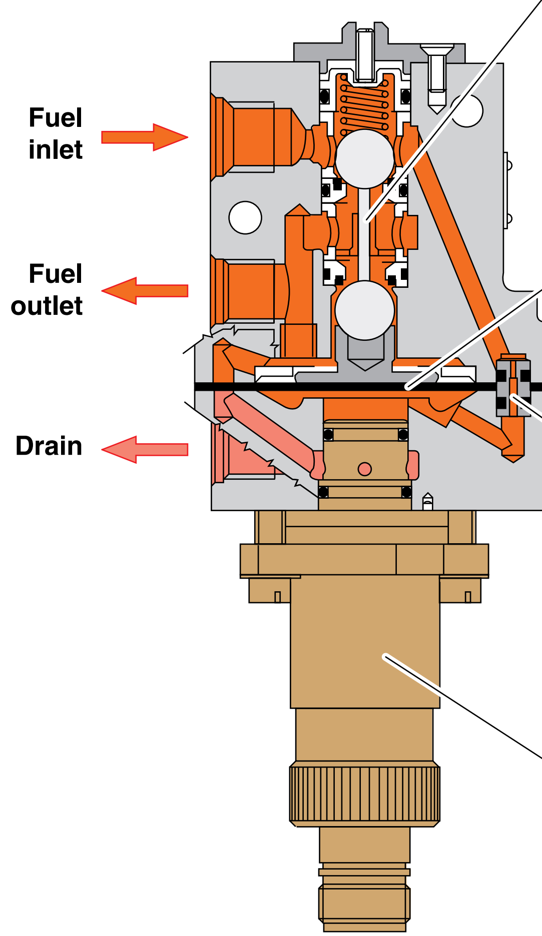
Dual valve

The dual valve is actuated by a diaphragm subjected to the fuel pressure. It includes a valve which opens or closes the fuel passage to the injection wheel, and another valve which drains off the unburnt fuel which remains in the injection line.

Power turbine overspeed electro-valve

When the valve is energised, it drains off the fuel under the diaphragm and thus causes the dual valve to close ; the engine shuts down automatically.





OVERSPEED AND DRAIN VALVE - DESCRIPTION

OVERSPEED AND DRAIN VALVE - OPERATION

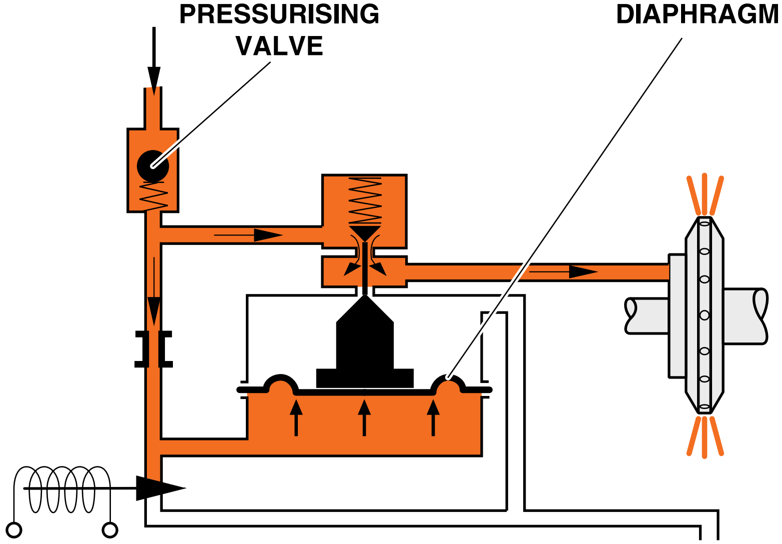
We can consider two main operating positions : engine operation (fuel supply) and engine shut-down (fuel shut-off and injection wheel drain).

Engine running position

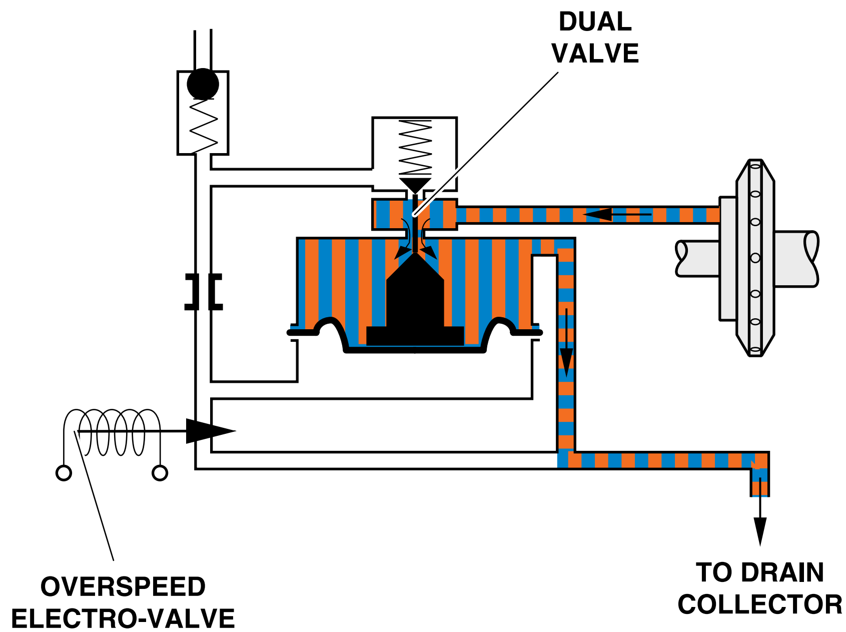
As soon as the fuel pressure reaches the set value of the pressurising valve (≈ 220 kPa / 32 PSI ; which is quickly reached), the pressure is admitted under the diaphragm which causes the drain valve to close and the fuel supply valve to open. The fuel flows to the injection wheel and is sprayed into the combustion chamber.

Shut-down position

The normal shut-down (main valve closed by the throttle lever) causes the pressure to decrease. The pressurising valve closes, the pressure decreases under the diaphragm which causes the supply valve to close and the drain valve to open (this drains the fuel to the drain collector, in order to prevent blockage of the injection wheel by carbonisation of unburnt fuel). Engine shut-down can also be selected by the electro-valve which, when it opens, causes the pressure to decrease under the diaphragm and thus causes the system to change to the shut-down position (shut-down in case of power turbine overspeed, controlled by the DECU).



ENGINE RUNNING POSITION



SHUT-DOWN POSITION

OVERSPEED AND DRAIN VALVE - OPERATION

MAIN INJECTION SYSTEM - GENERAL

Function

The system sprays fuel into the combustion chamber, in order to obtain a stable and efficient fuel combustion process.

Position

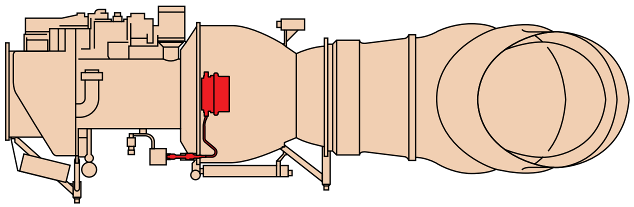
- Internal part of the combustion chamber, on the turbine-compressor shaft.

Main characteristics

- Type : centrifugal injection
- Wheel with calibrated orifices
- Radial fuel supply.

Main components

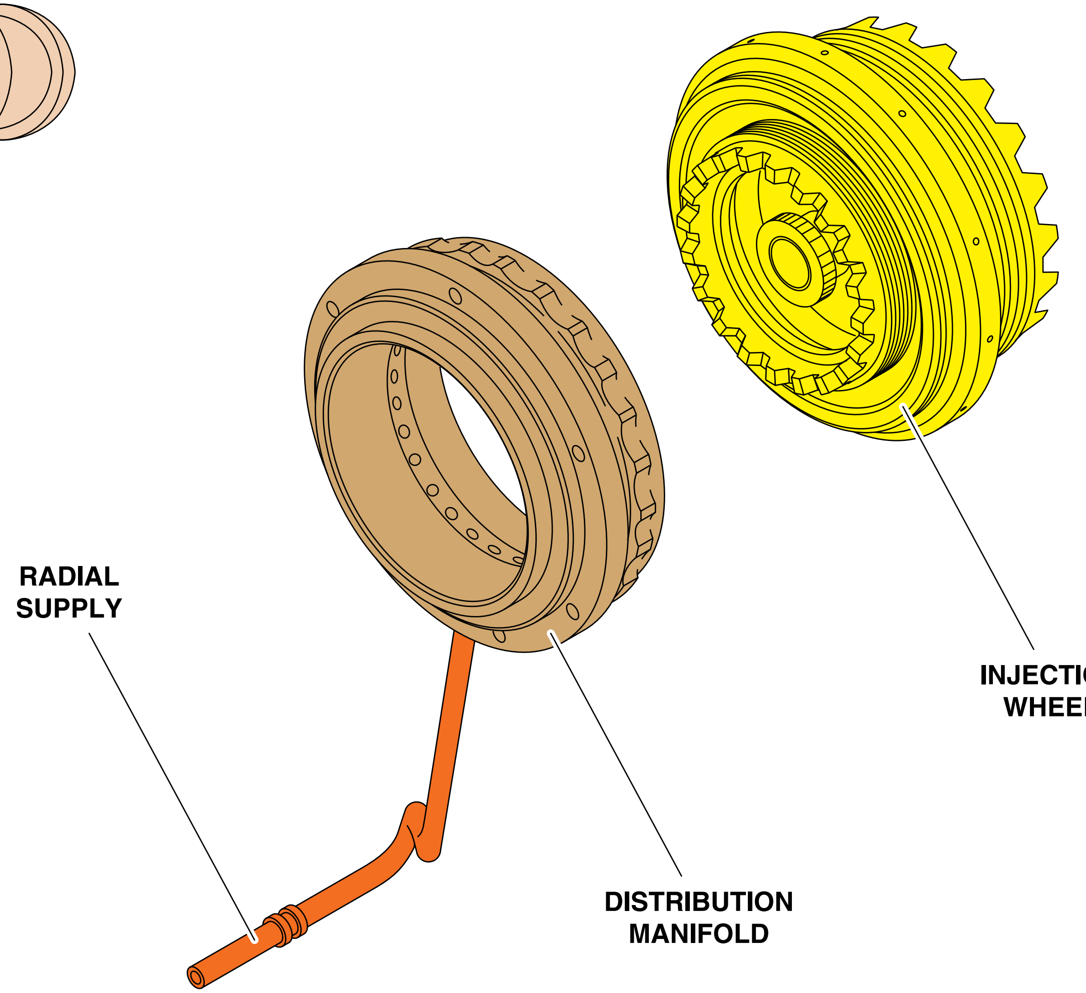
- Fuel inlet union
- Supply pipe
- Centrifugal injection assembly (distribution manifold and wheel).



Type
Centrifugal injection

Wheel
With calibrated orifices

Supply
Radial fuel supply



MAIN INJECTION SYSTEM - GENERAL

MAIN INJECTION SYSTEM - DESCRIPTION - OPERATION

Description

The injection system includes the fuel inlet union ; the supply pipe and the centrifugal injection assembly.

Fuel inlet union

Located at the compressor casing front part. It is fitted with two plugs to check for leaks.

Internal supply pipe

The pipe connects the fuel inlet union to the injection system. It is fitted between the combustion chamber front swirl plate and the diffuser holder plate.

Centrifugal injection assembly

This assembly consists of a distribution manifold and a rotating wheel. The distribution manifold fitted into the diffuser holder plate is drilled with axial jets which deliver the fuel. The wheel, mounted by curvic-couplings between the compressor shaft and the turbine shaft, is drilled with calibrated orifices which form the fuel spraying jets. Sealing between the distribution manifold and the wheel is achieved by pressurised labyrinth seals.

Operation

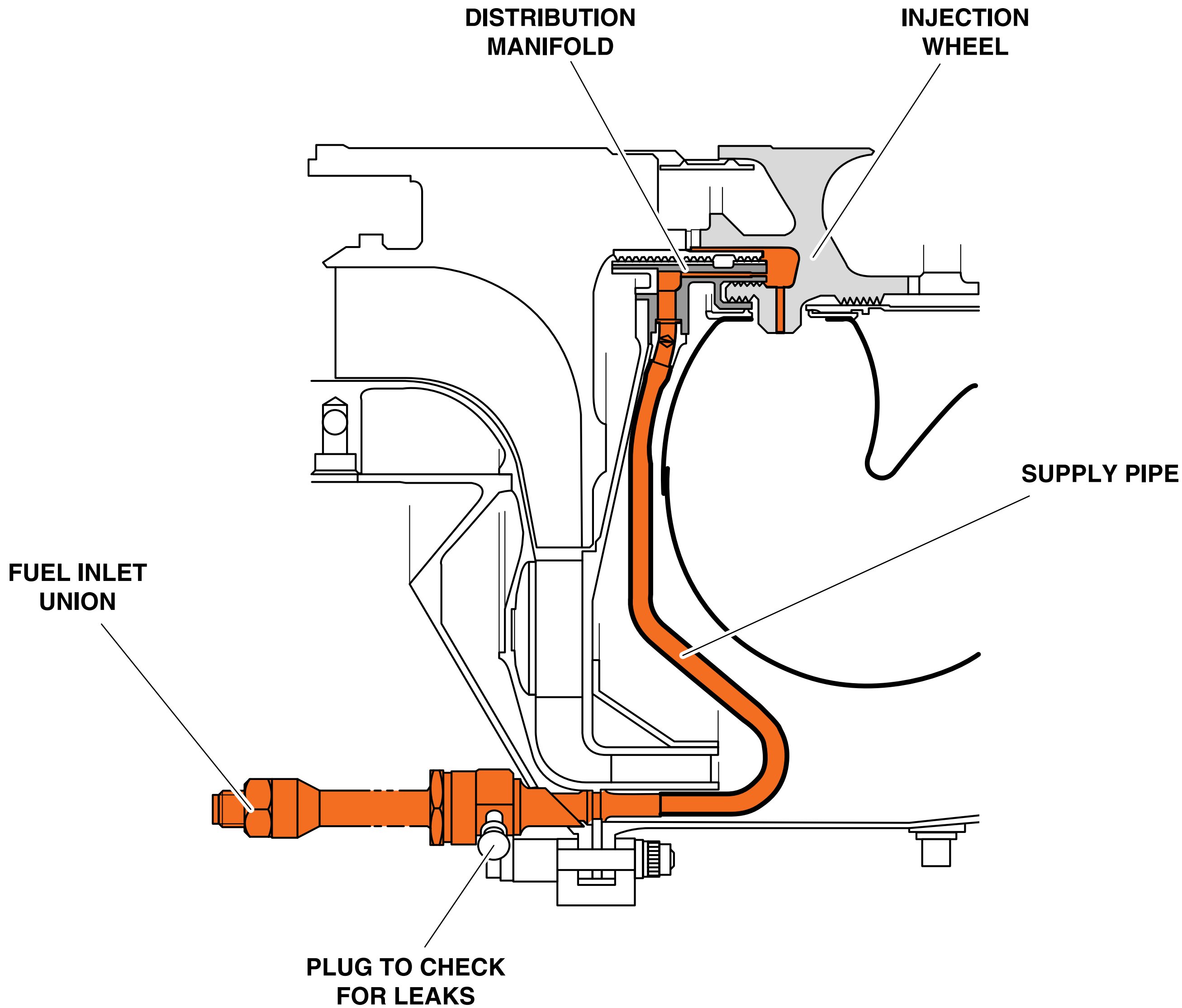
The fuel is delivered to the distribution manifold through an internal supply pipe.

The fuel then passes to the centrifugal wheel chamber.

As the wheel is rotating at high speed (N1 speed) the fuel is centrifuged out through the calibrated orifices and is sprayed into the combustion chamber, between the two swirl plates.

It should be noted that the injection pressure is supplied by the centrifugal force and therefore the fuel system does not require very high pressure.

The fuel sealing is ensured by pressurised labyrinth seals. There is a small air leak into the fuel chamber. During engine shut-down, the fuel which remains in the wheel is drained through the valve assembly.



MAIN INJECTION SYSTEM - DESCRIPTION - OPERATION

START INJECTOR - GENERAL

Function

The injectors spray the fuel into the combustion chamber during engine starting.

Position

- At the upper part of the turbine casing (one at 2 o'clock, the other at 10 o'clock)
- They penetrate into the mixer unit.

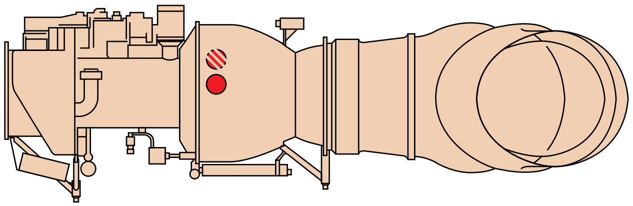
Main characteristics

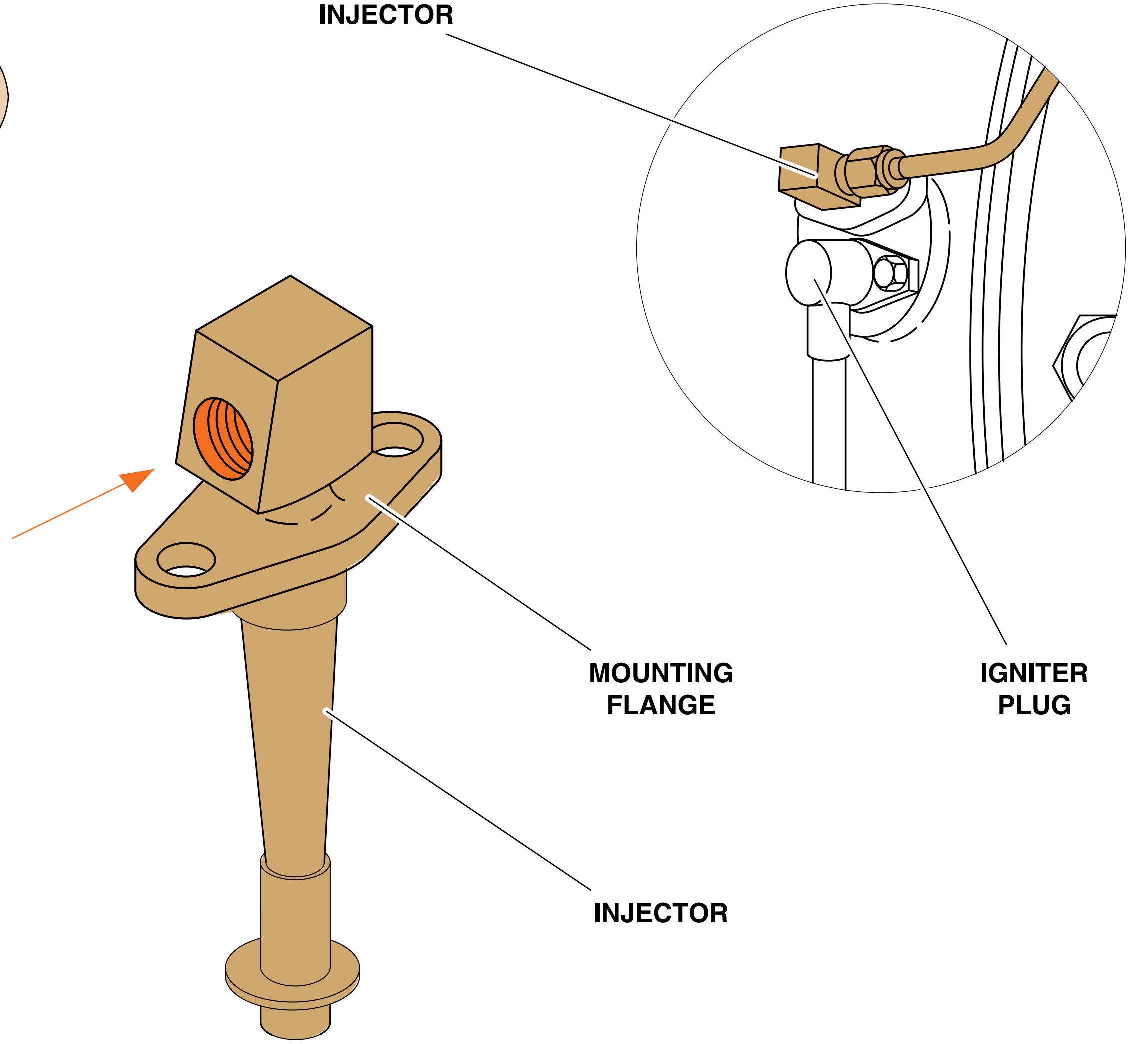
- Type : simple injector
- Ventilation : by circulation of air.

Note *: Each injector is mounted beside an igniter plug.*

Main components

- Mounting flange
- Fuel inlet union
- Injector.





Type
Simple injector

Quantity
2

Ventilation
By circulation of air

START INJECTOR - GENERAL

START INJECTORS - DESCRIPTION - OPERATION

Description

The injectors are mounted on the upper part of the turbine casing. They penetrate into the combustion chamber through holes in the mixer unit.

They are secured on a boss by means of bolts. Seals and spacers prevent leaks and adjust the depth of penetration into the combustion chamber.

Injector components

- Injector body
- Fuel inlet (threaded to receive a union)
- Mounting flange (securing by 2 bolts)
- Jet.

Operation

Starting

During starting the injectors are supplied with fuel.

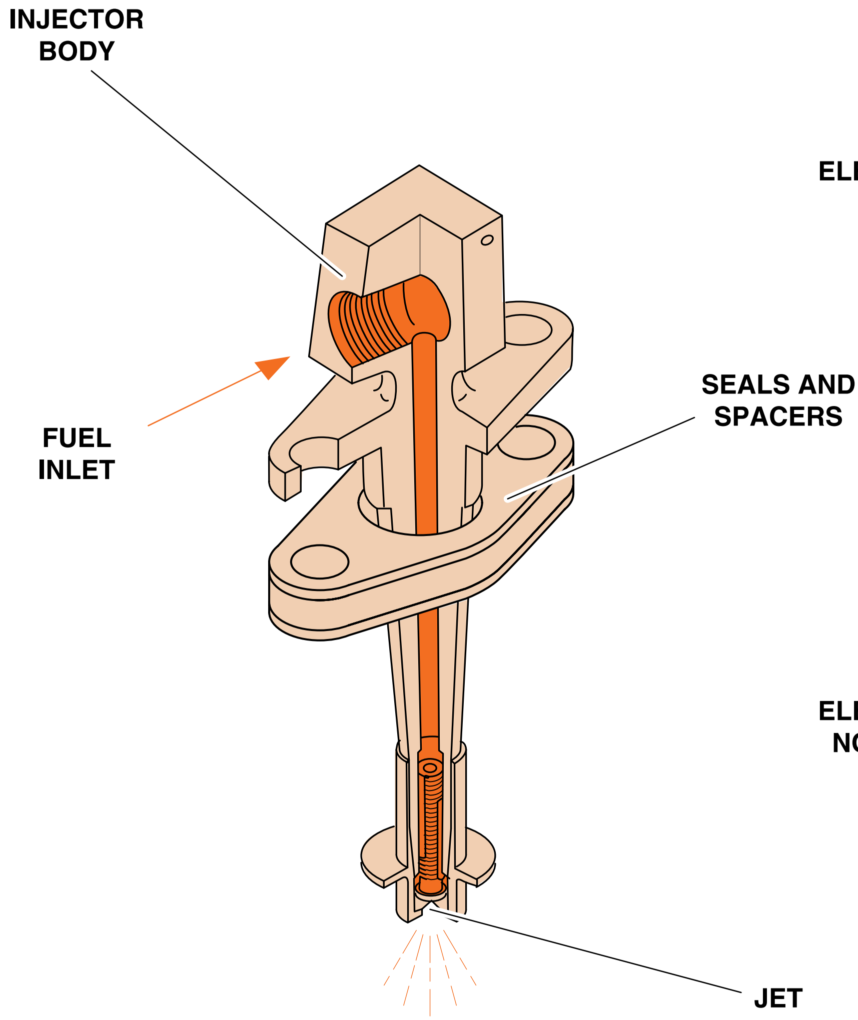
The fuel is atomised by the jet and is ignited by the sparks from the igniter plugs. The flames thus produced, ignite the fuel sprayed by the centrifugal injection wheel.

Normal running

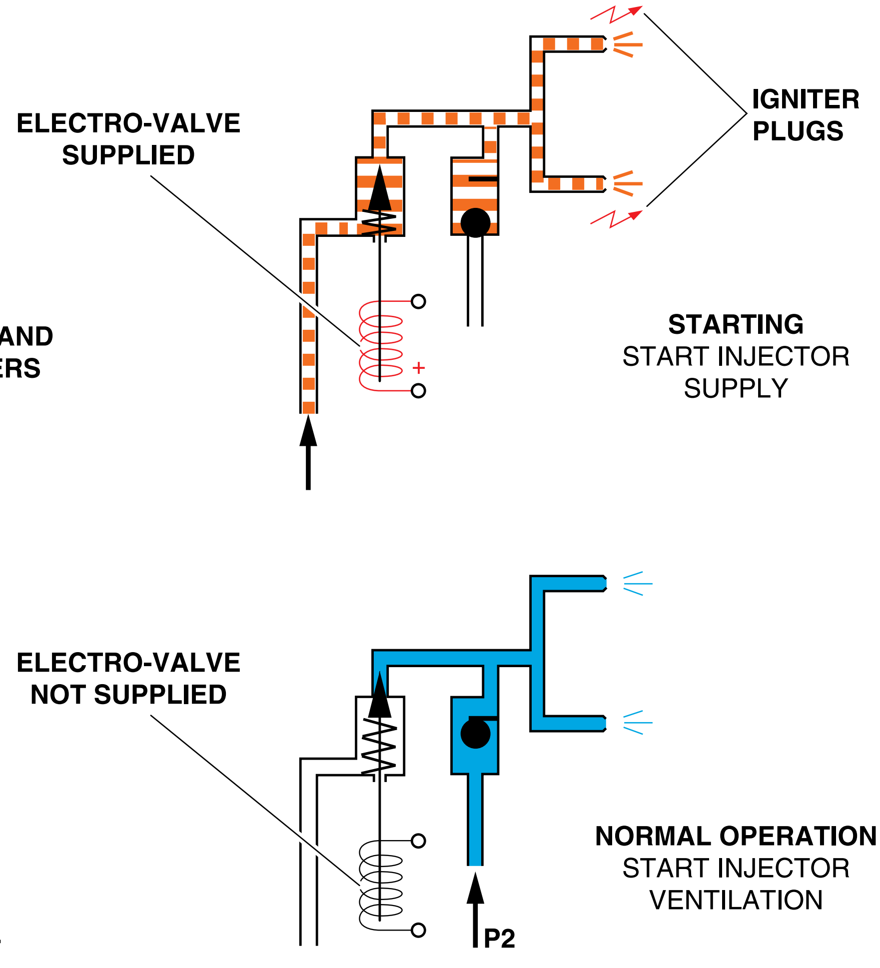
When the engine reaches self sustaining speed (approx. 45 % N1), the fuel supply to the injectors is shut off.

The pressure air is then admitted into the system to ventilate the injectors. The ventilation avoids blockage of the injectors by carbonisation of the residual fuel.

It should be noted that ventilation is continuous during engine running.



DESCRIPTION



OPERATION

START INJECTORS - DESCRIPTION - OPERATION

COMBUSTION CHAMBER DRAIN VALVE - GENERAL

Function

The valve drains overboard any unburnt fuel remaining in the combustion chamber.

Position

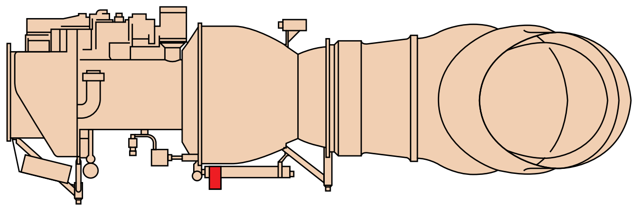
- Screwed through the drain collector into the lower part of the turbine casing.

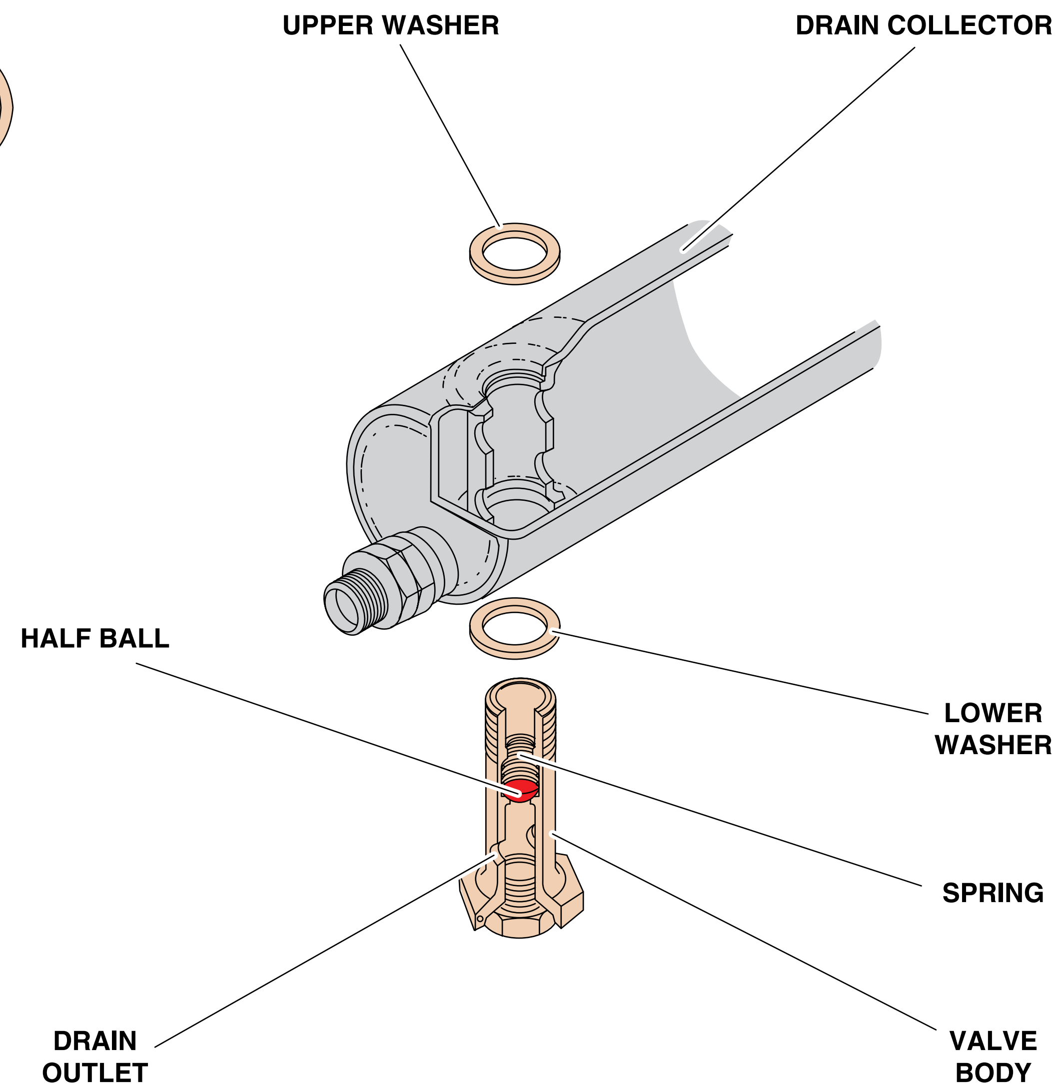
Main characteristics

- Type : half ball valve
- Setting : ≈ 300 kPa (43.5 PSI). Closing pressure obtained at about 15 % N1.

Main components

- Valve body
- Half ball valve
- Spring
- Drain outlet
- Washers.





Type
Half ball valve

Setting
300 kPa (43.5 PSI) (≈ 10 % N1)

COMBUSTION CHAMBER DRAIN VALVE - GENERAL

COMBUSTION CHAMBER DRAIN VALVE - DESCRIPTION - OPERATION

Description

The valve comprises :

- A union (screwed into the lower part of the turbine casing)
- A ball valve actuated by the air pressure. A spring keeps the valve open
- An outlet orifice (into the drain collector).

Operation

The valve has two positions : open and closed.

Open position

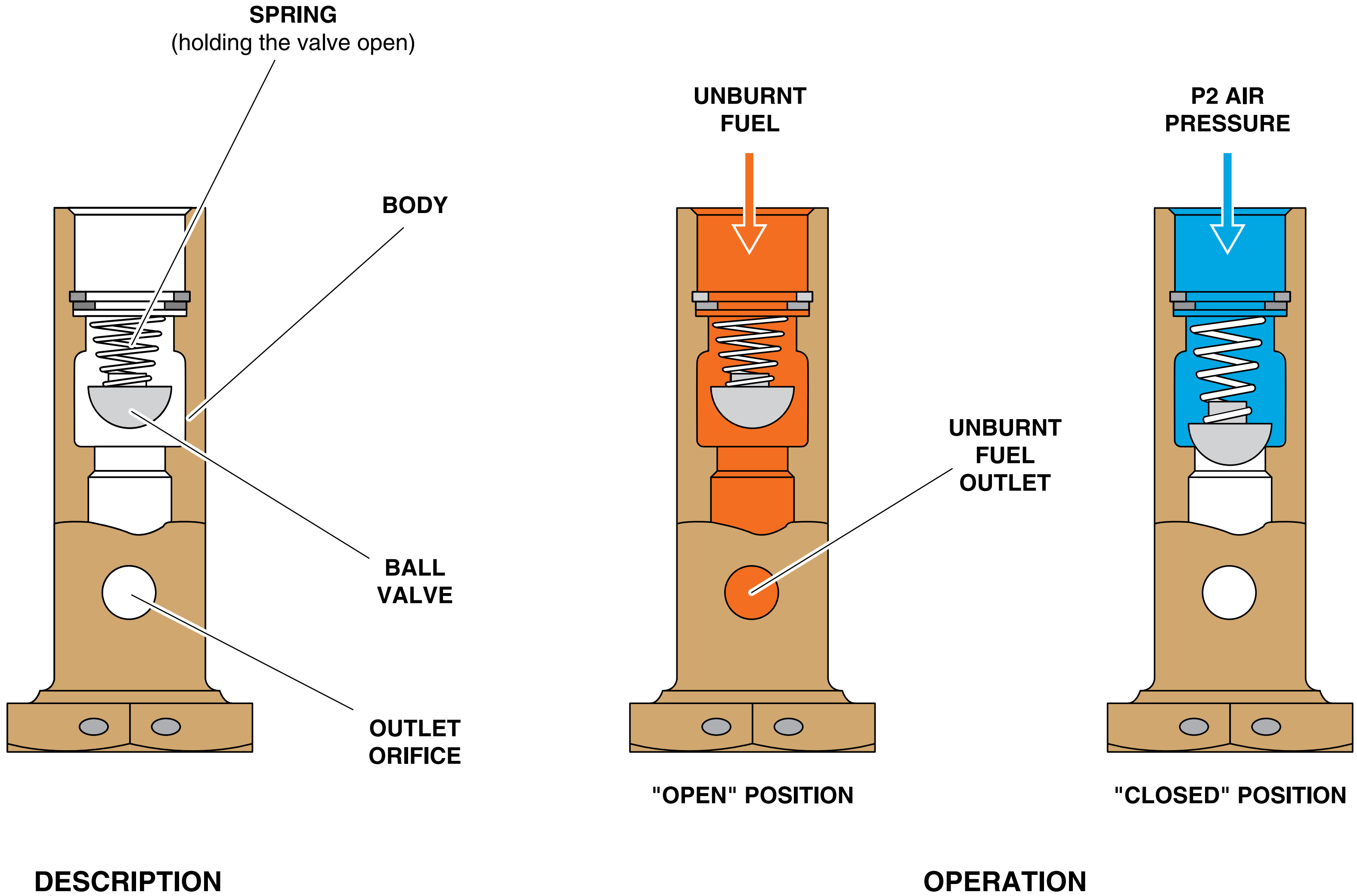
When the engine is not running and at the beginning of start, the valve is held open by the action of the tension spring.

The unburnt fuel falls to the lower part of the turbine casing and is drained into the drain collector through the valve. This drain ensures that no fuel accumulates in the combustion chamber which could cause starting problems (e.g. : overtemperature).

Closed position

As the engine starts, the combustion chamber air pressure increases, the ball is pushed down and closes the drain.

The valve closes during the initial phase of starting.



COMBUSTION CHAMBER DRAIN VALVE - DESCRIPTION - OPERATION

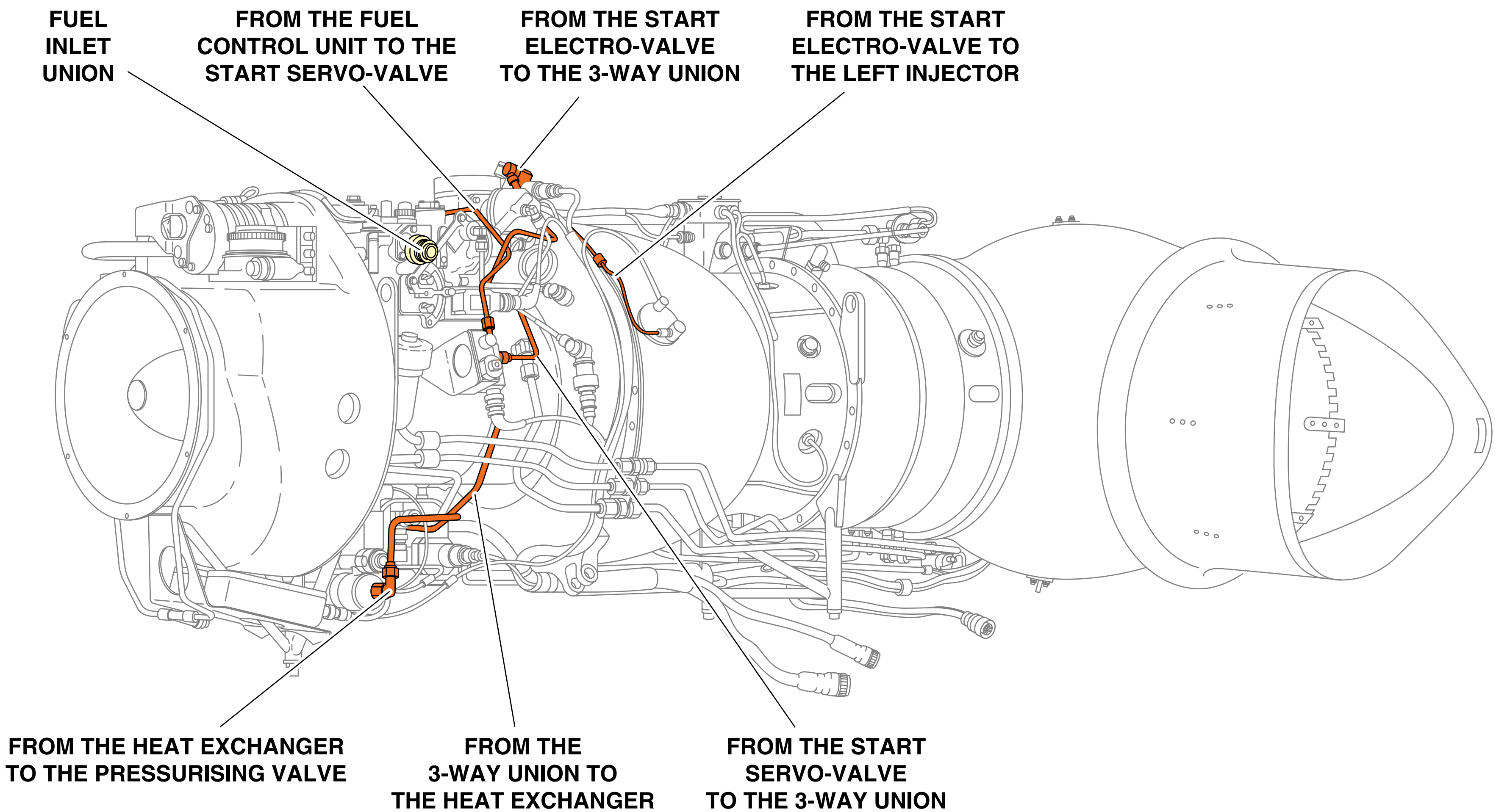
FUEL PIPES (1)

Description

The fuel pipes ensure the circulation of fuel between the components of the system.

Pipes (left hand side)

- Fuel inlet union
- From heat exchanger to check valve
- From start electro-valve to left injector
- From start servo-valve to 3-way union
- From fuel control unit to start servo-valve.

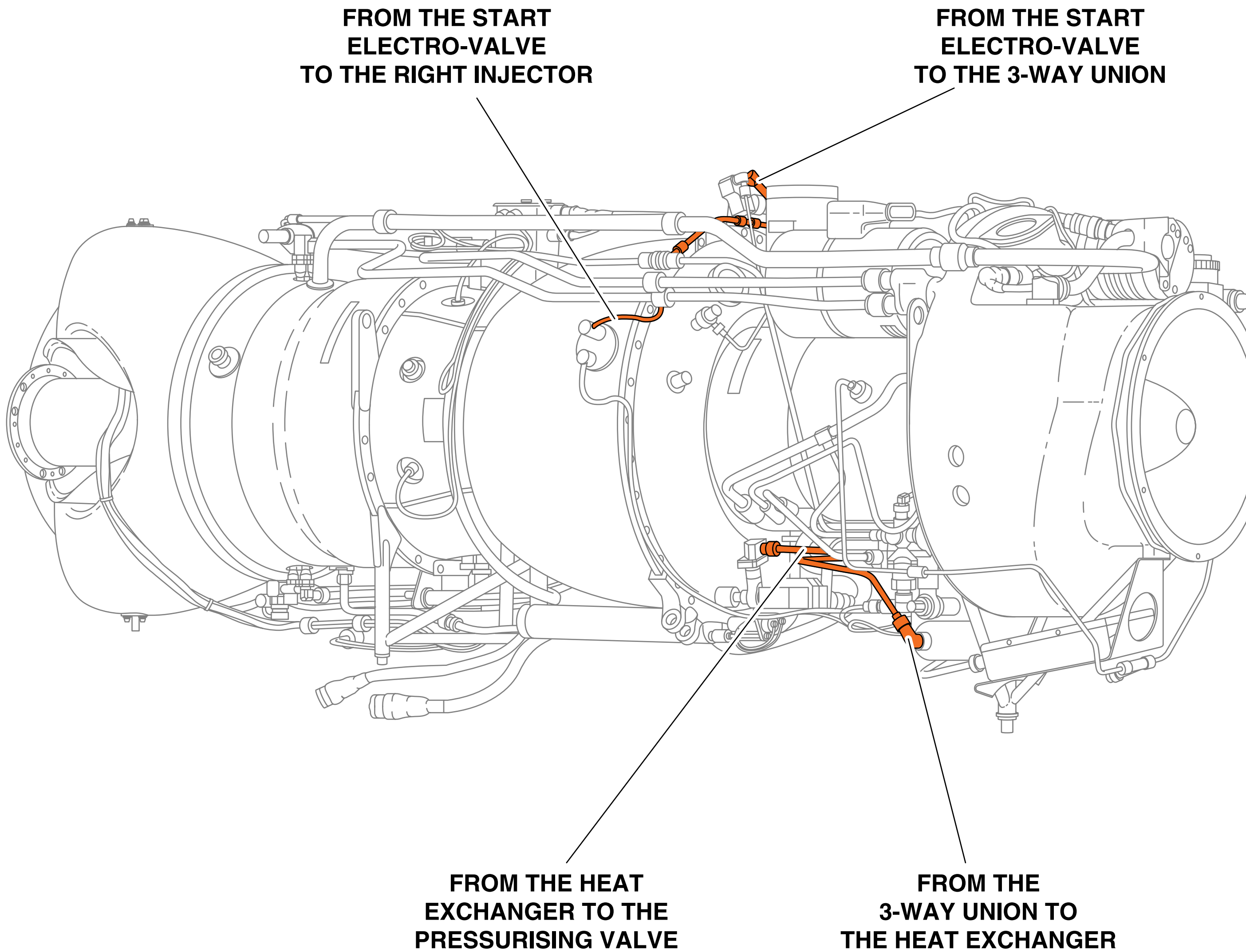

FUEL
INLET
UNION
FROM THE FUEL
CONTROL UNIT TO THE
START SERVO-VALVE
FROM THE START
ELECTRO-VALVE
TO THE 3-WAY UNION
FROM THE START
ELECTRO-VALVE TO
THE LEFT INJECTOR
FROM THE HEAT EXCHANGER
TO THE PRESSURISING VALVE
FROM THE
3-WAY UNION TO
THE HEAT EXCHANGER
FROM THE START
SERVO-VALVE
TO THE 3-WAY UNION

FUEL PIPES (1)

FUEL PIPES (2)

Pipes (right hand side)

- From 3-way union to heat exchanger
- From heat exchanger to the pressurising valve
- From start electro-valve to right injector
- From start electro-valve to 3-way union.


FROM THE START
ELECTRO-VALVE
TO THE RIGHT INJECTOR
FROM THE START
ELECTRO-VALVE
TO THE 3-WAY UNION
FROM THE HEAT
EXCHANGER TO THE
PRESSURISING VALVE
FROM THE
3-WAY UNION TO
THE HEAT EXCHANGER

FUEL PIPES (2)

7 - CONTROL SYSTEM

CONTROL SYSTEM - GENERAL

Functions

The system is designed to adapt the engine to the aircraft power requirements whilst remaining within defined limits.

The main functions are :

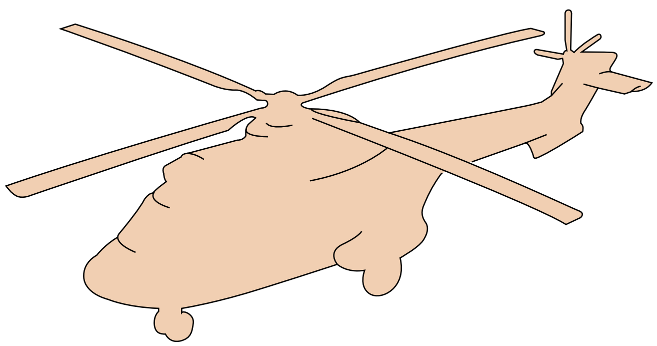
- Starting
- Speed control
- Various limits
- Manual control
- Bleed valve control (off-set threshold)
- Overspeed protection
- System monitoring and fault management.

Main characteristics

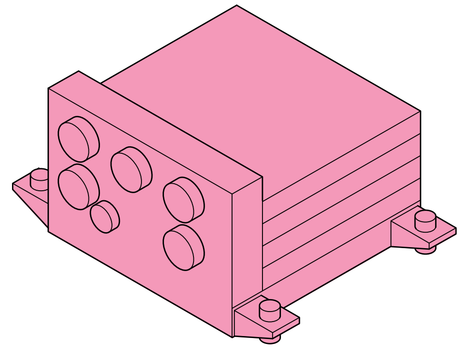
- Composite control system : single channel digital electronic and hydromechanical
- "Emergency" manual control.

Main components

- DECU (one per engine, supplied by the engine manufacturer but mounted in the airframe)
- Engine (engine and systems) and particularly the hydromechanical control unit
- Aircraft (various systems).

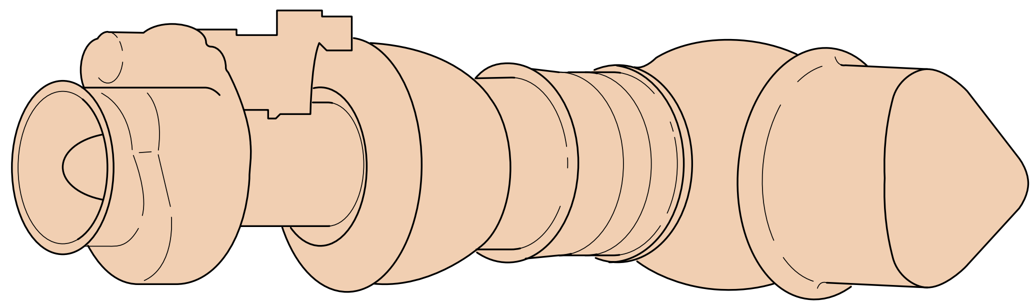


AIRCRAFT
(various systems)



DIGITAL ENGINE CONTROL UNIT

MAIN FUNCTIONS
- Starting - Speed control - Various limits - Manual control - Bleed valve control - Overspeed protection - Monitoring



ENGINE
(engine and engine systems)

CONTROL SYSTEM - GENERAL

CONTROL SYSTEM - DESCRIPTION

The complete system includes aircraft components, engine components and the DECU.

Aircraft components

- Control components (logic and analog signals)
- Monitoring components (indicators, power loss, IFDS, HUMS, warning lights…)
- DECU power supply
- Start and stop selection logic.

Engine components

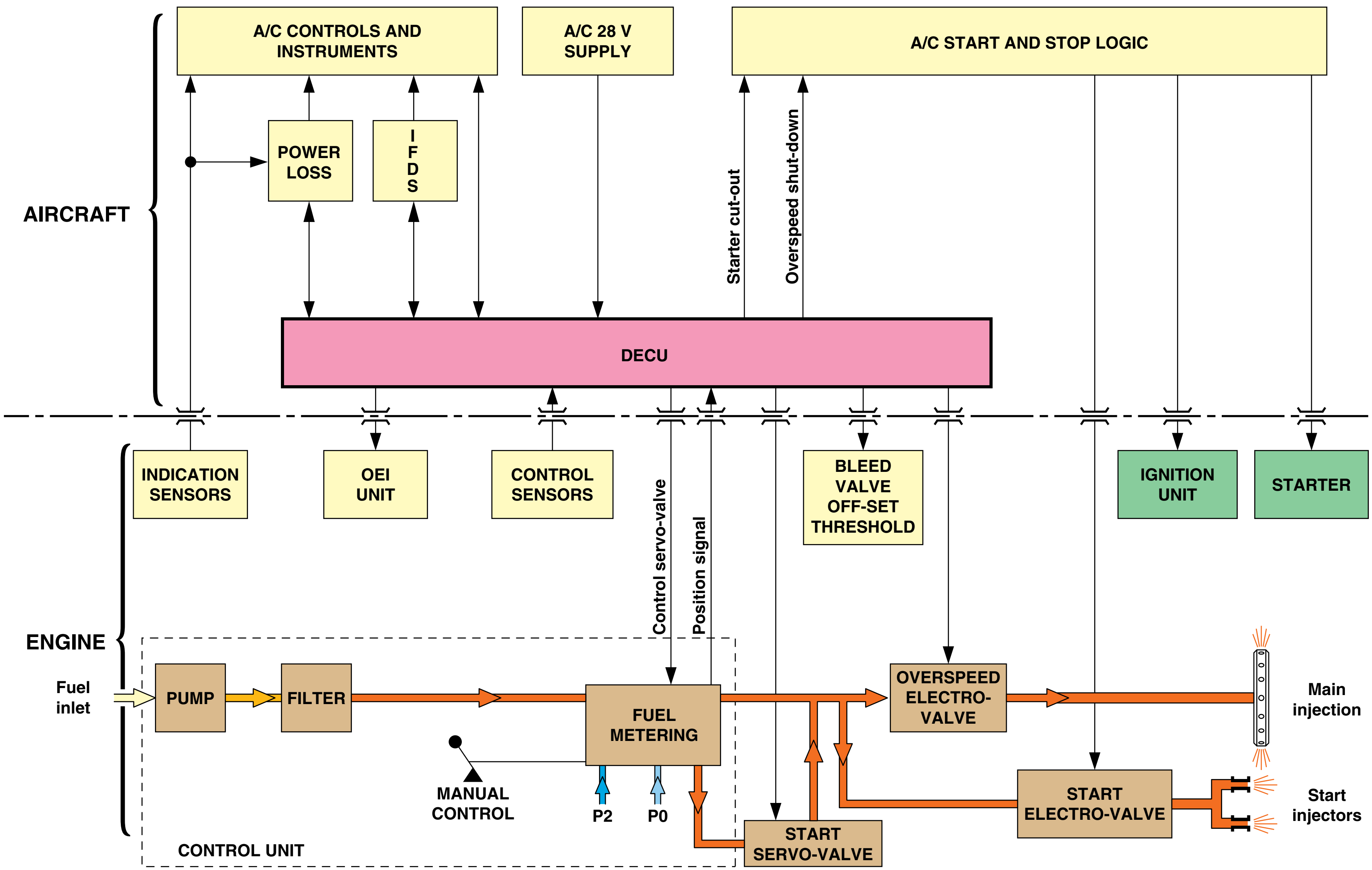
- Hydromechanical control unit :
  - Pump
  - Filter
  - Metering unit (with manual control)
  - Speed governor
  - Acceleration controller
- Start servo-valve
- Overspeed and drain electro-valve
- Start electro-valve
- Indicating system sensors
- Control system sensors
- Ignition unit
- Starter
- Bleed valve off-set threshold solenoid valve
- OEI unit.

DECU

Computer which controls and monitors the engine.

- Digital type
- Mounted in the aircraft but provided by the engine manufacturer
- Analog power turbine overspeed protection
- One DECU per engine with cross monitoring
- Serial link with the aircraft.

Note *: IFDS - Integrated Flight Display System*
HUMS - Health and Usage Monitoring System.



CONTROL SYSTEM - DESCRIPTION

CONTROL SYSTEM - OPERATION (1)

This part classifies the various functions of the system.

Starting

This function guarantees a start under all operating conditions.

Speed control

The power turbine rotation speed is maintained constant.

Various limitations

The engine is kept within determined limits : N1 max and min, acceleration and deceleration, torque, gas temperature, fuel flow…

Twin-engine configuration

The system takes into consideration the twin-engine configuration (load sharing) and the failure of one engine.

Compressor bleed valve

Opening and closing control of the compressor bleed valve in off-set threshold.

Manual control

The system permits manual engine control in the event of failure of the automatic control system.

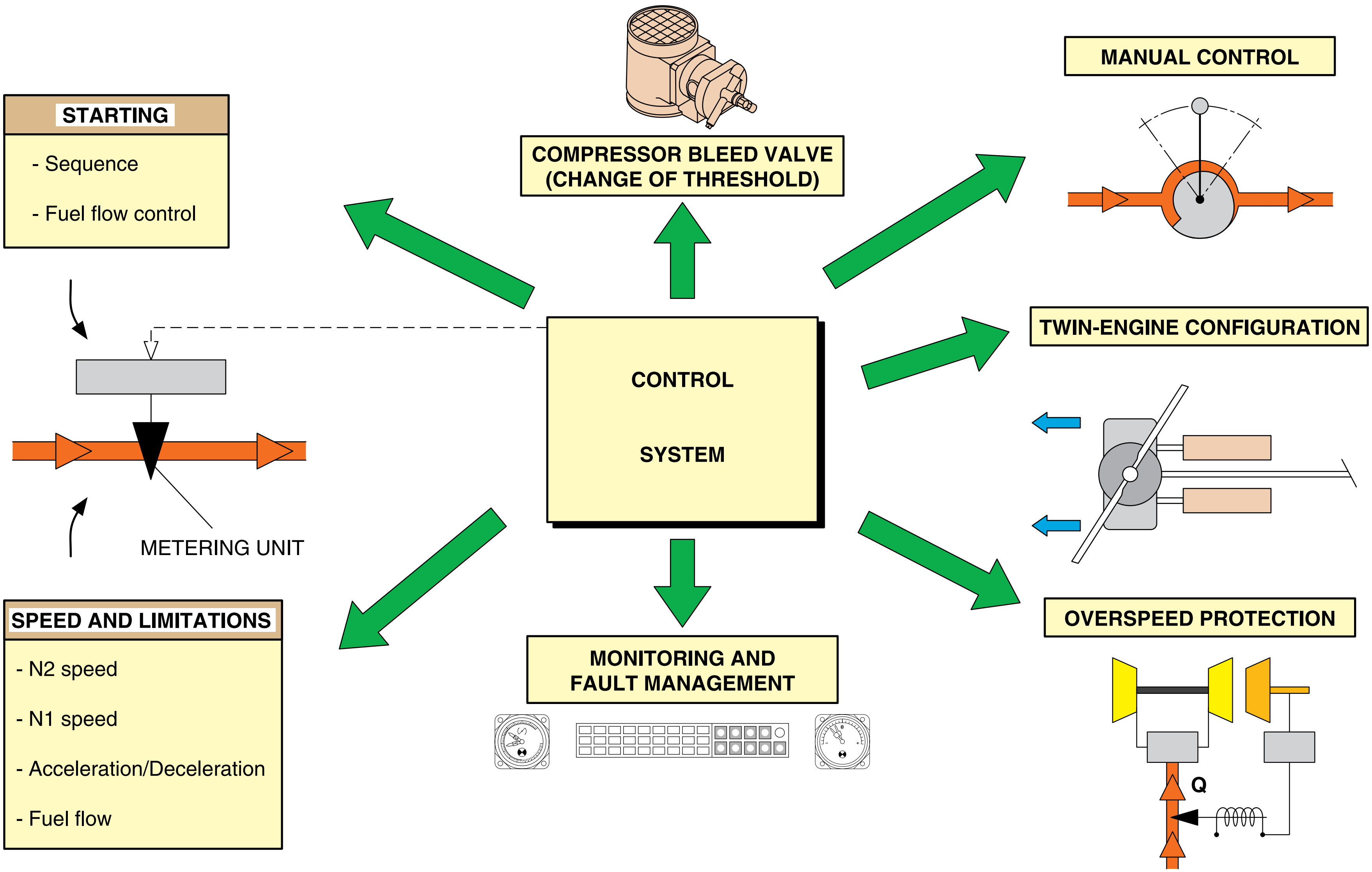
Overspeed protection

Automatic engine shut-down in the event of power turbine overspeed.

Monitoring

Engine monitoring and fault management.

Note *: 16 parts corresponding to each function are treated in the following pages.*



CONTROL SYSTEM - OPERATION (1)

CONTROL SYSTEM - OPERATION (2)

Starting

This function includes the starting sequence, starting fuel flow control, idling, the transition from idle to flight.

Starting sequence

The system ensures the cranking (starter), the ignition (ignition unit) and the fuel supply.

The control is selected through the aircraft system and the DECU. The DECU de-energises the starting accessories at a determined N1 value (self-sustaining speed). The system is also designed to allow a manually controlled start.

Note *: Refer to "FUEL SYSTEM" and "STARTING" chapters for more details of engine starting.*

Starting fuel flow control

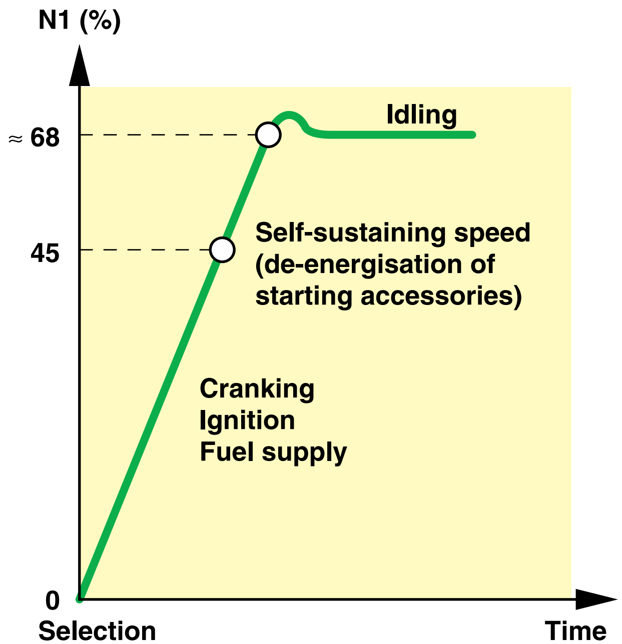
During starting the fuel flow is metered so as to give a rapid start without overheat.

To this end, the flow is controlled according to different laws :

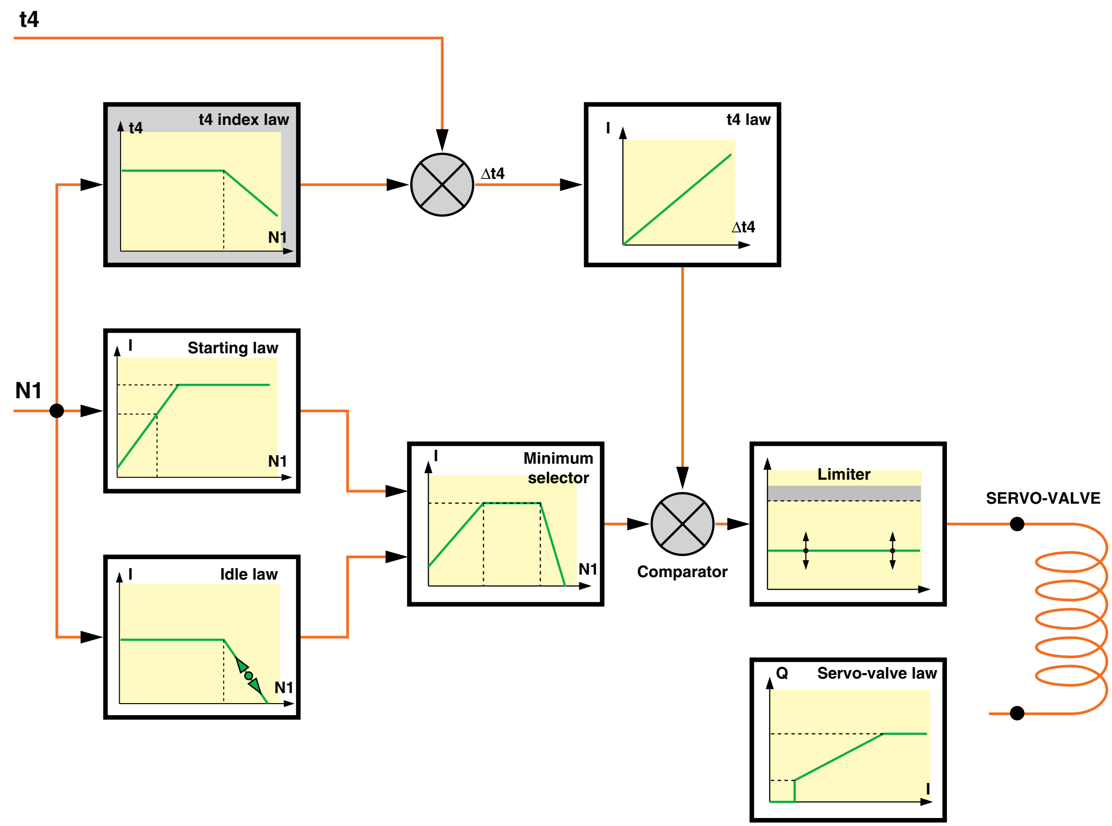
- Basic flow law (pre-set of 2 mA which determines a flow of 25 l/h (55 lbs/hr) through the servo-valve)
- Starting flow law as a function of N1 speed (from 2 mA 0 % N1 to 30 mA 45 % N1)
- Flow correction law as a function of the gas temperature t4 indexed proportional to N1 above 45 % N1
- Idle law (proportional type speed control) to stabilise the speed at the end of starting (N1 around 68 %)

The system comprises :

- The electronic stage in the DECU which includes :
  - Law units : pre-setting, N, t4, idling
  - Minimum selector
  - Comparator
  - Flow/signal limiter
- The start servo-valve which meters fuel according to current received.



STARTING SEQUENCE



STARTING FUEL FLOW CONTROL

CONTROL SYSTEM - OPERATION (2)

CONTROL SYSTEM - OPERATION (3)

Starting (continued)

Idle

At the end of the start sequence, the speed stabilises at idle rating.

The rating is defined by a speed maintained constant by the proportional control system and the servo-valve (N1 ≈ 68 %).

Transition from idle to flight

This is selected by moving the flow control lever from the starting position to the flight position.

The transition is terminated when the system enters into power turbine nominal speed control.

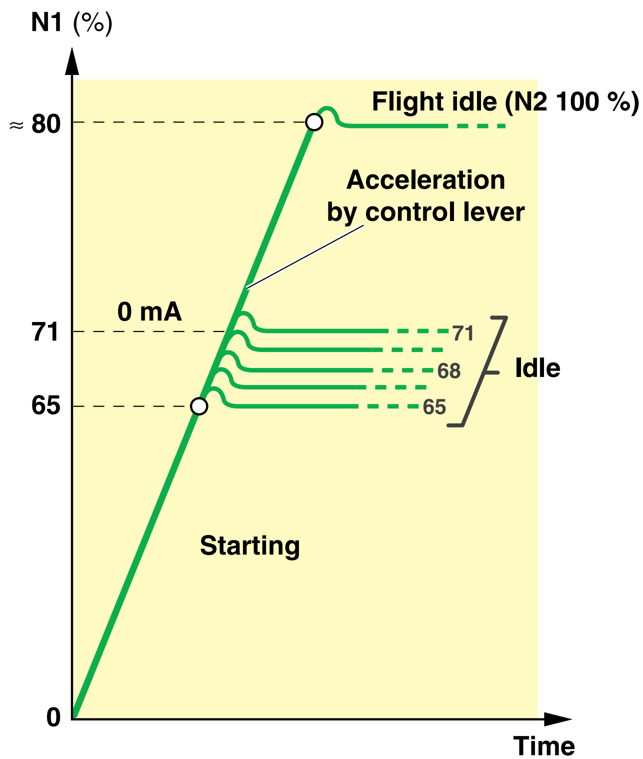
The lever displacement opens the main valve and releases the acceleration controller cam.

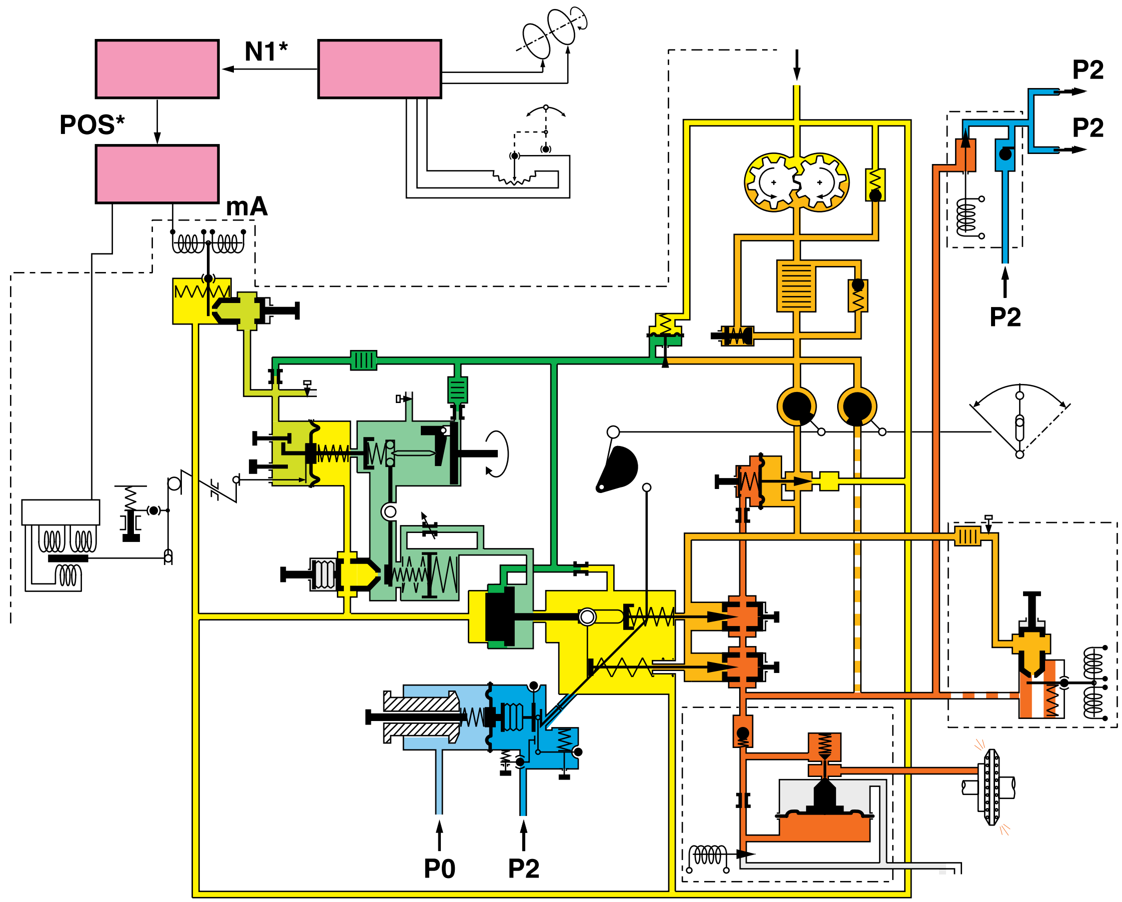
The flow is no longer determined by the servo-valve but by the main valve.

When 71 % N1 is reached, the servo-valve intensity is set to 0 mA to prevent interference between the idle control and the min N1 control. When the control lever is pulled back to the starting position, it causes the engine to shut-down.

When the power turbine speed reaches its nominal value (≈ 100 %) the speed control system operates and the fuel flow is determined by the metering needle in the Fuel Control Unit.

Note *: The flight position is obtained when the lever is fully open (52 °).*





TRANSITION IDLE - FLIGHT IDLE

CONTROL SYSTEM - OPERATION (3)

CONTROL SYSTEM - OPERATION (4)

Control - General

Configuration

The gas generator supplies power to the power turbine which is connected to the helicopter main rotor.

Installation requirements

The main requirements of the system are :

- Constant NR
- Max torque C limitation
- Constant N2
- Max N1 limited (several ratings)
- Min N1 limited
- Acceleration and deceleration control
- Fuel flow limit
- Load sharing in twin-engine configuration.

Adaptation to requirements

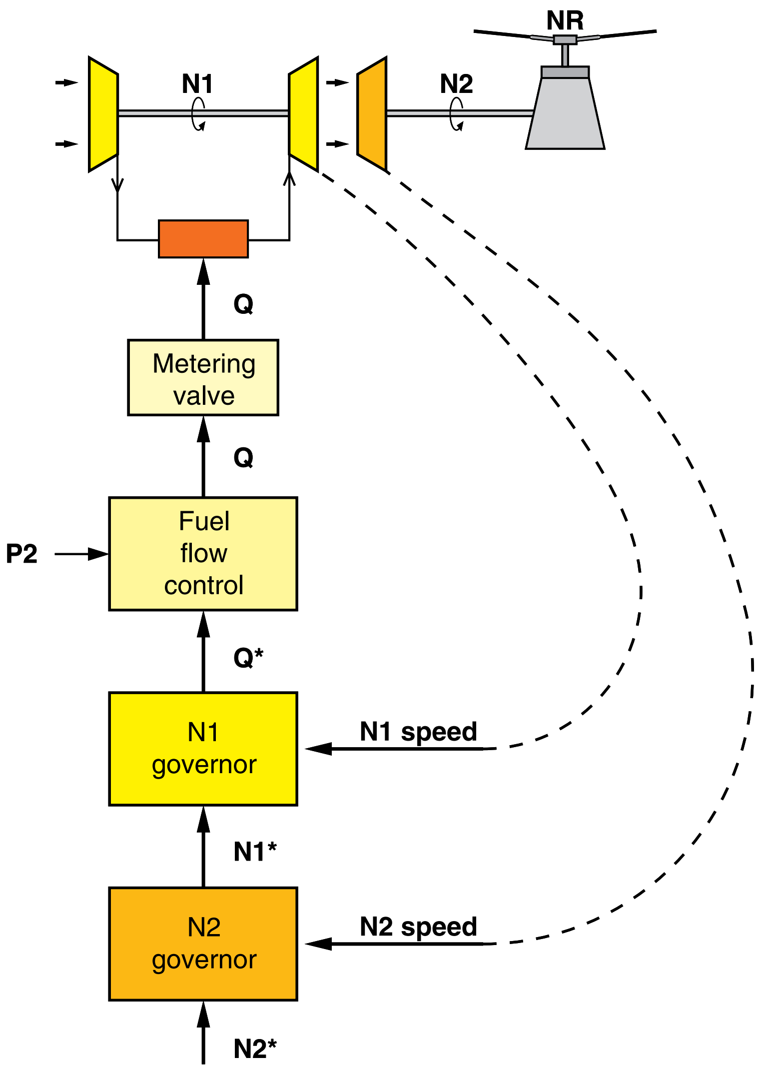
The adaptation is ensured by the control system (DECU and metering unit) by metering the fuel flow Q injected into the combustion chamber.

Thus, the gas generator adapts automatically to the requirements (variable N1) to maintain a constant N2 whilst keeping all the other parameters within determined limits.

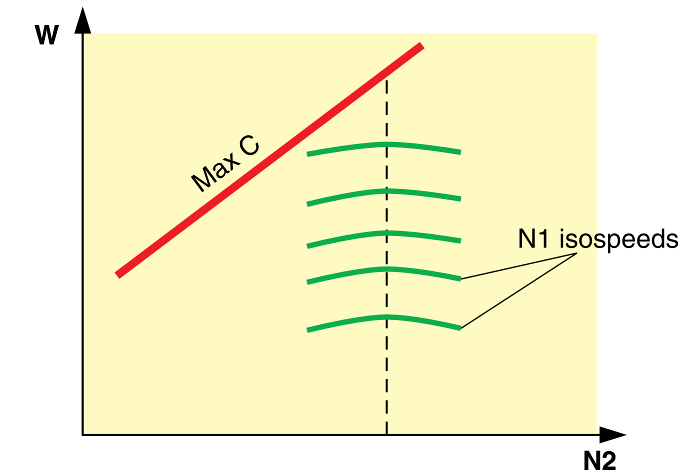
Principle of the control loop

Three stages can be considered in the control loop.

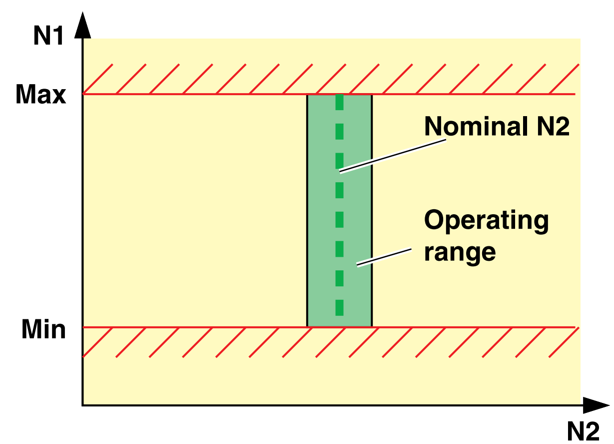
- N2 governor. This determines an N1* datum as a function of the difference between an N2* datum and the actual N2
- N1 governor. This determines a fuel flow datum Q* as a function of the difference between the N1* datum and the actual N1
- Fuel flow control unit. This determines a fuel flow Q as a function of the Q* datum and various signals for the acceleration control.



CONTROL LOOP



POWER / N1, N2



N1 / N2

CONTROL - GENERAL

CONTROL SYSTEM - OPERATION (4)

CONTROL SYSTEM - OPERATION (5)

Speed control - General

The power turbine N2* datum is calculated as a function of :

- A variable datum as a function of the helicopter collective pitch position (anticipator)
- A fixed datum (nominal N2).

The difference between the datum and the actual speed is treated by a proportional controller which determines the gas generator speed datum N1* (electronic control).

The hydromechanical N1 governor compares the N1* datum to the actual N1 and determines a fuel flow datum Q* as a function of the difference.

The fuel flow control unit meters the fuel flow by limiting its variation as a function of the compressor outlet pressure P2 (acceleration control).

Static droop and compensation

In this type of governor, the N1 speed is made inversely proportional to N2. The N1/N2 relation illustrates this proportionality and the N2 variation is called "static droop".

The static droop ensures the system stability, but it is not acceptable because the helicopter rotor requires a constant speed (NR = k.N2).

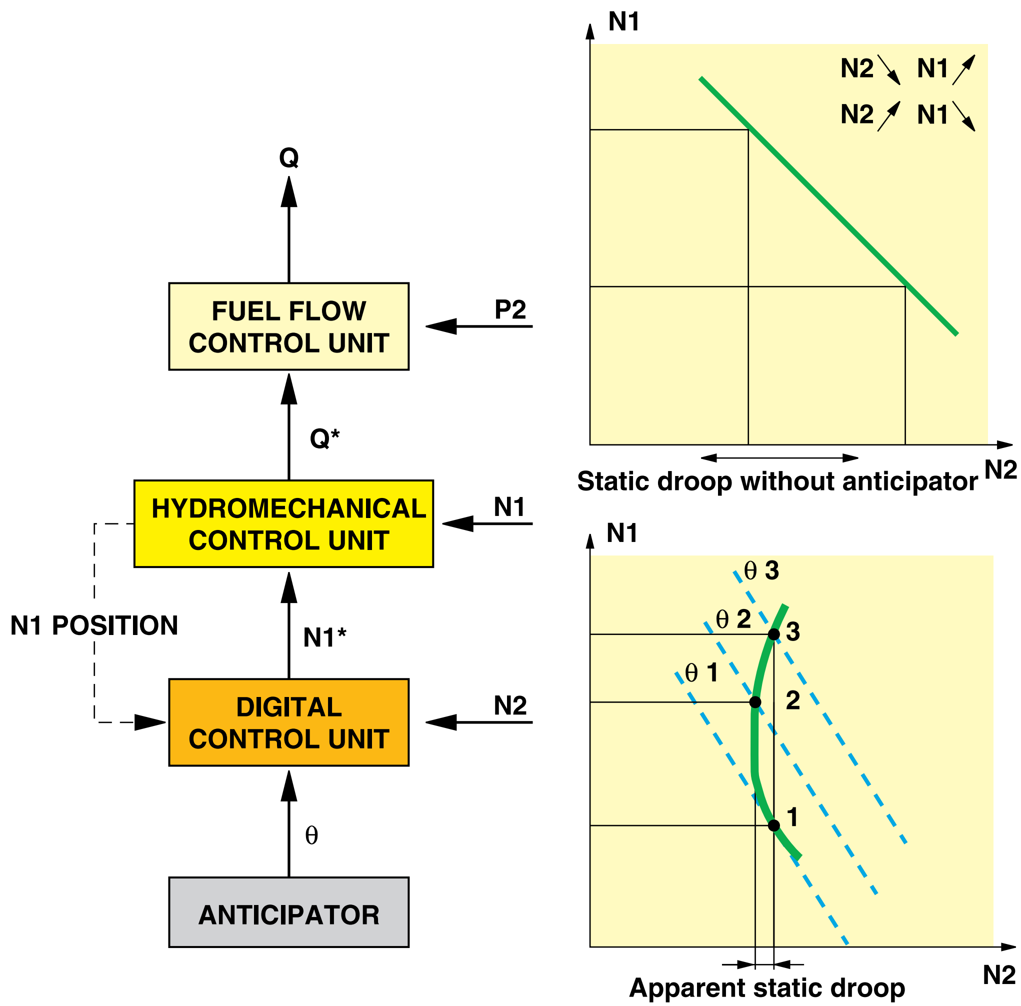
As the largest load variations come from the collective pitch, a link between the governor and the collective pitch compensates the static droop. Furthermore, the detection phase is advanced (this explains the name "anticipator") to reduce the response time.

Static droop lines are obtained for each angle of the collective pitch and in operation an apparent static droop line which stays in a narrow speed range is obtained.

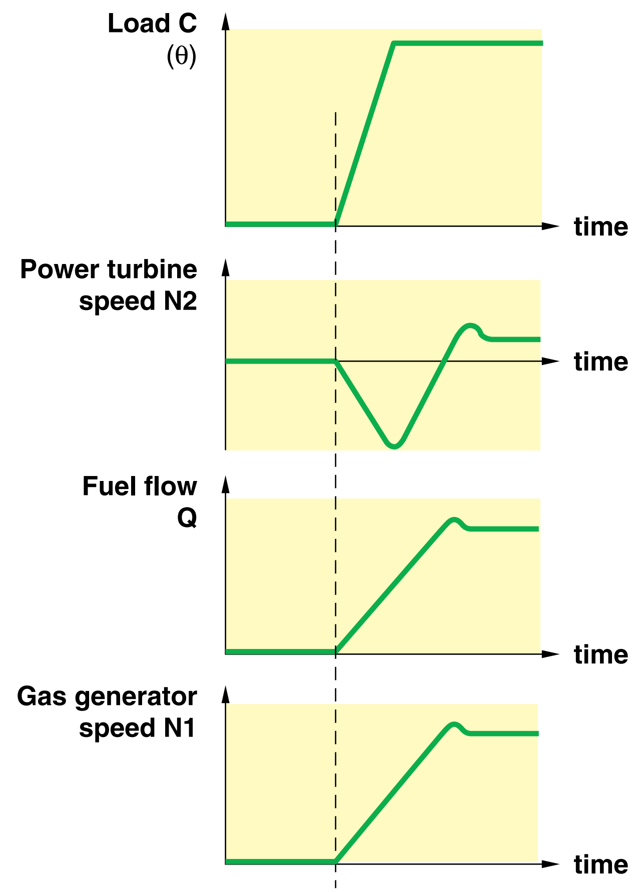
Example of transient condition

When the load is increased, the N2 tends to reduce, the system responds and increases the fuel flow Q. The N1 increases until the N2 returns to nominal, with however a slight static droop.

It can be noted that on the MAKILA 1A2, the static droop is overcompensated, i.e. that the N2 speed increases slightly when N1 increases.



SPEED CONTROL



EXAMPLE OF TRANSIENT CONDITION
(load increase)

SPEED CONTROL - GENERAL

CONTROL SYSTEM - OPERATION (5)

CONTROL SYSTEM - OPERATION (6)

Speed control - Digital stage

The power turbine rotation speed is detected by two electro-magnetic sensors.

The anticipator outputs a voltage which is proportional to the datum pitch angle. This signal which is a direct representation of the power required, compensates the static droop of the speed governor. There is no anticipator input when the engine is reduced to training idle, thus the engine operates on a fixed static droop line and so cannot provide power as long as the other engine is operating normally ; consequently it remains dis-engaged.

The N2 proportional governor generates a ΔN1* datum signal which is proportional to the difference between the speed datum (levels of datum : normal 100 % NR, platform approach N2 +10 RPM, ILS, NR -6 RPM) and the power turbine actual speed.

The ΔN1* datum signal is added to the main N1* datum signal which is function of the collective pitch.

The signal obtained is then compared to :

- A max datum (OEI 30 sec. max N1, OEI 2 min. max N1, AEO max N1, Training OEI 30 sec. or 2 min. max N1) through the minimum selector
- Min datum (65 %) through the maximum selector.

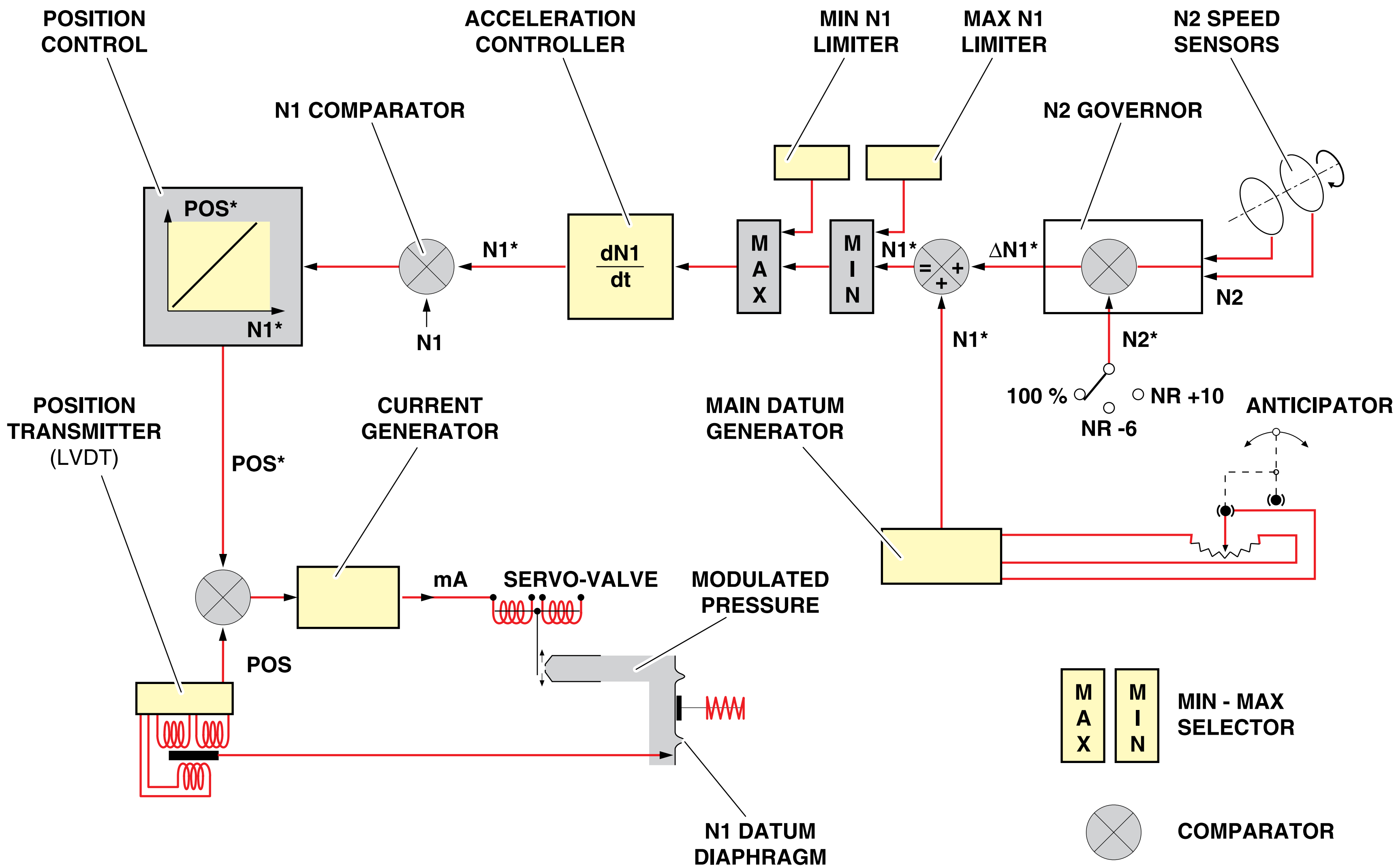
The acceleration and deceleration controller compares the N1* datum variation to the rate of acceleration limit permitted by the engine, and transmits the datum, modified if necessary, to the position transmitter. The system then compares the final N1 datum with the real N1 (comparator) in order to determine the datum position POS* which represents the N1 datum (refer to the note).

The loop is controlled by comparing the datum POS* with the obtained actual position POS (position of the N1 governor piston diaphragm) measured by the position transmitter LVDT. The difference, or error, is sent to a proportional-integral amplifier which generates a current (mA).

The servo-valve transforms the current into modulated hydraulic pressure Pm.

The modulated pressure is applied to the diaphragm which, through a push-rod, "sets" the speed datum on the gas generator governor ; as we will see later, the gas generator governor executes the datum by altering the fuel flow. The diaphragm also controls the position transmitter LVDT which signals the actual position for the control linkage.

Note : *The authority of this drift recovery system is limited (≥ 3 sec.). In stabilised conditions this drift is due in particular to the hydromechanical unit. The max recoverable drift is ± 1 % twin engine and ± 3 % in single engine mode. If the drift exceeds these limits a maintenance message is transmitted. Furthermore, to avoid a specious message during shut-down, it is recommended to select the stop position directly (without pausing in the reduction notch).*



SPEED CONTROL - DIGITAL STAGE

CONTROL SYSTEM - OPERATION (6)

CONTROL SYSTEM - OPERATION (7)

Speed control - Hydromechanical stage

Fuel from the fuel pump passes through the pressure reducing valve, which reduces the fuel pressure by means of a metering valve, controlled by a diaphragm.

The fuel at reduced pressure (≈ 400 kPa (58 PSI)) passes through a strainer and a fixed calibrated orifice. A certain amount of fuel passes through the potentiometric jet of the servo-valve.

A modulated pressure (as a function of the leak) builds up downstream of the calibrated orifice. It acts on the diaphragm, whose position determines the speed datum required by the gas generator governor.

When the electrical current supplied to the servo-valve by the DECU varies, the magnetic forces cause the flap valve to move, which changes the leak rate and thus modifies the modulated pressure.

The variation of the modulated pressure causes the diaphragm to move, and produces a new datum (new pressure of the datum spring). The diaphragm displacement is limited by two stops (N max and N min) corresponding to mechanical stops beyond the electronics stops. The position of the diaphragm is fedback to the DECU by a transmitter.

When the strength of the datum spring varies (demand of a new datum), the lever moves and the leak varies. The modulated pressure which controls the metering unit through the damping device also varies.

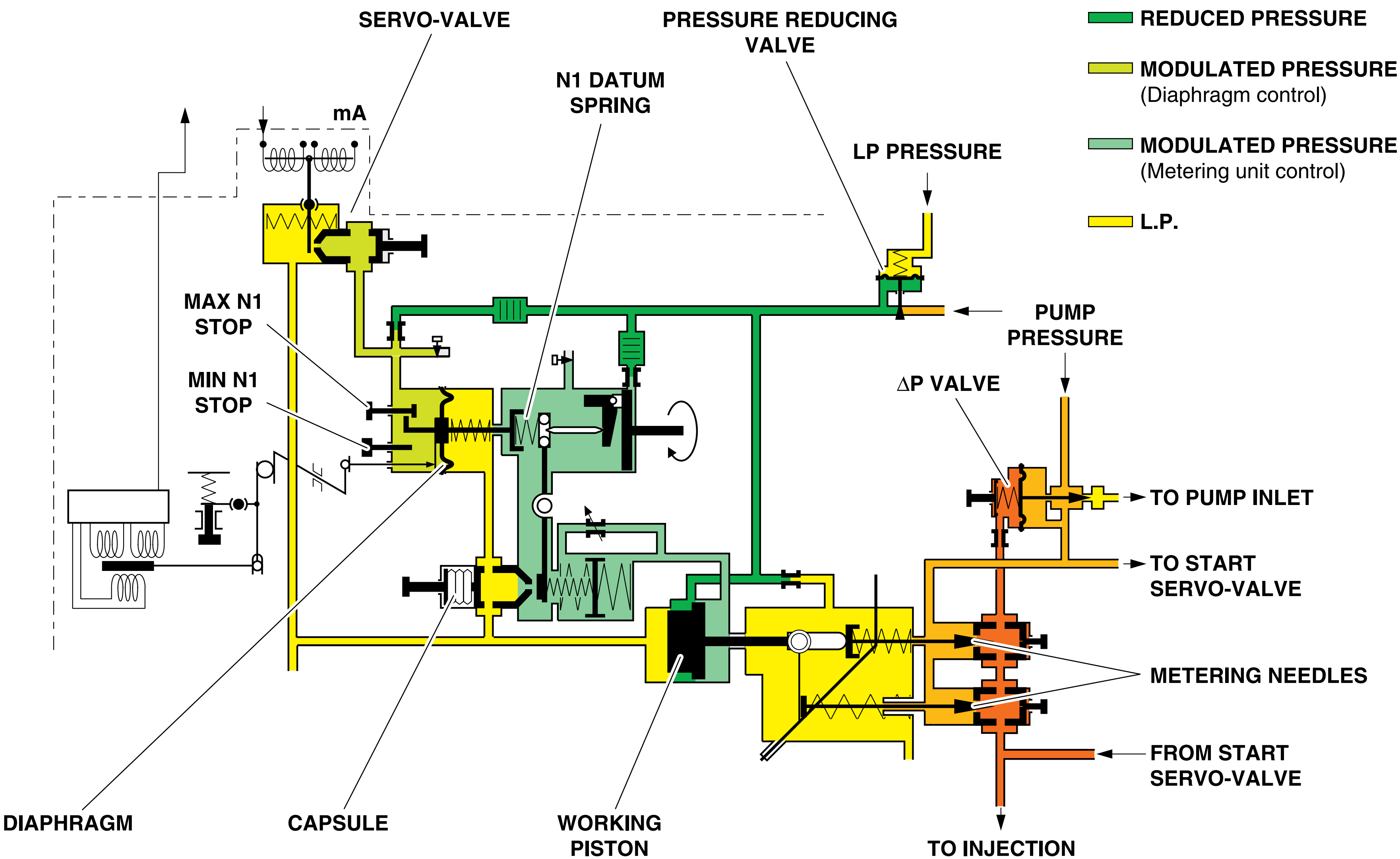
The working piston moves and drives the metering valve until the N1 datum is reached. The generator speed increases or decreases to adapt itself to the new load conditions in order to maintain the power turbine nominal speed.

Under stable conditions, the centrifugal force of the flyweight balances the spring force. The lever is set to a fixed position ; the flap valve is also set to a fixed position which determines the flow which is necessary to obtain the required rotation speed. The system is in balance.

Summary

The system continuously detects the power turbine actual speed and anticipator signals, and produces a gas generator speed datum which is transformed into a pressure by the servo-valve. This datum is used by the gas generator governor to meter the fuel flow.

Thus the gas generator rotation speed is adapted to output the necessary power, in order to maintain a constant power turbine speed to within the value of residual static droop. This is all carried out reliably and quickly.



SPEED CONTROL - HYDROMECHANICAL STAGE

CONTROL SYSTEM - OPERATION (7)

CONTROL SYSTEM - OPERATION (8)

Acceleration limitation

Under stabilised conditions, there is a clearance between the fork and the acceleration metering needle. The position of the S1 metering needle is determined by the working piston of the governor, and the position of the S2 metering needle by the fork.

Under load increase transient conditions, the governor "responds" and the working piston moves rapidly. Under the action of its spring, the S1 metering needle opens to abutment of the fork. This displacement represents the instant flow increase, which initiates the acceleration. Then the subsequent increase in the P2 pressure causes the capsule to contract ; this causes the S1 and S2 metering needles to open progressively.

This clearance represents the instant acceleration increase.

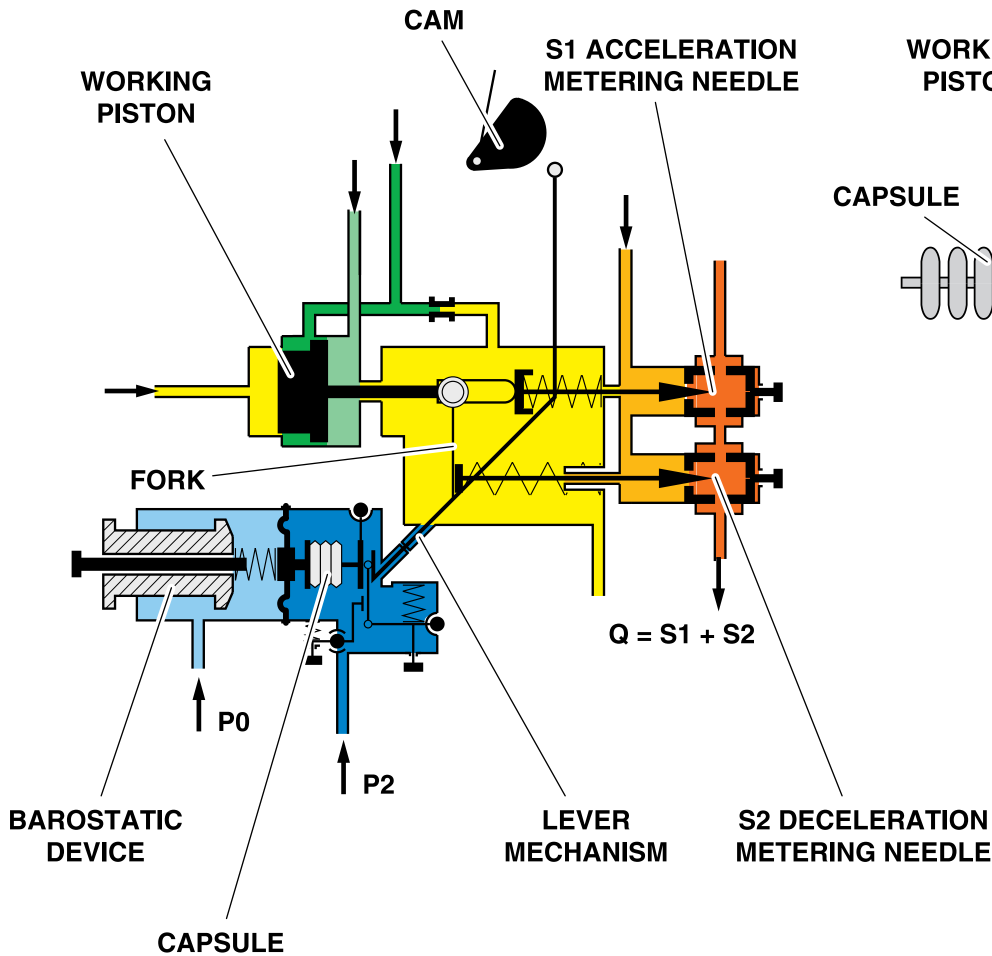
This control of the increase of fuel flow prevents the compressor surge likely to occur in the event of rapid acceleration.

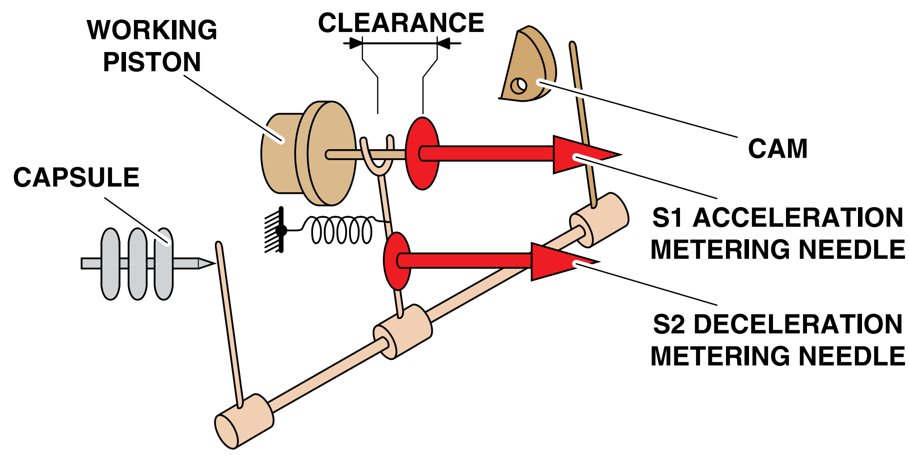
Deceleration limitation

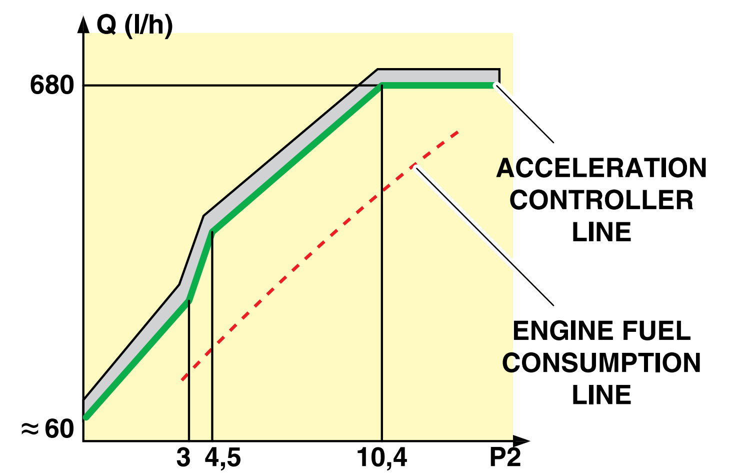
Under load decrease transient conditions, the governor also responds very rapidly and the S1 acceleration metering needle closes.

However, a certain quantity of parallel flow is maintained by the S2 deceleration metering needle which closes only after expansion of the capsule due to the P2 reduction.

This controlled flow decrease prevents flame-out, which might occur on very rapid deceleration.







ACCELERATION AND DECELERATION LIMITATIONS
(fuel flow Q as a function of compressor pressure (P2))

ACCELERATION AND DECELERATION LIMITATIONS
CONTROL SYSTEM - OPERATION (8)

CONTROL SYSTEM - OPERATION (9)

N2 datums and limits

The fixed speed datum (power turbine speed N2, and consequently rotor speed NR) is determined by the DECU.

The variable speed datum is determined by the link with the rotor collective pitch, which increases the datum according to the collective pitch, in order to compensate the static droop and advance the detection phase.

The link is realised using one twin channel potentiometer per engine which gives the main variable datum to the DECU.

This datum increases proportionally with the pitch.

N1 limits

The gas generator rotation speed varies between two extreme limits in order to adapt itself to the conditions. These limits correspond to stops calculated by the electronic stage.

Maximum speed

The maximum rotation speed is automatically limited by the DECU. It depends on the operating mode selected by the pilot and on the atmospheric conditions (Zp and t0) :

- 30 sec. and 2 min. OEI ratings in "normal" mode (case of one engine inoperative)
- 30 sec. OEI training rating on 2' OEI training in "training" mode (simulation of one engine inoperative)
- AEO rating (intermediate stop between take-off and OEI ; automatic stop of the take-off rating).

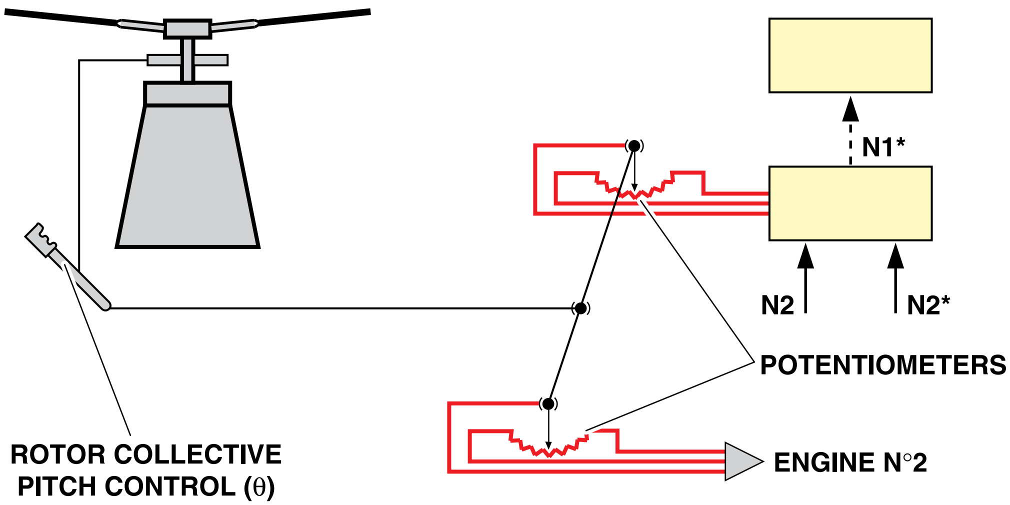
The max ratings are controlled as a function of Zp altitude in order to ensure a power limitation and as a function of t0 temperature in order to ensure a t3 limitation.

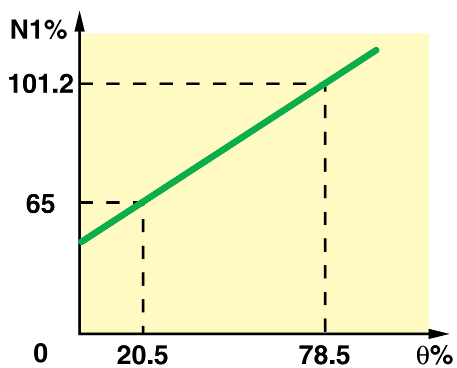
The maximum speed stop of the hydromechanical unit is a safety stop.

Minimum speed

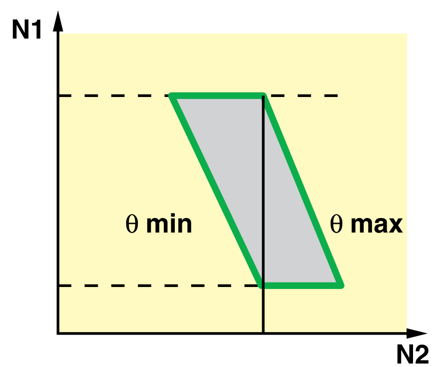
The minimum speed is also limited by the DECU in order to avoid too low speeds, which correspond to critical ratings. During operation, this stop is practically never reached because, even at a zero torque, the compressor drive power requires a higher speed.

The minimum speed stop of the hydromechanical unit is a safety stop.

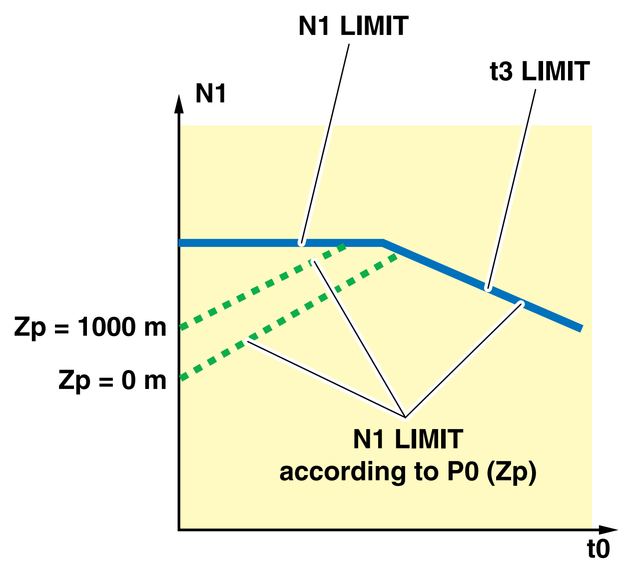




N1 / COLLECTIVE PITCH
RELATIONSHIP GRAPH
(main datum)



N1 / N2 RELATIONSHIP GRAPH



MAX N1 ROTATION SPEED LIMITS

LIMITS OF SPEED

CONTROL SYSTEM - OPERATION (9)

CONTROL SYSTEM - OPERATION (10)

OEI ratings

If the "Power Loss" system detects a ΔN1 between the two engines (ΔN1 > 7.5 %), the DECU "OEI rating" input is enabled. The stop of the twin engine max rating is withdrawn. The DECU then permits the 30 sec./2 min. OEI ratings.

The max N1 rating in twin engine operation is approximately 101.2 % N1 (t0 ≤ 15 °C (59 °F)) and is determined by the DECU.

Note *: Refer to the chapter "ENGINE INDICATING" for the "Power Loss" system description.*

OEI mode selection

Two different sequences can be carried out :

Sequence 1 : 30 sec. OEI rating

As the OEI mode is selected, the 30 sec. OEI indicator light is illuminated on the ΔNG indicator. If the N1 value overcomes the 2 min. OEI rating, a timer is activated.

25 seconds after the activation, the indicator light flashes. The pilot must select the "2 min. OEI" rating with the selector switch "30 sec./2 min. OEI".

Note : *If the rating reaches the "30 sec. OEI" rating, the engine flag is activated. The engine, the DECU and OEI unit must be sent back to the engine manufacturer.*

Sequence 2 : "2 min. OEI" rating

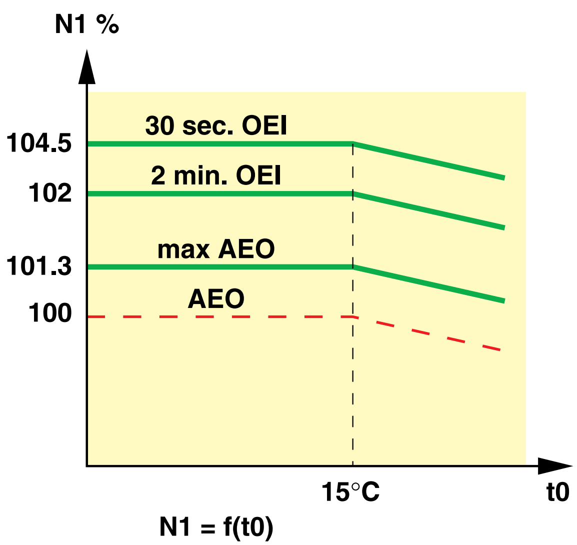
When this rating is selected, the DECU calculates a speed stop which corresponds to the 2 min. OEI. The indicator light is illuminated. Two minutes and 25 seconds after the selection, the indicator light flashes. The pilot must use the "continuous OEI" rating.

Reset of the timers

When the engine rating is lower than "continuous OEI" rating, the DECU resets the 30 sec. OEI and 2 min. OEI timers.

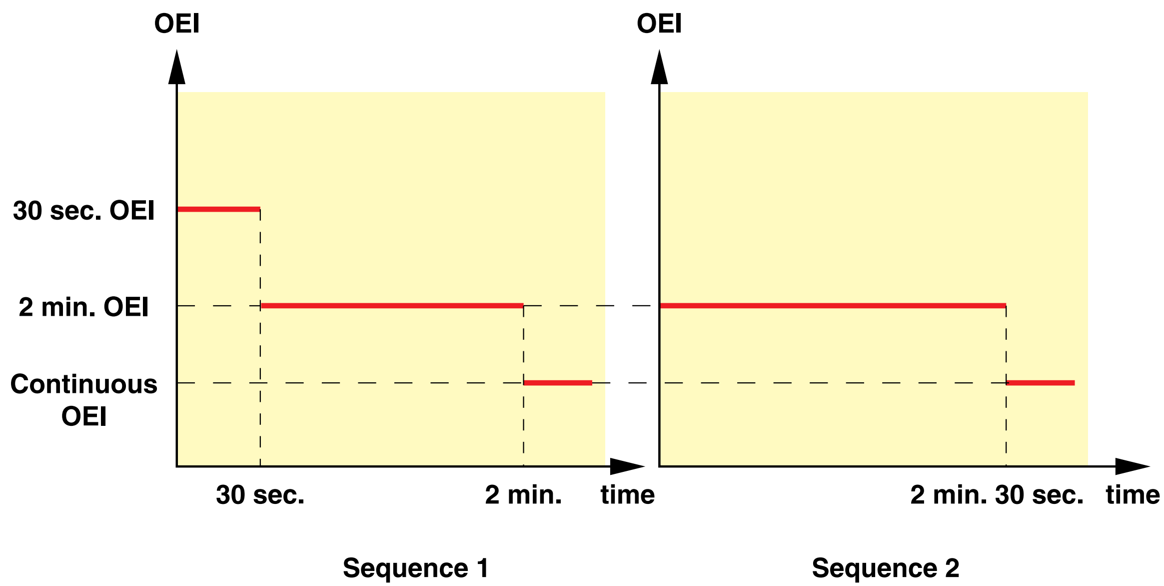
OEI rating counter

The DECU counts the number of OEI applications, and the operating cumulated time.



N1 LIMITS IN TWIN-ENGINE AND SINGLE ENGINE CONFIGURATION

RATINGS



OEI MODE SELECTION

OEI RATINGS

CONTROL SYSTEM - OPERATION (10)

CONTROL SYSTEM - OPERATION (11)

Training mode

The system includes a facility which permits the simulation of an engine failure to train the pilot for a real failure.

For this function the DECU is connected to a selector switch.

The selector switch selects the training mode on one of the engines.

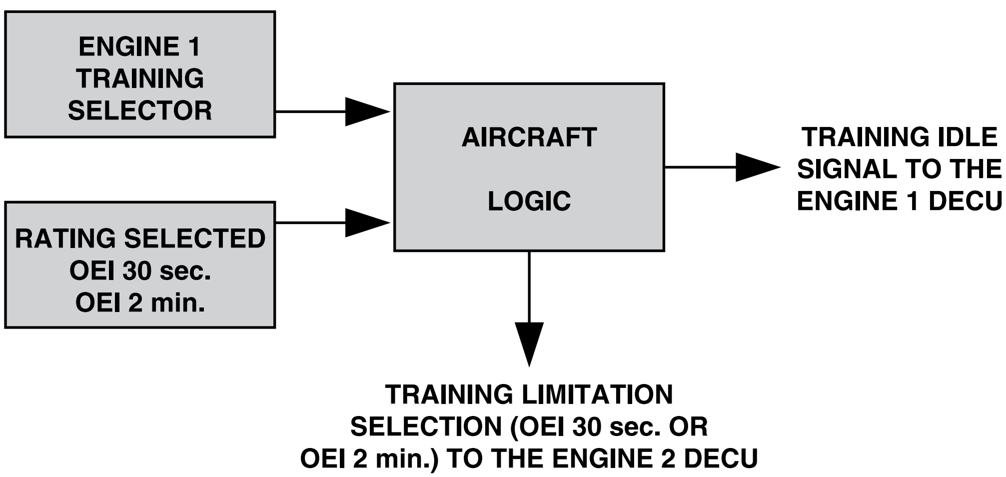
The operating criteria are :

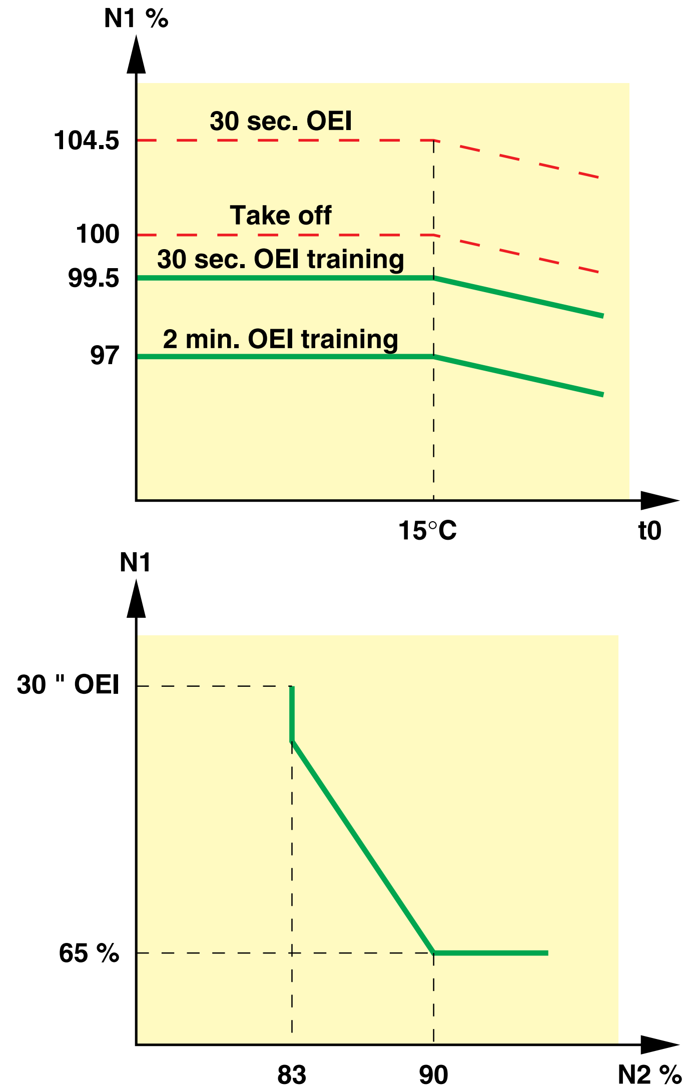
- The training mode is used with a reduced take-off weight helicopter and a reduced flight envelope (refer to aircraft manual)
- The selected engine is automatically reduced to idle rating 90 % (65 % N1 approx.)
- On the second engine, the rating is automatically limited by the DECU to a "Training OEI" rating, lower than the take-off rating in twin-engine configuration.

Thus, the simulation is achieved safely without excessive stress on the engine.

It is possible to return to AEO mode at any time.

The indication in training mode is exactly the same as in normal mode. But the maintenance counters are not activated.





TRAINING MODE

CONTROL SYSTEM - OPERATION (11)

CONTROL SYSTEM - OPERATION (12)

Fuel flow limits

The transient fuel flow is limited, as described earlier, by the acceleration controller to obtain an optimum acceleration without compressor surge. This acceleration also determines the response time of the control system. The slope of the controller is adjustable, but the adjustment is carried out only in the workshop, on a test bench.

The minimum flow (which avoids flame-out) is limited by a stop on the deceleration metering needle.

The maximum flow is determined by full opening of the metering needles for a given ΔP setting. This is a factory setting, which is actually an extreme power limit.

Under manual flow control (emergency control), the maximum flow is limited to a lower value in order to avoid any overshoot.

Torque limit

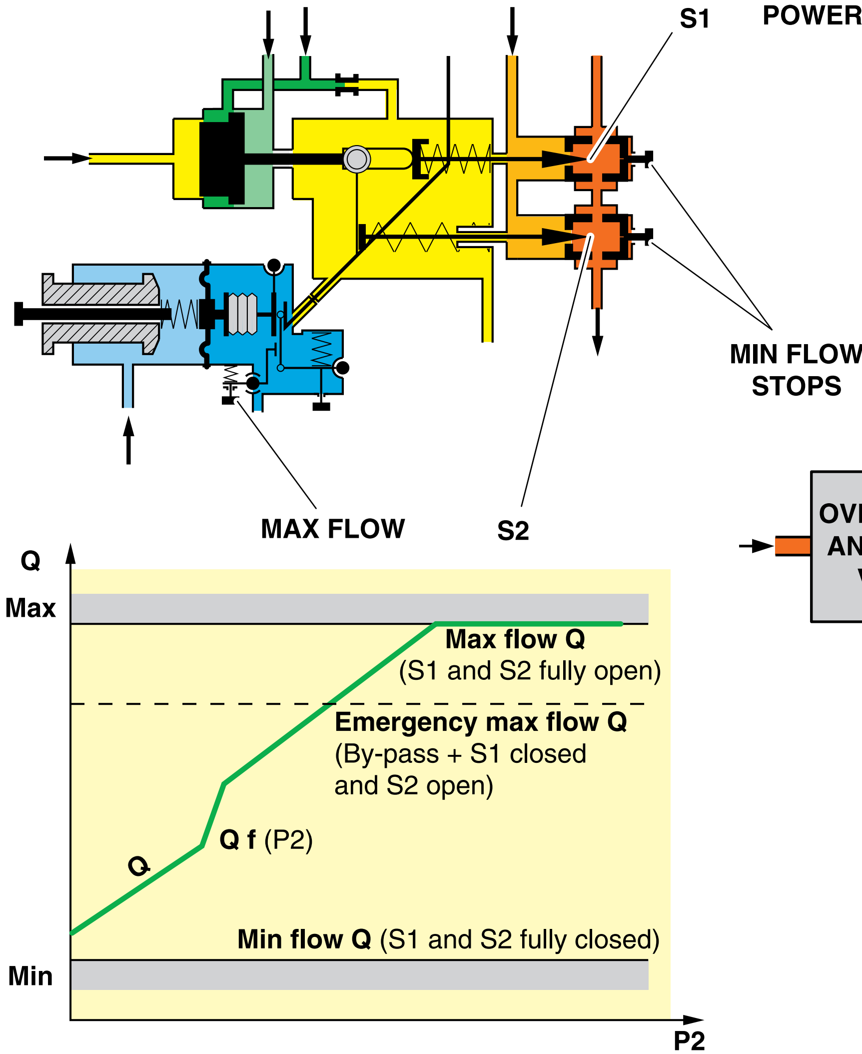
A maximum torque limit is imposed by the mechanical transmission components. The flight manual indicates the limits associated with torque, refer to chapter "INDICATING SYSTEM" for the measurement system.

Power turbine overspeed protection

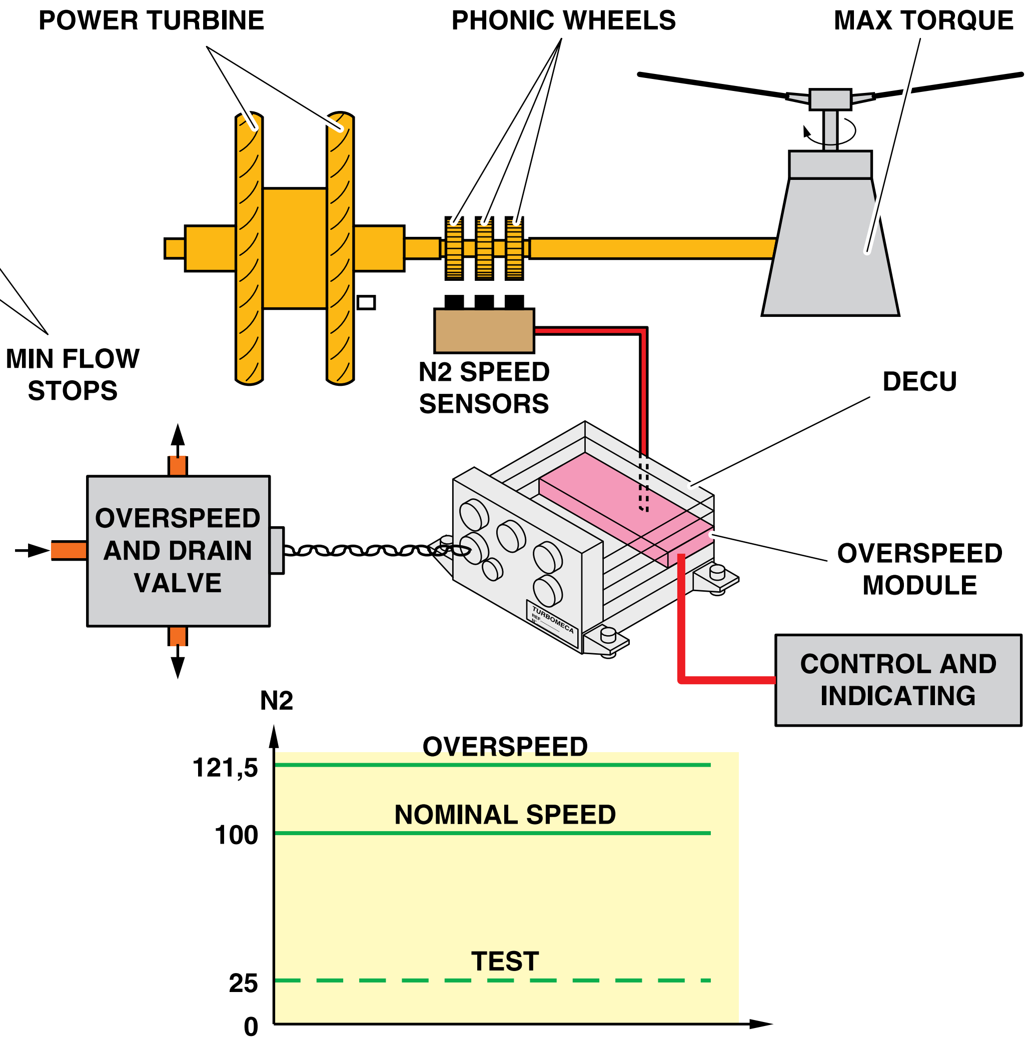
This protection system essentially provides for a power shaft failure which would cause a very rapid acceleration which could not be contained by the control unit. It includes two speed sensors, a module of the DECU and the overspeed and drain valve.

This system provides an automatic shut-down of the engine in the event of power turbine overspeed. The system requires a very quick response and a high reliability.

Refer to the corresponding DECU unit for more details.



FUEL FLOW LIMITS



POWER TURBINE OVERSPEED PROTECTION

CONTROL SYSTEM - OPERATION (12)

CONTROL SYSTEM - OPERATION (13)

Manual control

A mechanical control is connected to the Fuel Control Unit. It is used during starting and shut-down, but also as a manual control in the event of a control system failure.

Stop (0° to ≈ 7°)

The two valves are closed, the cam keeps the needles closed, there is no flow.

Automatic starting (12° to 23°)

The main valve is partially open, the flow is metered by the start servo-valve (controlled by the DECU).

Acceleration (23° to 52°)

The main valve progressively opens and beyond a certain angle, the cam no longer acts on the metering valve.

Flight (52°)

The main valve is fully "open" and the flow is metered by the control system.

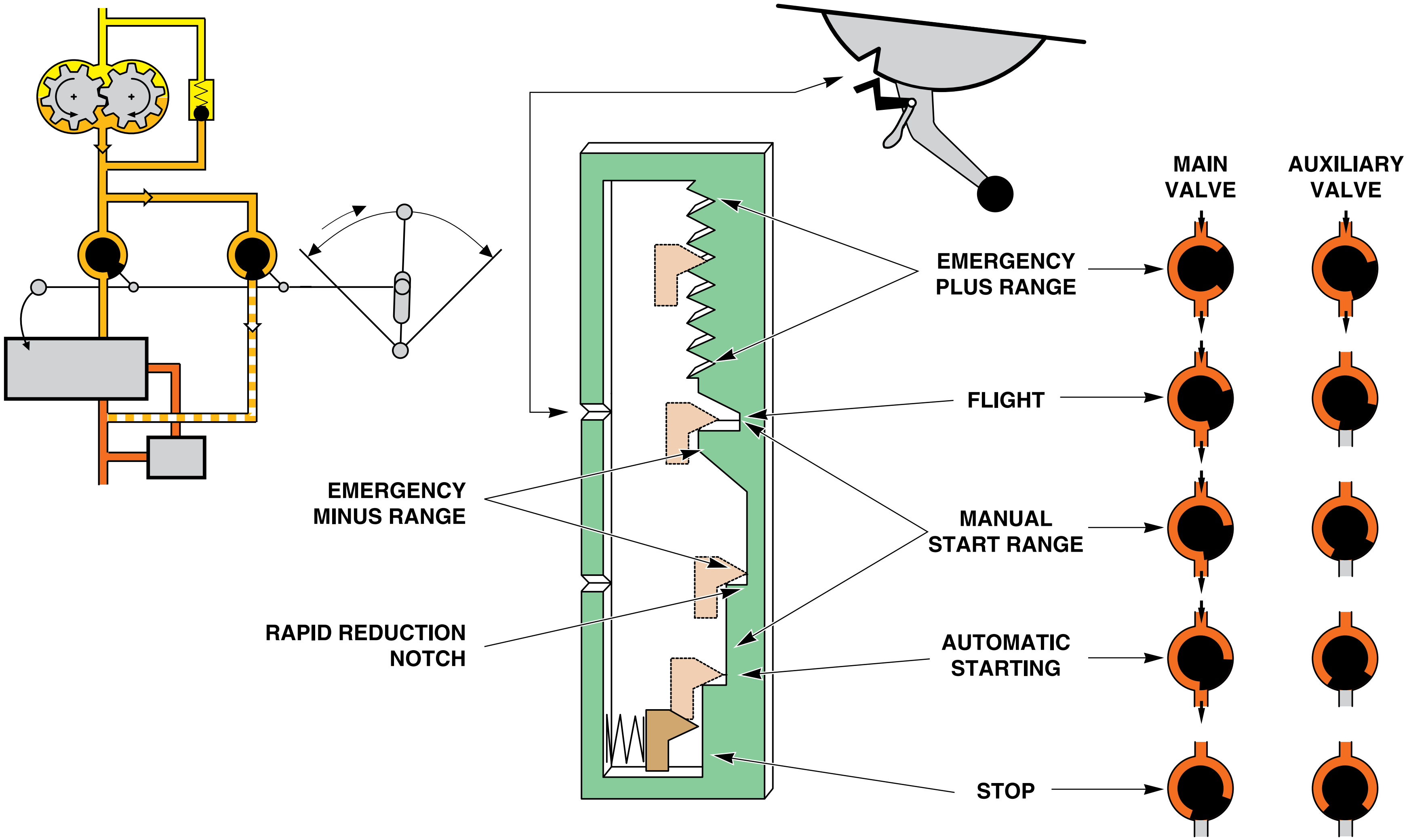
Emergency minus range

This range, comprised between the rapid reduction notch and the flight notch, permits a manual control through the main valve in case of control system failure.

The rapid reduction notch (30°) maintains the main fuel flow valve partially open to prevent engine flame out in manual control.

Emergency plus range (62° to 90°)

The auxiliary valve opens and provides a flow which by-passes the control system. The max flow is limited.



MANUAL CONTROL
CONTROL SYSTEM - OPERATION (13)

CONTROL SYSTEM - OPERATION (14)

Twin-engine configuration

Principle of load sharing

Under normal conditions, the helicopter rotor is driven by the power turbines of the two engines ; consequently :

NR = k N2 eng 1 = k N2 eng 2

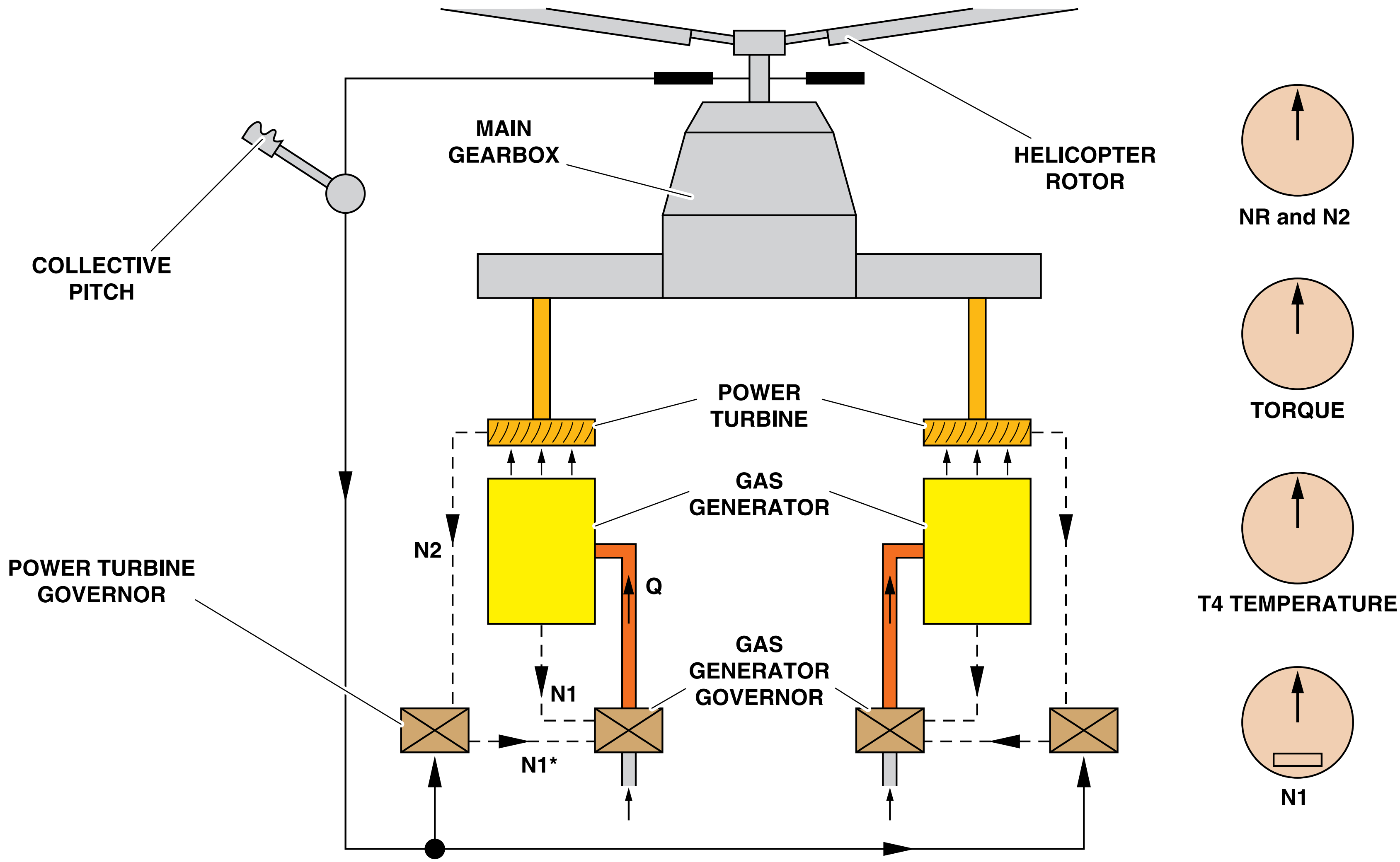
As the speed signals received by the two governors are identical (which is also true for collective pitch signals), they determine identical N1 settings which are sent to the gas generator governors, which meter the flows in order to keep them constant.

As the power is closely linked to the N1 speed, and as the power turbine efficiency varies little from one turbine to another, a good load share is obtained.

Operation on a single engine

In this case, the engine which stays running supplies the power, and the stopped engine is uncoupled by the free wheel.

The limit rating of the operating engine is represented by an OEI rating, which is automatically set by the DECU (refer to OEI ratings).



TWIN-ENGINE CONFIGURATION

CONTROL SYSTEM - OPERATION (14)

CONTROL SYSTEM - OPERATION (15)

Failure processing

The control system ensures a continuous monitoring (Built In Test Equipment) of all the parameters : circuit continuity, signal validity, tests before starting, power supply, etc.

Three pre-determined levels of failure are set :

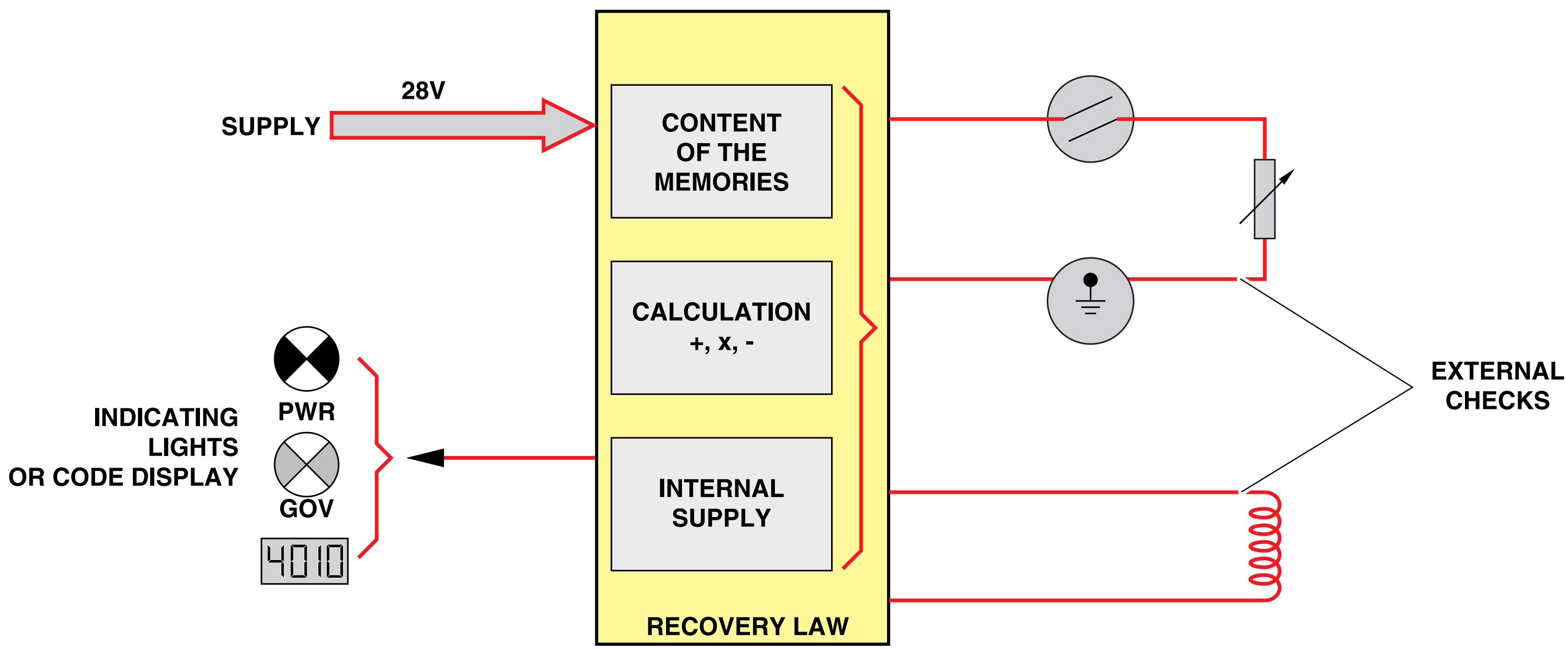
- Major failure : the red indicating light "PWR" illuminates and the DECU sets the engine rating at 85 % N1 (e.g. : failure of two N2 channels)
- Minor failure : the amber indicating light "GOV" illuminates and the fuel control is achieved by means of recovery laws (loss of N1 signal and LVDT sensor)
- Loss of redundancy : the amber indicating light "GOV" flashes during engine shut-down. Indication by the maintenance system, and maintenance corrective action on ground (e.g. : loss of one 28V supply, or a N2 channel).

Recovery laws

In case of failure of one of the DECU analog inputs, the control system operates from recovery laws : these recovery values are substituted for the faulty values until the input becomes correct. The table shows these different laws.

Note : *The loss of the air intake t1 signal causes the DECU to operates with the t0 signal from the helicopter air data system. If these two sensors are defective, the control system uses the corresponding recovery law.*

Pitch θ	Failure if $\theta > 95\ \%$ $\theta < 5\ \%$ $\frac{d\theta}{dt} > \pm 200\ \%/s$ Recovery law = 16° of pitch
N1 speed	Failure if $\frac{dN1}{dt} > 28\ \%/s$ $\frac{dN1}{dt} < -66\ \%/s$ Stabilised rating = 85 % of N1
N2 speed (two channels)	Failure if $\frac{dN2}{dt} > 576\ \%/s$ $\frac{dN2}{dt} < -96\ \%/s$ Stabilised rating = 85 % of N1
P0 pressure	Failure if $P0 > 110$ kPa $P0 < 260$ kPa $\frac{dP0}{dt} > \pm 5$ kPa Recovery law = 75 kPa
t1 temperature	Failure if $t1 > 59$ °C $t1 < -58$ °C $\frac{dt1}{dt} > \pm 30$ °C/s Recovery law = +15 °C
t4 temperature	Failure if $-55° > t4 > 1050$ °C if $N1 < 17\ \%$ $+150° > t4 > 1050$ °C if $N1 \geq 17\ \%$ $\frac{dt4}{dt} > \pm 210$ °C/s Recovery law = 780 °C



FAILURE PROCESSING

CONTROL SYSTEM - OPERATION (15)

CONTROL SYSTEM - OPERATION (16)

Maintenance aid

The DECU includes a Built In Test Equipment which outputs a failure diagnosis to the instrument panel through a RS 232 serial data link.

This maintenance system identifies the faulty system and locates the defective component.

The DECU also stores in its memory the cycles and operating times. These data are sent to the Maintenance Test Control Panel through the RS 232 serial data link.

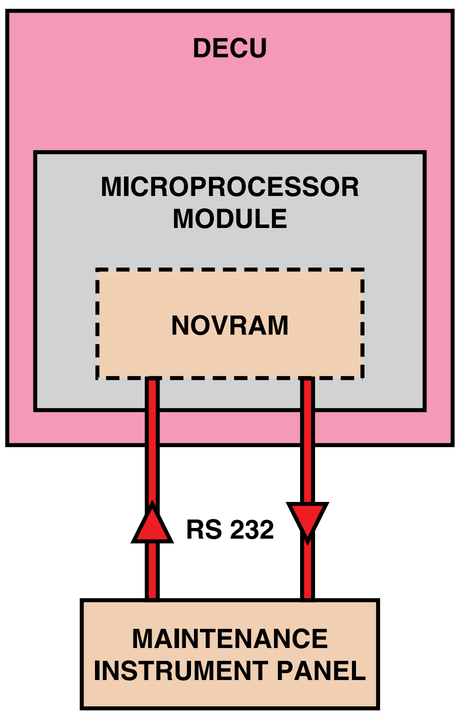
Health monitoring system

The system compares the engine in operation, with a "reference" engine under the same conditions.

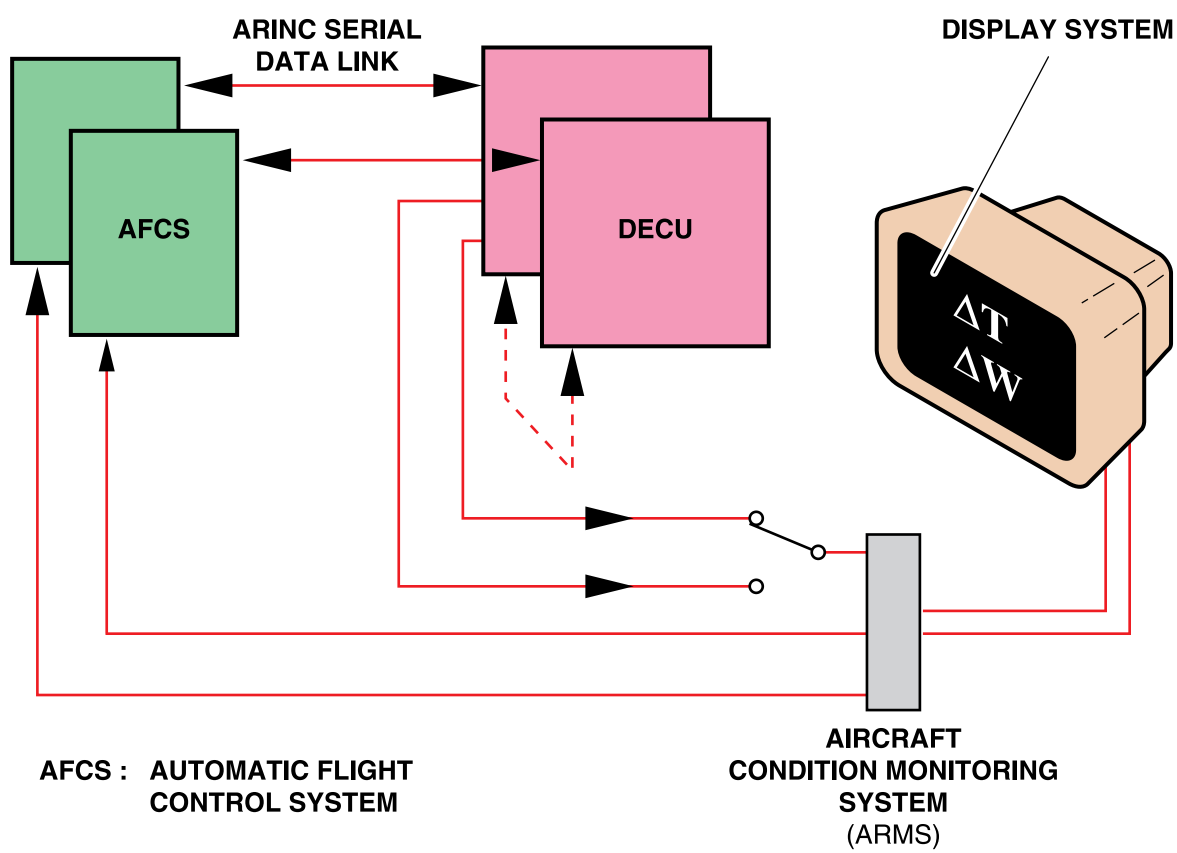
The "reference" engine is the "minimum" engine which would give the aircraft guaranteed performance.

The data of the reference engine are stored in the memory of the Automatic Flight Control System.

Note *: AFCS : Automatic Flight Control System. Refer to the chapter "INDICATING SYSTEM" and to the chapter "MAINTENANCE" for more details on the maintenance aid and the health monitoring system.*



MAINTENANCE AID



HEALTH MONITORING

CONTROL SYSTEM - OPERATION (16)

FUEL CONTROL UNIT - GENERAL

Function

The FCU ensures the supply and control of the fuel.

Position

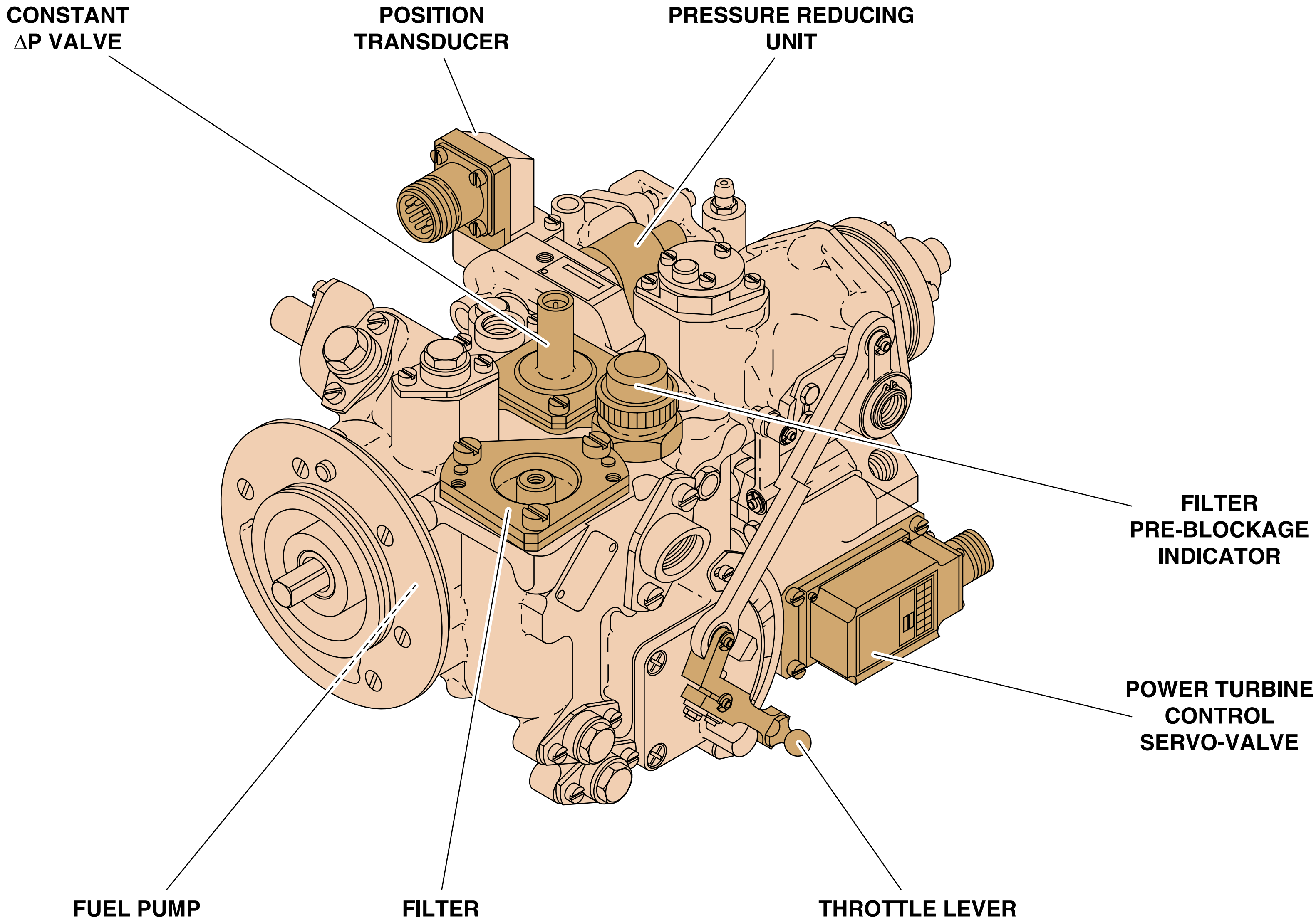
- On the left rear upper part of the accessory gearbox.

Main characteristics

- Type : hydro-mechanical with an electrical servo-valve
- Mass :
- Dimensions :
- Hydraulic fluid : fuel.

Main components

- Fuel pump (with pressure relief valve)
- Pressure reducing valve
- Filter (with by-pass valve and pre-blockage indicator)
- Manually controlled valves
- Power turbine control servo-valve
- Position transmitter LVDT
- Control system components (N1 governor, N2 governor, acceleration controller)
- Metering unit (metering needles, constant ΔP valve).



FUEL CONTROL UNIT - GENERAL

FUEL CONTROL UNIT - GENERAL DESCRIPTION

The fuel control unit includes all the components necessary for the supply, filtering, control and metering of the fuel.

Fuel pump

Gear type pump driven by the engine. The pump has a pressure relief valve.

Fuel filter

Metallic filter at the pump outlet. It has a by-pass valve and a pre-blockage indicator.

Pressure reducing valve

Diaphragm valve which provides a reduced pressure to supply the hydraulic control system.

Manual control

Manual lever which operates the main valve, the auxiliary valve and the acceleration controller cam.

Power turbine control servo-valve

Servo-valve with two windings electrically supplied by the DECU. It includes an electrical stage (windings) and a hydro-mechanical stage (flap valve and potentiometric jet).

Position transmitter

This is a Linear Voltage Displacement Transducer (LVDT) which transmits to the DECU the position of the N1 governor diaphragm.

Speed governor

Of hydro-mechanical type, it includes :

- The N1 speed datum diaphragm (displacement between the min and max N stops)
- The N1 speed detection flyweight
- A hinged lever and potentiometric jet for the modulated pressure
- A temperature compensation capsule
- A damping device (isochronous piston and scroll)
- A working piston for the metering valve control
- Calibrated jets with filtering strainers for the modulated pressures.

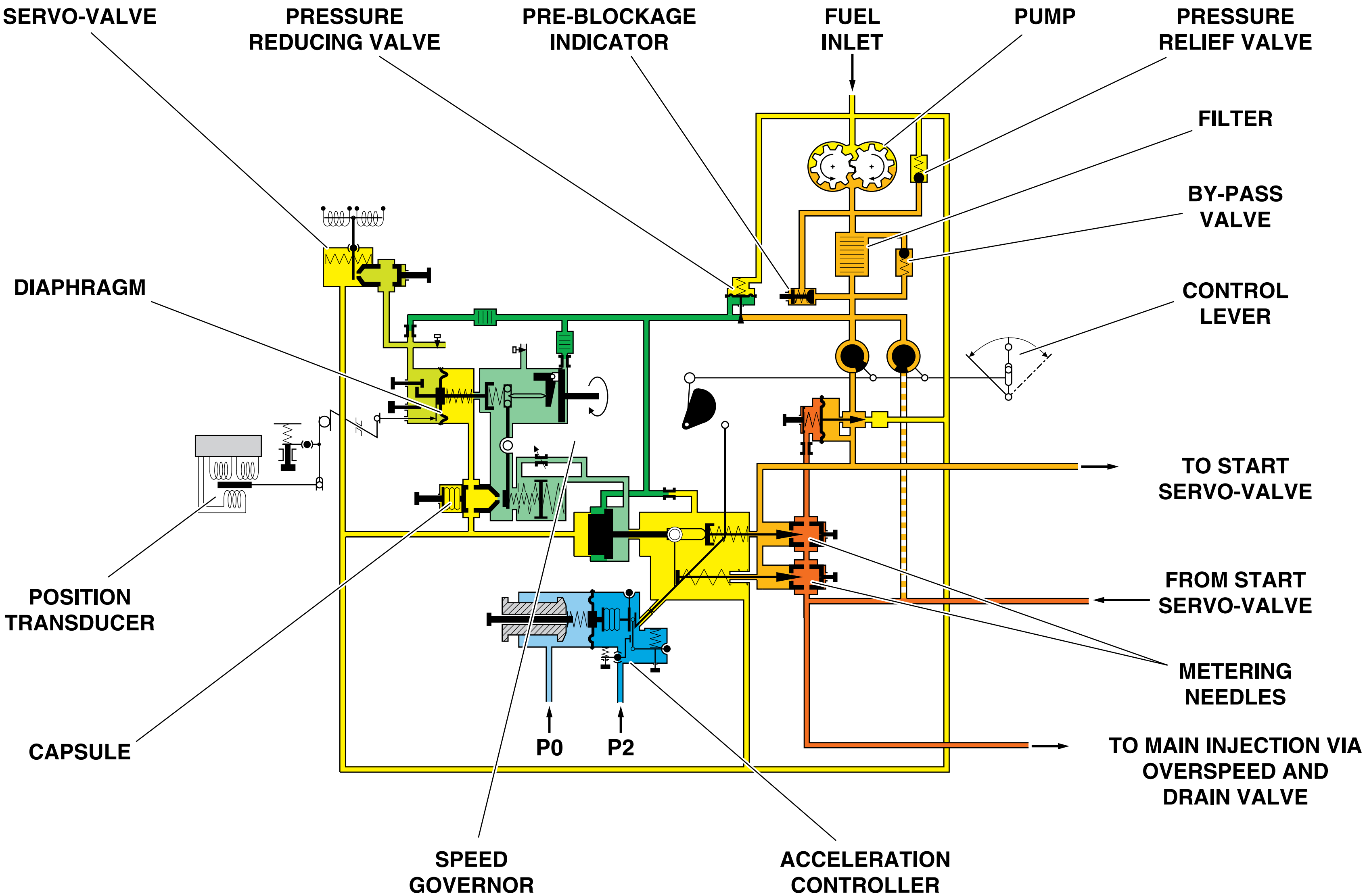
Acceleration controller

Included in the metering unit, it comprises :

- A barostatic corrector
- An acceleration controller capsule
- A lever mechanism
- Adjusting devices (max flow, acceleration slope).

Metering unit

It essentially comprises two metering needles (acceleration metering needle and deceleration metering needle) and a constant ΔP valve.



FUEL CONTROL UNIT - GENERAL DESCRIPTION

FUEL CONTROL UNIT - PUMP

Function

The pump supplies fuel under determined conditions of pressure and flow.

Position

- At the front part of the FCU.

Main characteristics

- Type : gear type
- Rotation speed : f (N1)
- Relief valve setting : 4000 kPa (580 PSI).

Description

The pump includes two gears :

- A driving gear, driven by a shear-type shaft
- A driven gear which drives the flyweight of the speed governor.

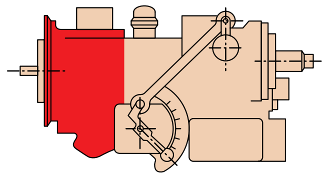
The gears are supported on self adjusting journal bearings. Two lip seals ensure the shaft sealing.

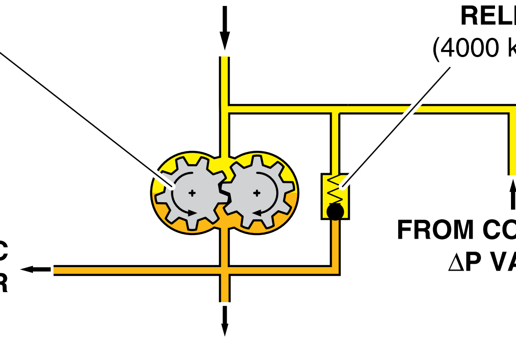
The pump includes a tapered pressure relief valve.

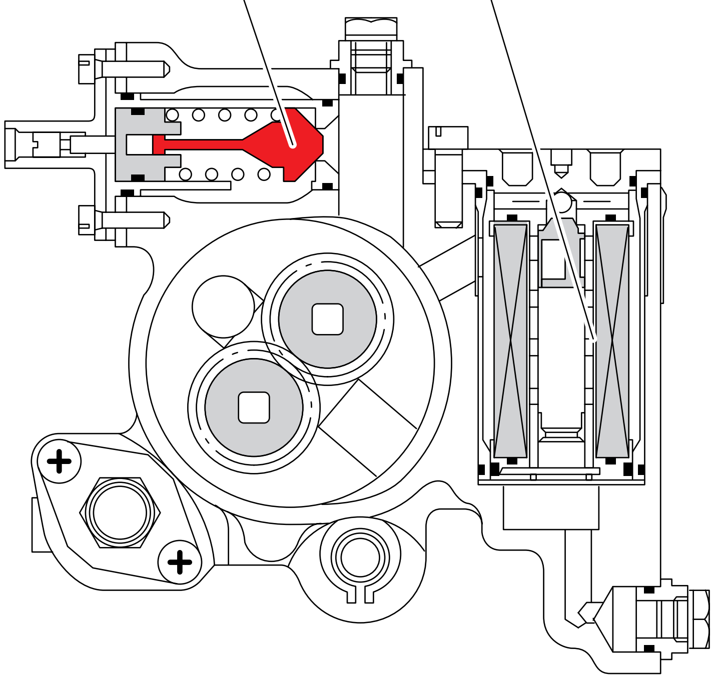
Operation

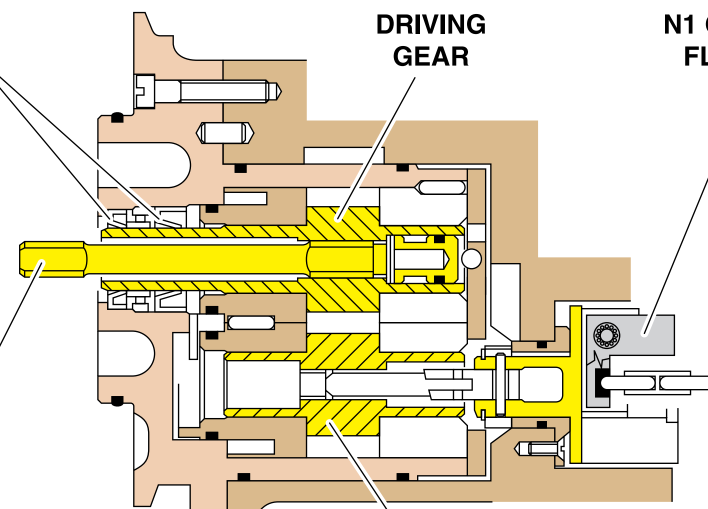
The amount of fuel supplied by the pump is always greater than that required by the engine ; the excess is returned to the pump inlet by the constant ΔP valve.

In the event of overpressure, the pressure relief valve opens and returns some of the flow to the pump inlet.









FUEL CONTROL UNIT - PUMP

FUEL CONTROL UNIT - FILTER

Function

The filter retains any particles that may be in the fuel in order to protect the metering unit components.

Position

- In the system : at the pump outlet
- On the FCU : at the left front upper part.

Main characteristics

- Type : metal mesh filter
- Filtering ability : 20 microns
- By-pass valve setting : ΔP 200 kPa (29 PSID)
- Pre-blockage indicator setting : ΔP 150 kPa (21.75 PSID).

Description

The filter assembly comprises :

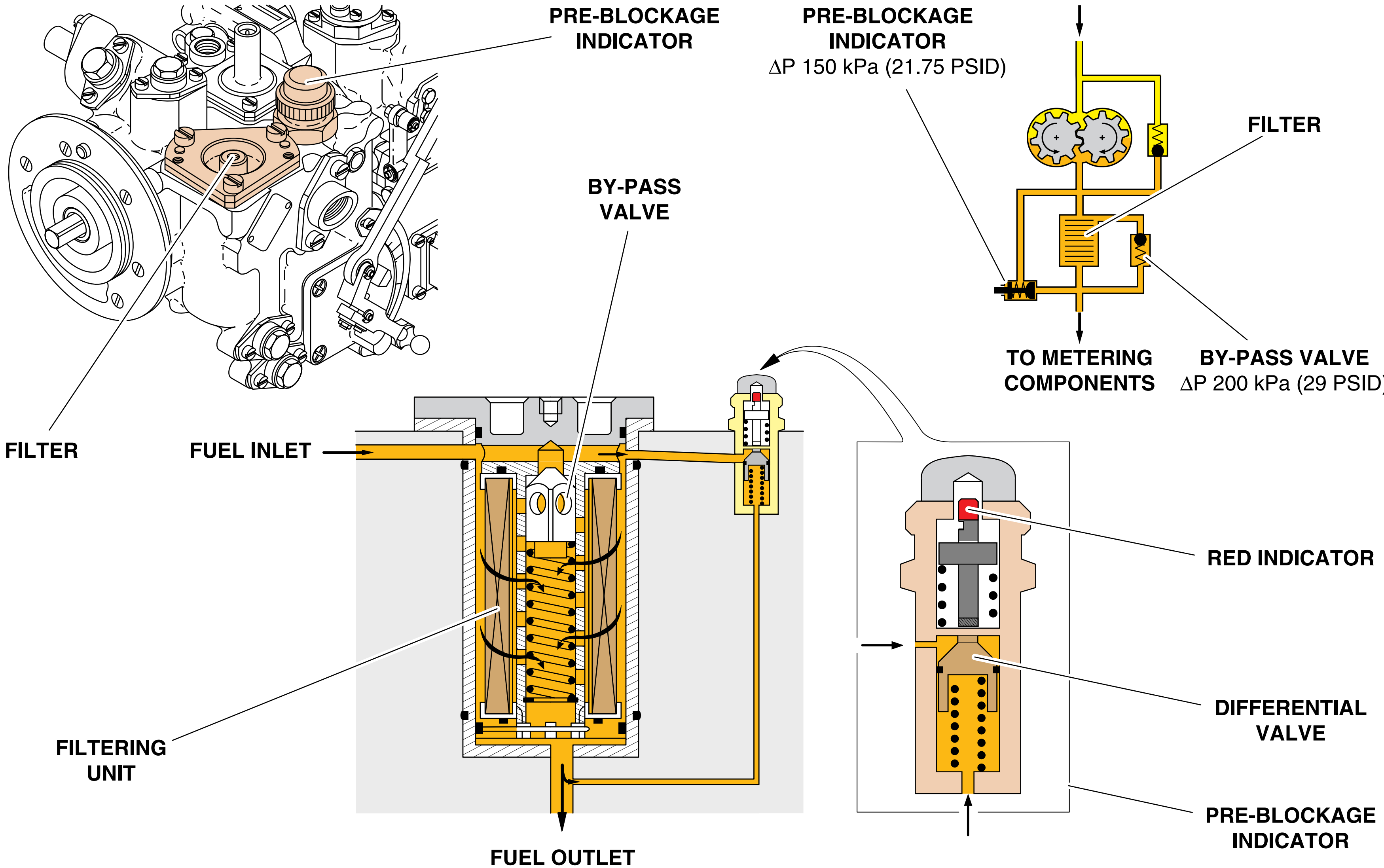
- A metal cartridge mounted in the FCU body
- A by-pass valve : differential valve pre-loaded by a spring and located inside the metal cartridge
- A pre-blockage indicator : differential valve with magnet part and indicator.

Operation

During normal operation, the fuel flows from the outside to the inside of the filter. It retains particles larger than 20 microns.

When the filter begins to clog the indicator appears.

When the filter becomes sufficiently clogged the by-pass valve opens.



FUEL CONTROL UNIT - FILTER

FUEL CONTROL UNIT - PRESSURE REDUCING VALVE

Function

This valve provides a reduced pressure to supply the control hydraulic system.

Position

- In the system : after the filter
- In the FCU : middle part, right hand side.

Main characteristics

- Type : diaphragm valve
- Setting : 400 kPa (58 PSI).

Description

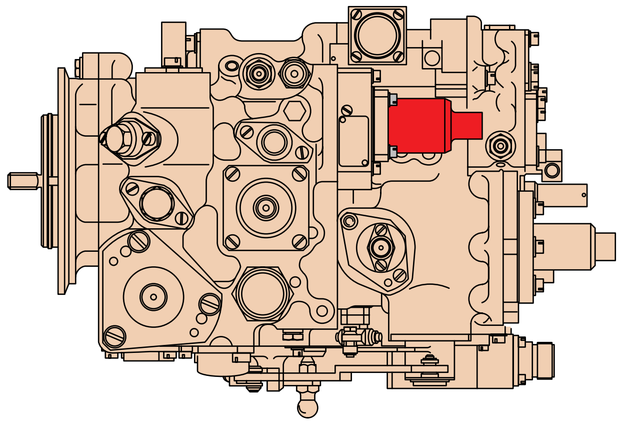
The valve includes a diaphragm which is subjected on one side to the reduced pressure and on the other to the low pressure plus the force of a spring.

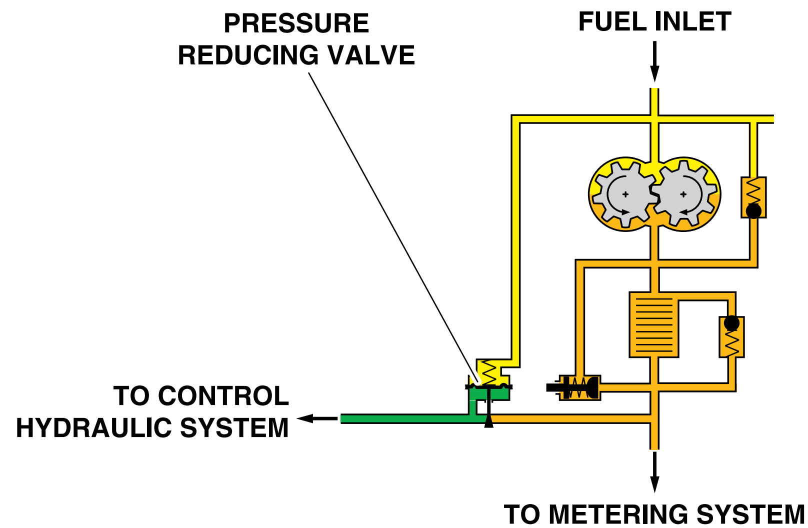
The diaphragm controls a metering valve which meters the fuel flow.

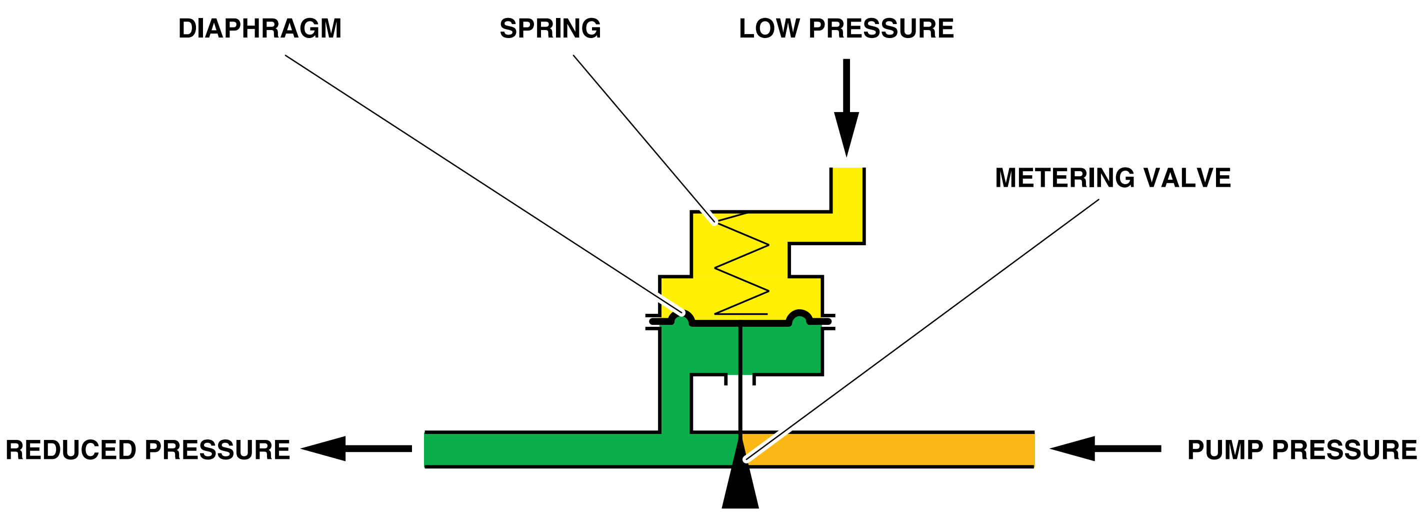
Operation

When the engine is stopped, the valve is maintained open under the spring force. During normal operation, the fuel which comes from the pump acts on the diaphragm and the metering valve reduces the flow in order to reduce the pressure.

The reduced pressure is used to elaborate modulated pressures and as a reference pressure.







FUEL CONTROL UNIT - PRESSURE REDUCING VALVE

FUEL CONTROL UNIT - MECHANICAL CONTROL

Function

The FCU mechanical control is used for starting, shut-down and emergency control.

Position

- In the system : between the pump and the metering unit
- On the FCU : left side of the FCU.

Main characteristics

- Type : mechanical lever and rotating valves
- Graduation : 0° to 90°.

Description

The lever operates two valves and a cam. The main valve is located on the supply line of the main metering unit.

The auxiliary valve is located in by-pass of the metering unit.

The cam acts on the lever system of the acceleration controller.

The control lever moves in front of a graduated scale.

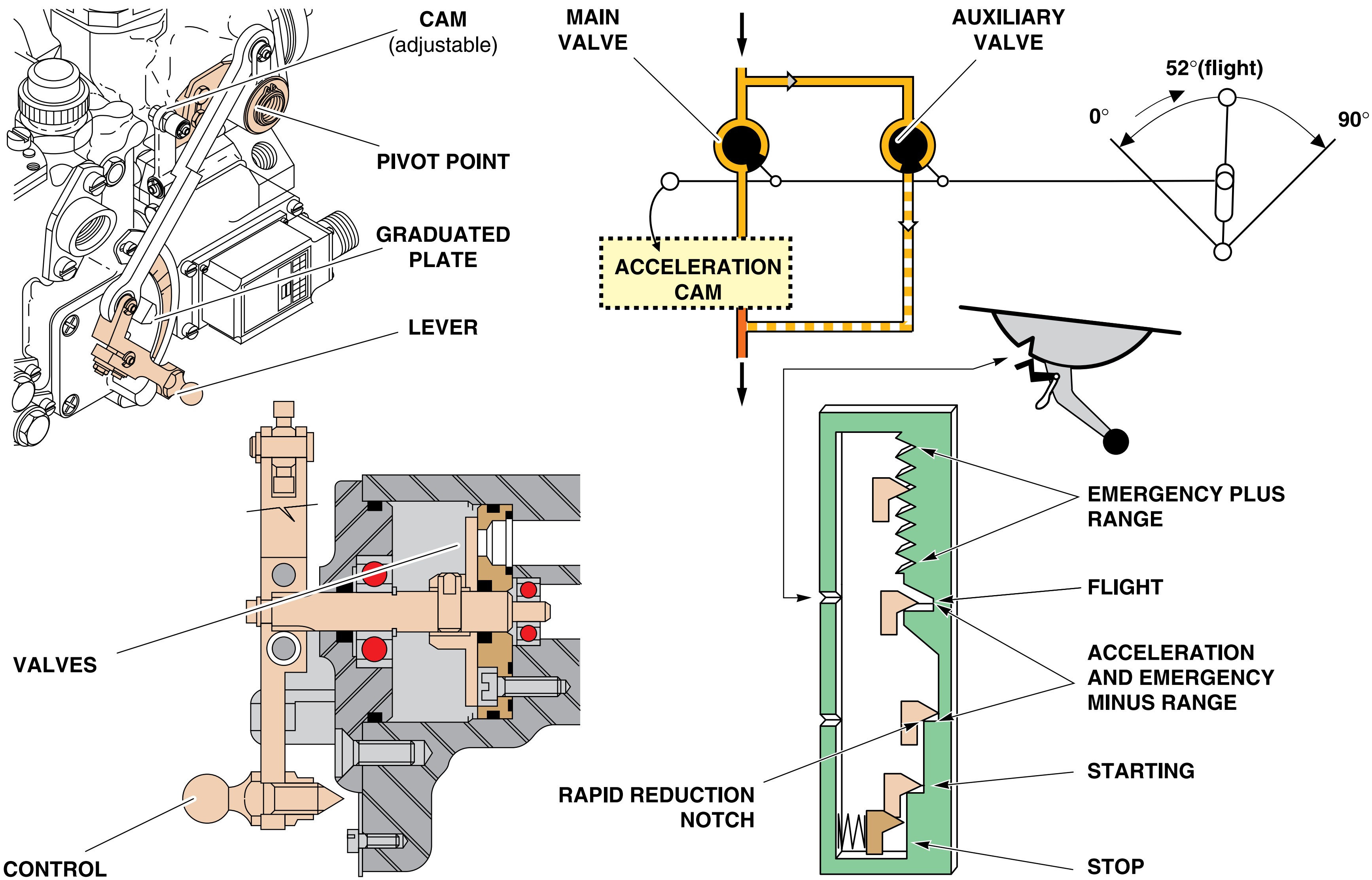
Operation

The main positions are :

- Stop (0° to 7°). The two valves are closed
- Starting (12° to 23°). The main valve is partially open
- Flight (52°). The main valve is fully open
- Reduction (30°). The main valve is partially open.

We can also note :

- The manual starting range (7° to 52°)
- The emergency plus range (62° to 90°). The auxiliary valve opens progressively
- The emergency minus range (52° to rapid reduction notch).



FUEL CONTROL UNIT - MECHANICAL CONTROL

FUEL CONTROL UNIT - METERING UNIT

Function

This unit meters the fuel flow under the control of the DECU.

Position

Rear part of the FCU.

Main characteristics

- Type : metering needles, constant ΔP valve with diaphragm

- Flow : min stop on metering needles, max stop on acceleration controller.

Description

The unit comprises an acceleration metering needle, a deceleration metering needle, and a constant ΔP valve.

The metering needles are profiled needles which moves in orifices.

The acceleration metering needle, has a spring which tends to open it. It is controlled by the speed governor.

The deceleration metering needle, of the same type provides a parallel flow ; it is directly controlled by the lever of the acceleration controller.

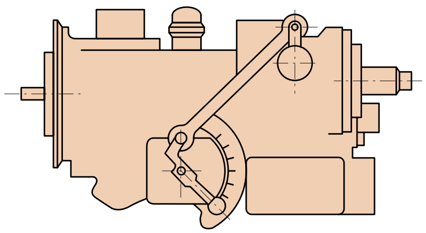
The constant ΔP valve has a diaphragm subjected to the fuel pressure difference across the metering needles plus the spring force. The diaphragm controls a valve which determines the return of excess fuel.

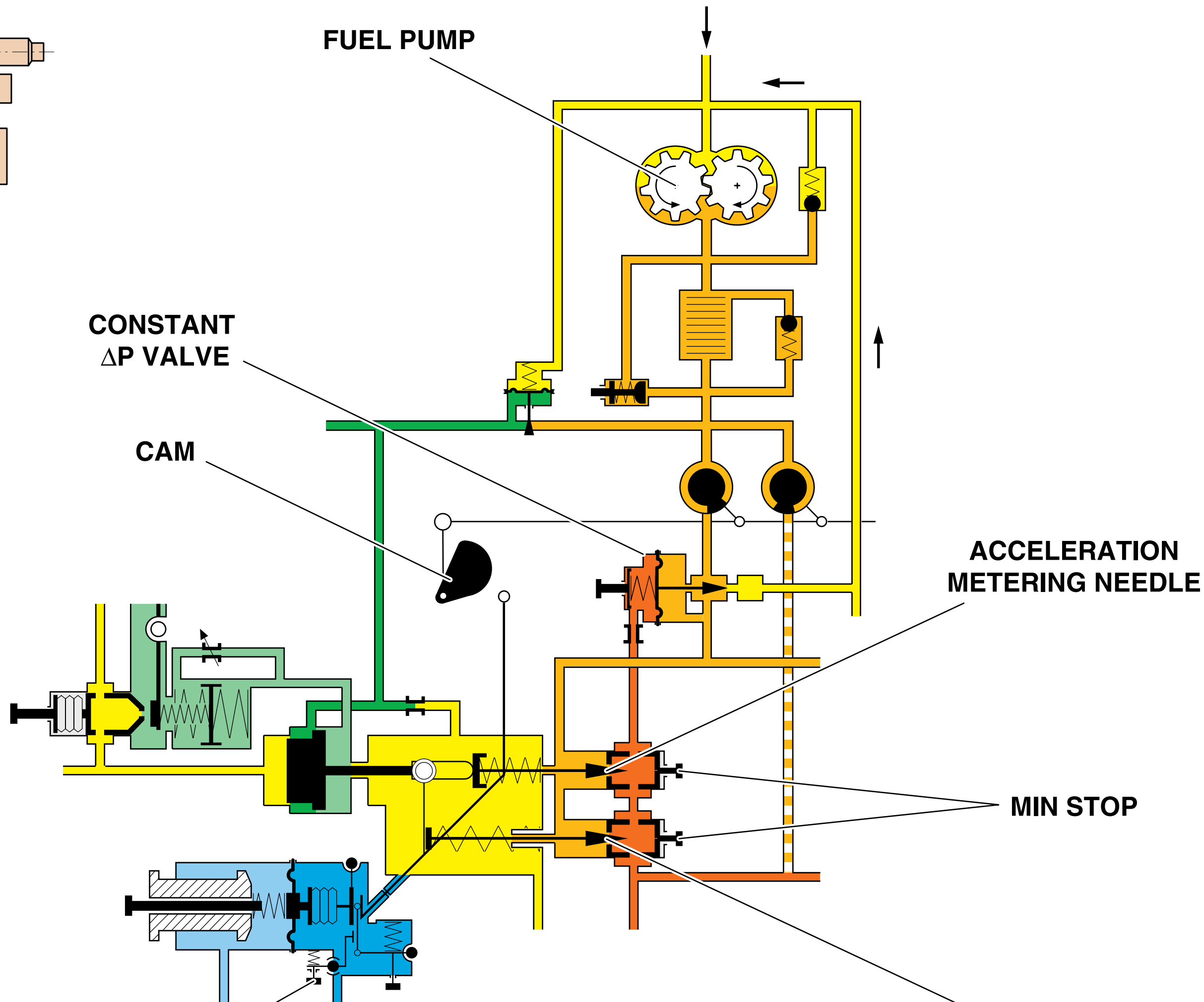
Operation

In normal operation, the fuel flows between the orifice and the metering needles (acceleration metering needle flow + deceleration metering needle flow).

In order to obtain a flow which depends only on the position of the metering valve, a constant ΔP valve maintains a constant pressure difference on either side of the metering needles. Any change in the differential pressure is detected by the valve which returns a variable quantity of fuel to the pump inlet. In fact the pump always supplies a flow which is higher than the engine requirements, and the surplus fuel is returned to the inlet through this valve. ΔP variations are caused by the pump, the downstream system, and obviously by the displacements of the metering valve. For example, when the metering valve opens, the ΔP decreases, the diaphragm moves and the valve closes the return. The flow to the engine increases, the upstream pressure increases, and the differential pressure returns to its nominal value.

During starting the cam maintains the valves closed ; the flow through the metering needles is very low (≈ 10 l/h (22 lbs/hr)). During acceleration (above 35°), the cam has no effect.





FUEL CONTROL UNIT - METERING UNIT

FUEL CONTROL UNIT - ACCELERATION CONTROLLER

Function

The controller limits the fuel flow variations in order to avoid compressor surge.

Position

Rear middle part of the FCU.

Main characteristics

- Type : mechanical
- Control : acceleration and deceleration.

Description

Main components :

- Aneroid capsule, which is subjected to the compressor discharge pressure (P2)
- Barostatic device ; diaphragm subjected to the atmospheric pressure (P0)
- Lever mechanism which links the capsule movement to the metering valve control. The end of one lever is forked, and the control plunger of the acceleration metering needle moves in this fork
- Cam : actuated by the control lever, it maintains the metering valve closed during starting
- The forked acts directly on the deceleration metering needle.

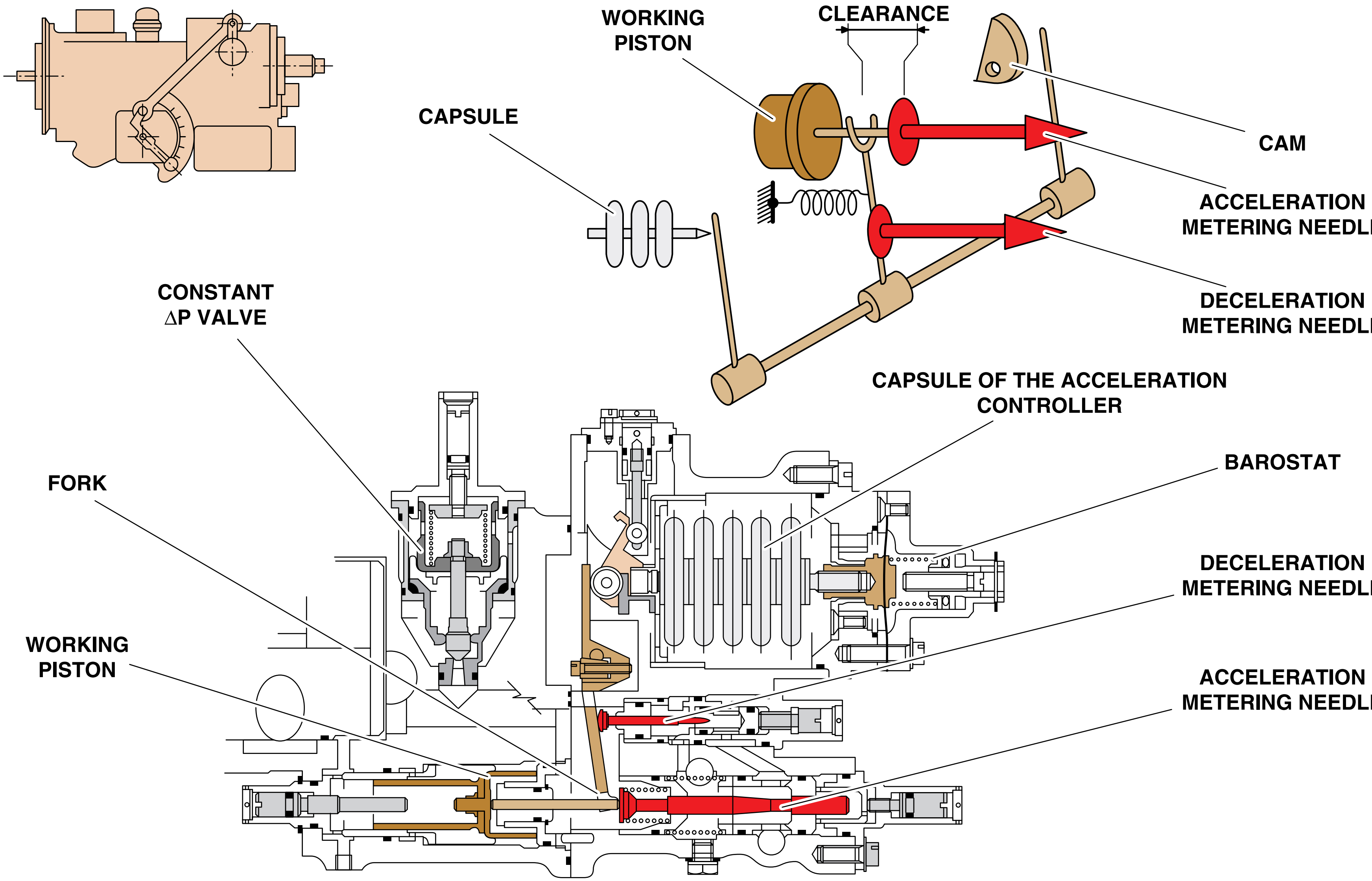
Operation of the acceleration controller

Under stabilised conditions, there is a clearance between the fork and the acceleration metering needle. The position of the metering needle is determined by the working piston of the governor.

Under load-increase transient conditions, the governor "responds" and the working piston moves. Under the action of its spring, the metering needle opens to the fork. This displacement represents the instant flow increase, which initiates the acceleration. Then, the subsequent increase in the P2 pressure causes the capsule to contract ; this causes the metering needles to open progressively. Thus the engine accelerates as a function of the P2 increase to avoid compressor surge.

Operation of the deceleration controller

Under load decrease transient conditions, the governor also responds very rapidly, and the acceleration metering needle closes. However, a certain quantity of parallel flow is maintained by the deceleration metering needle which closes only after expansion of the capsule due to the P2 variation. This control avoids flame-out which could occur on very rapid deceleration.



FUEL CONTROL UNIT - ACCELERATION CONTROLLER

FUEL CONTROL UNIT - CONTROL SERVO-VALVE

Function

The servo-valve elaborates an N1 speed setting as a function of the signal transmitted by the DECU.

Position

Middle part, left side of the FCU.

Main characteristics

- Type : servo-valve with two windings
- Input current : - 30 to + 30 mA
- Modulated pressure : ≈ 200 to 400 kPa (29 to 58 PSI).

Description

The servo-valve is fitted on the left side of the FCU. It includes an electric stage and a hydraulic stage.

The electric stage includes a solenoid with two windings which produce magnetic forces which are a function of the variable current provided by the DECU.

The hydraulic stage includes a flap valve which moves in front of a potentiometric jet.

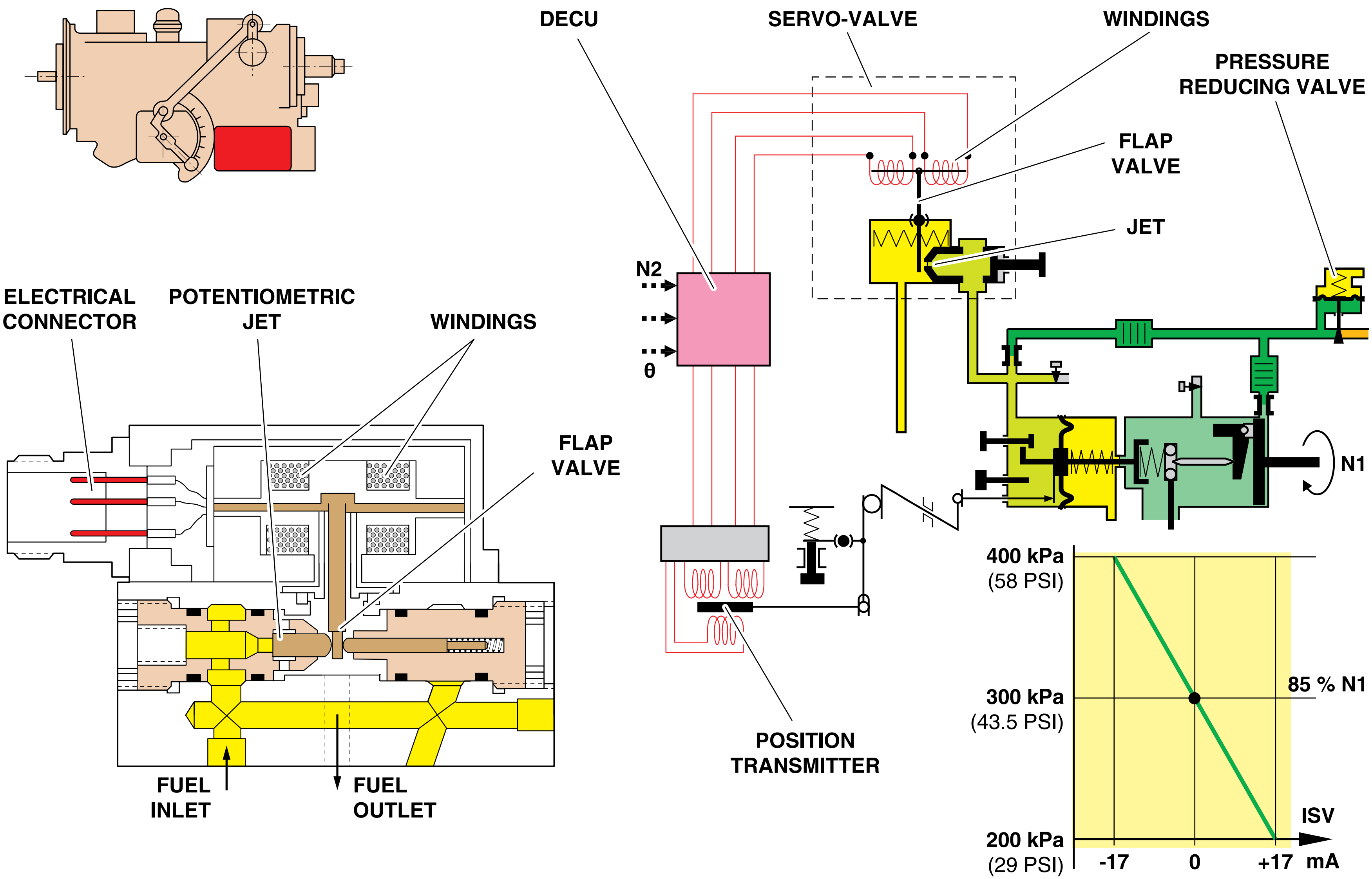
Operation

Fuel from the fuel pump passes through the pressure reducing valve, which reduces the pressure. Then the fuel passes through a strainer and a fixed calibrated orifice. A certain quantity of fuel passes through the potentiometric jet of the servo-valve to the low pressure system. A modulated pressure, which is a function of the leak, builds up ; this pressure acts on the diaphragm, whose position determines the required N1 speed setting.

When the electrical current supplied by the DECU varies, the magnetic forces cause the flap valve to move, which modifies the leak rate and thus the modulated pressure.

The variation of the modulated pressure causes the diaphragm to move ; the position is transmitted to the DECU by the position transmitter.

The current varies between -30 and +30 mA, which results in a modulated pressure between max N1 and min N1. In case of a total electric failure, the 0 mA determines a modulated pressure of approximately 300 kPa (43.5 PSI) which corresponds to approximately 85 % N1 (average power to continue the flight).



FUEL CONTROL UNIT - CONTROL SERVO-VALVE

FUEL CONTROL UNIT - POSITION TRANSMITTER

Function

The transmitter transmits the N1 diaphragm position to the DECU for the speed control circuit.

Position

At the rear upper part of the FCU.

Main characteristics

- Type : Linear Voltage Differential Transducer
- Current :
  - Primary : constant frequency and amplitude (supplied by the DECU)
  - Secondary : frequency equal to the primary supply with variable amplitude.

Description

The transmitter includes :

- 1 primary winding supplied by a datum voltage provided by the DECU
- 2 secondary windings
- A moving core connected to the N1 diaphragm.

Operation

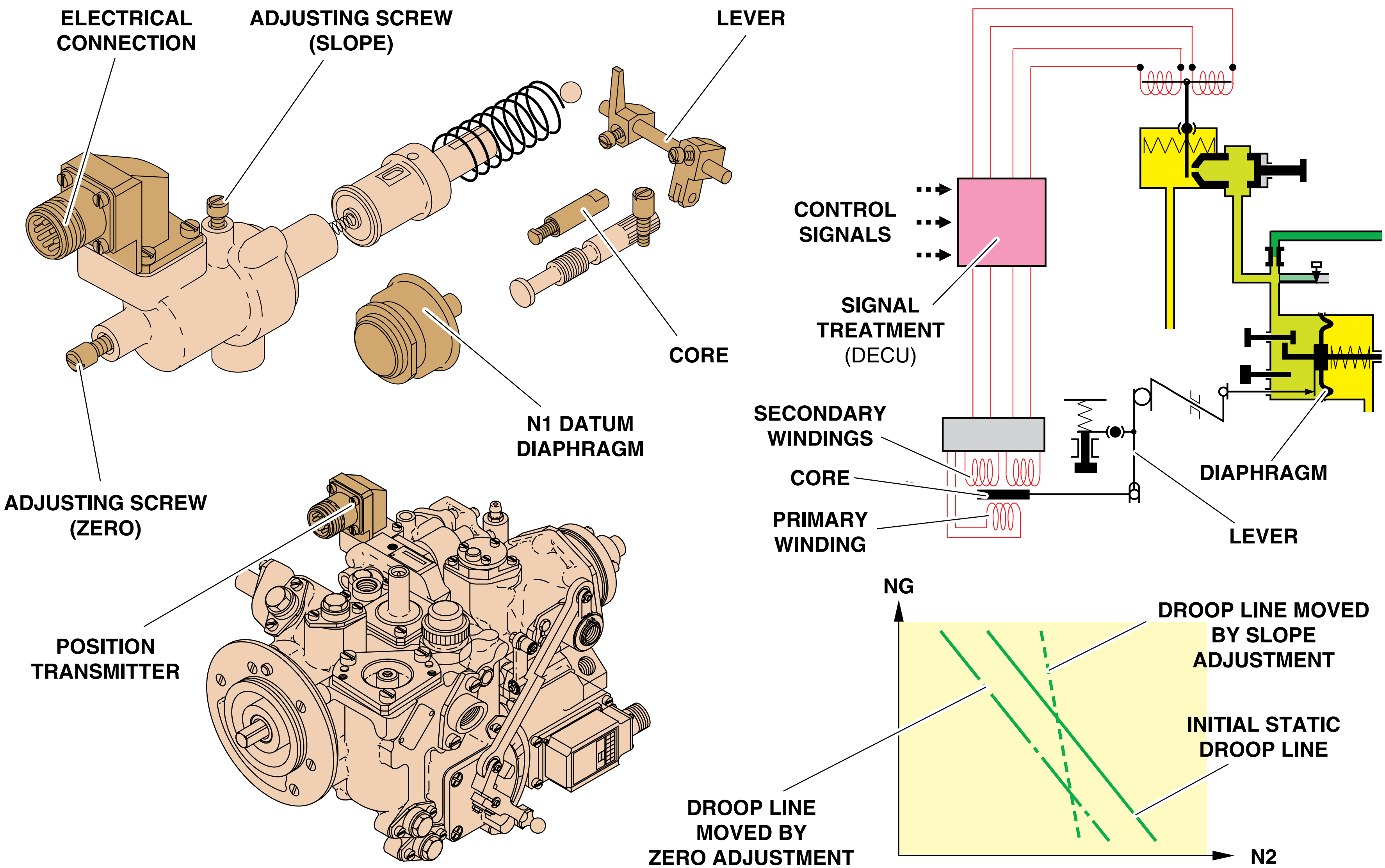
When the diaphragm is in the position equivalent to 85 % N1 the core is in the neutral position.

The magnetic field is equal in the two secondary windings and the alternating voltages that they produce are equal.

When the core moves out of the neutral position one secondary voltage increases whilst the other decreases.

Thus, by the direction of the signal variation and the calculation of the voltage difference, the direction and magnitude of displacement is measured.

It should be noted that two adjustments can be carried out on the transmitter. The position of the core in relation to the diaphragm can be adjusted by a slope screw and a zero screw.



FUEL CONTROL UNIT - POSITION TRANSMITTER

FUEL CONTROL UNIT - SPEED GOVERNOR - GENERAL

Function

The governor determines the N1 speed by metering the fuel flow.

Position

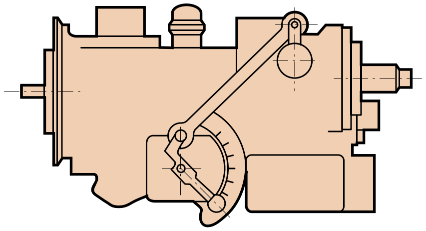
- In the FCU.

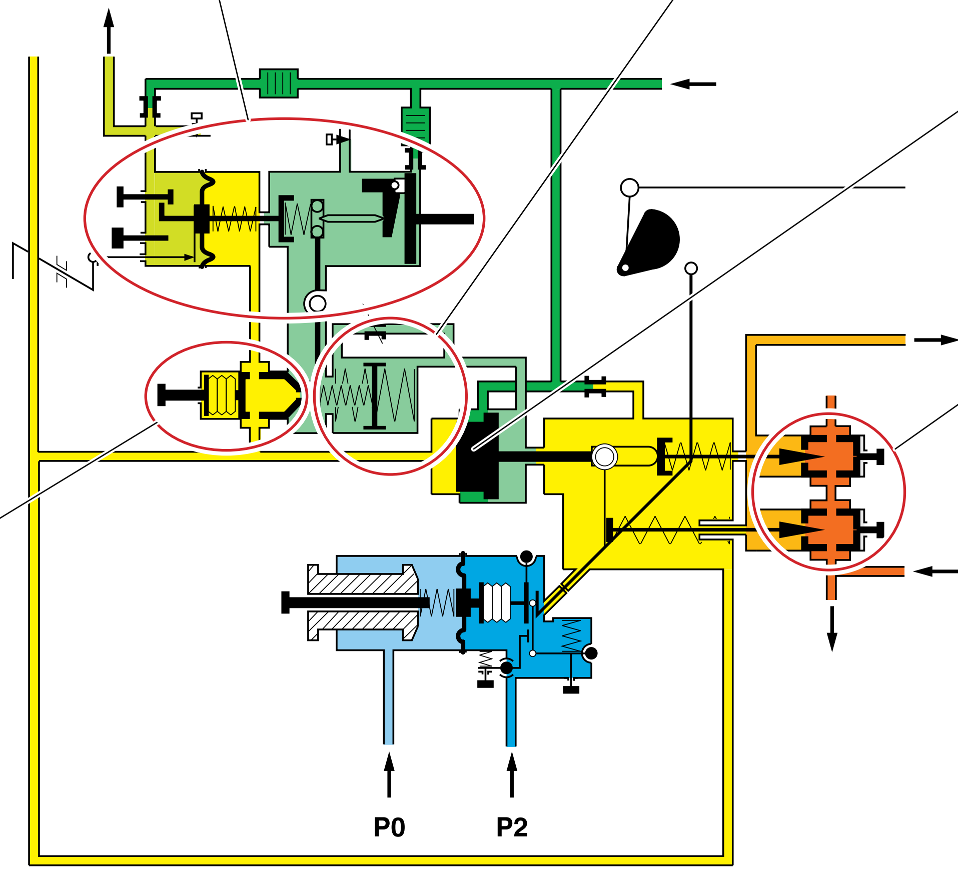
Main characteristics

- Type : integral hydromechanical
- Damping : isochronous
- Stops : min N1 and max N1
- Rotation speed : f (N1).

Main components

- Speed sensor
- Potentiometric jet
- Damping device
- Working piston
- Fuel metering needles.





FUEL CONTROL UNIT - SPEED GOVERNOR - GENERAL

FUEL CONTROL UNIT - SPEED GOVERNOR - DESCRIPTION

Speed sensor. It includes a flyweight driven at a speed proportional to N1 (in fact driven by the pump shaft). The flyweight centrifugal force is opposed to a counter spring which is loaded by the datum diaphragm. The diaphragm displacement is limited between two mechanical stops (min and max N1).

The balance of forces acts on an articulated lever whose lower part forms the flap valve.

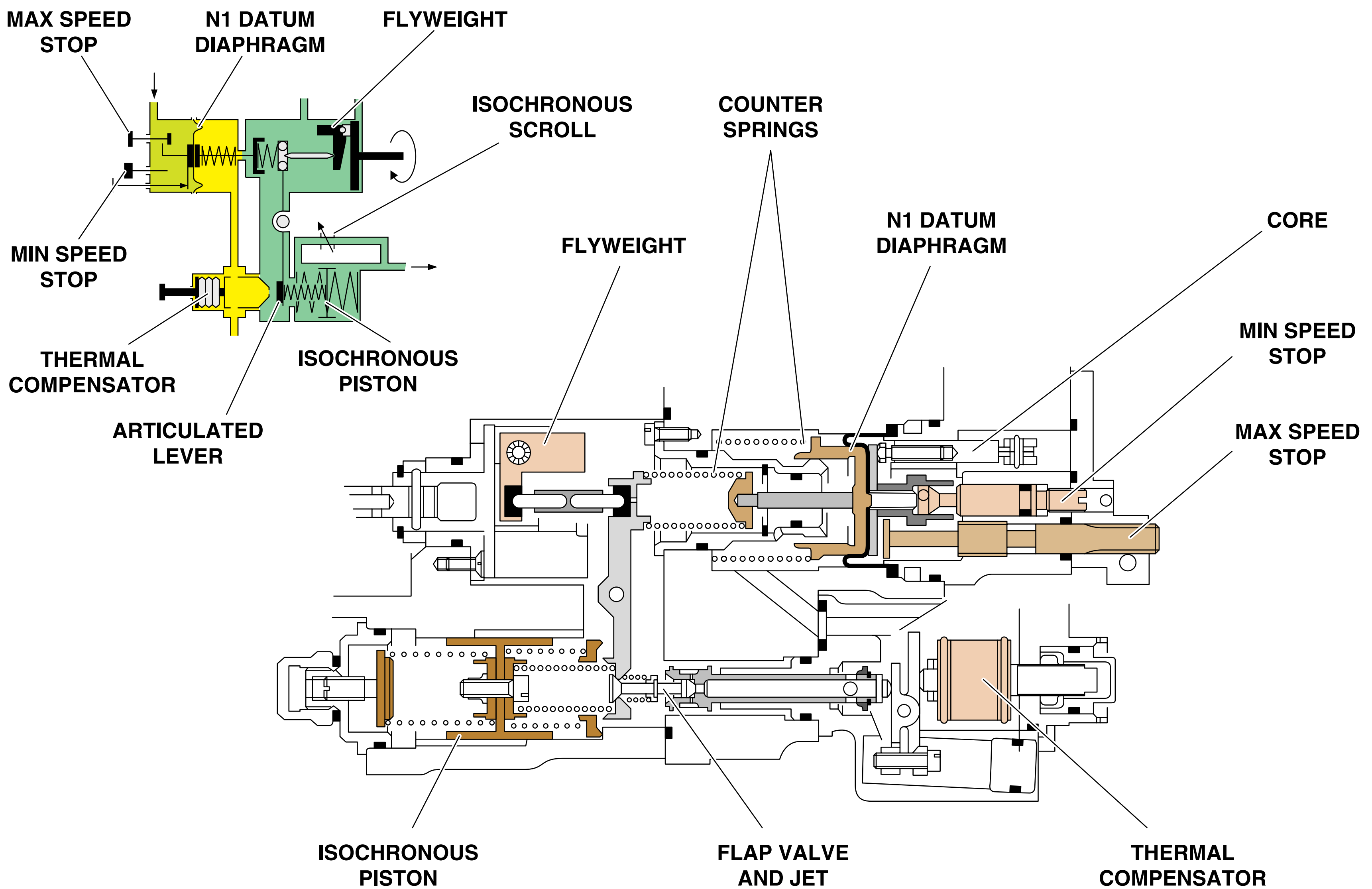
Potentiometric jet. This is a flap valve which moves in front of a calibrated orifice. The valve position determines the fuel leak and therefore the modulated pressure in the hydraulic system.

The potentiometric jet position is corrected as a function of the fuel temperature by a thermal compensator. This compensation moves the equilibrium point and has an effect on the max N1.

Damping device. Isochronous scroll and piston which damp the modulated pressure variations.

Working piston. The piston is subjected on one side to the modulated pressure, and on the other side to datum pressure. It controls the fuel metering needles through a rod and a plunger.

Hydraulic system. It includes the pressure reducing valve, the fixed calibrated orifices protected by strainers, and the ducts. We can note the drains on the two modulated pressure chambers.



FUEL CONTROL UNIT - SPEED GOVERNOR - DESCRIPTION

FUEL CONTROL UNIT - SPEED GOVERNOR - OPERATION

The operation is considered under stable conditions and under transient conditions.

Under stable conditions

The centrifugal force of the flyweight (real N1 speed) balances the counter spring force affected by the diaphragm (N1 datum).

The lever is set to a fixed position ; the flap valve is also set to a fixed position and determines a certain modulated pressure.

The working piston is in equilibrium and controls the position of the metering needle which determines the required fuel flow to obtain the datum rotation speed.

The system is in equilibrium.

Under transient conditions

Any speed variation is detected and the fuel flow is consequently altered.

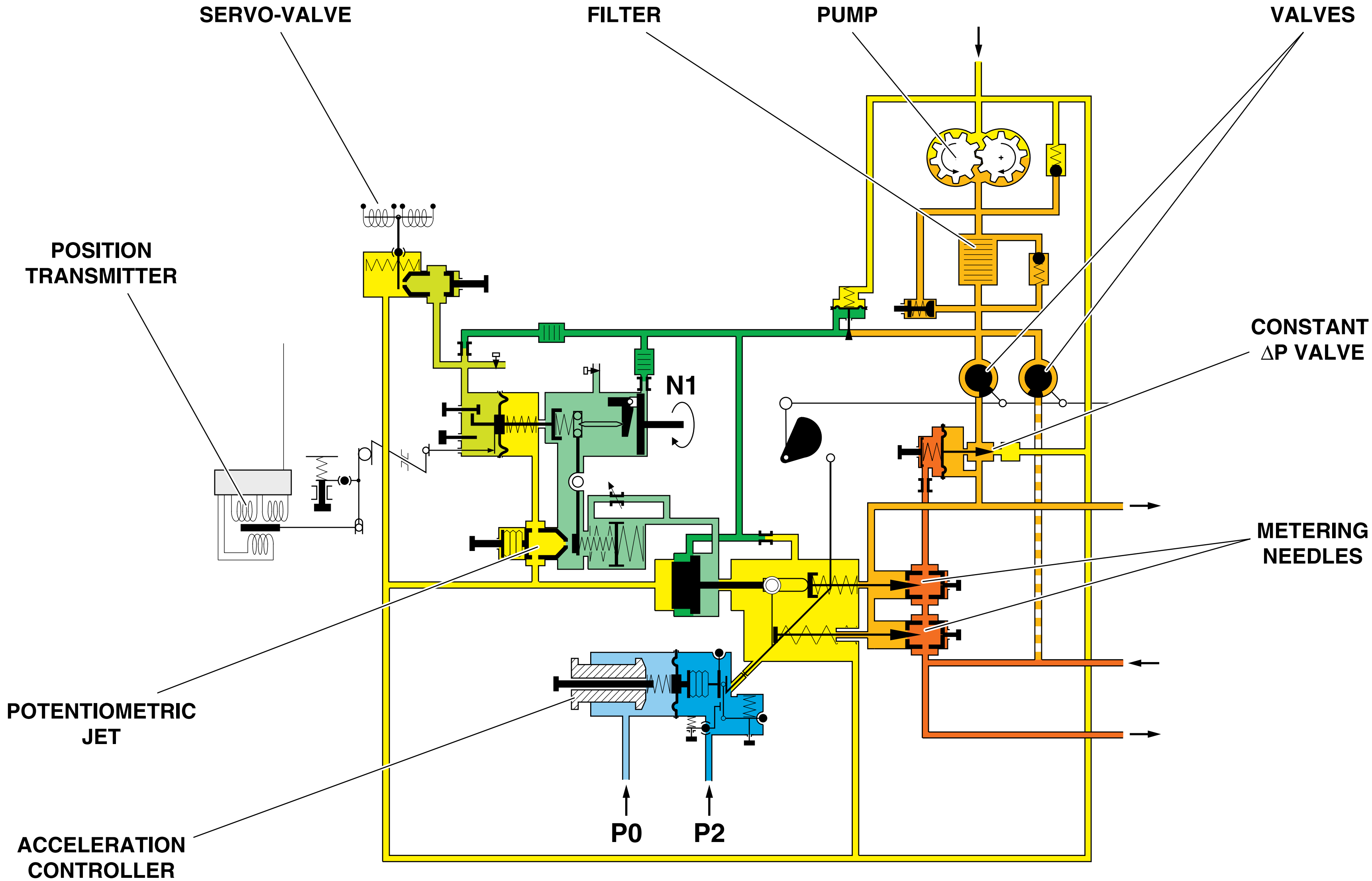
In case of load variation, the DECU produces a new N1 datum.

The current transmitted to the servo-valve changes, and the servo-valve produces a new modulated pressure. The diaphragm sets a new N1 datum.

The balance of forces is broken, the lever moves, the leak varies, and the modulated pressure through the damping device also varies (through the isochronous scroll and piston).

The working piston moves, and displaces the metering needle (within the limit admitted by the acceleration controller) until the N1 datum setting is reached.

The gas generator speed increases or decreases in order to become adapted to the new load conditions, and thus maintains the nominal speed of the power turbine in the designed range.



FUEL CONTROL UNIT - SPEED GOVERNOR - OPERATION

FUEL CONTROL UNIT - INTERFACES

This part considers the various interfaces of the Fuel Control Unit : mounting flange, mechanical control, unions, electrical connectors.

FCU mounting

The FCU is mounted on the rear part of the accessory gearbox by means of half-shells and a clamp. The drive shaft is engaged into the corresponding drive connection. The FCU mounting flange includes a locating pin.

Mechanical control

The aircraft mechanical linkage is connected onto the ball joint of the FCU control lever. Let us remember that the lever controls the two valves and the cam of the acceleration controller. Its position is indicated by a pointer which moves across a graduated scale.

Fuel unions

Some unions connect the FCU to the fuel system :

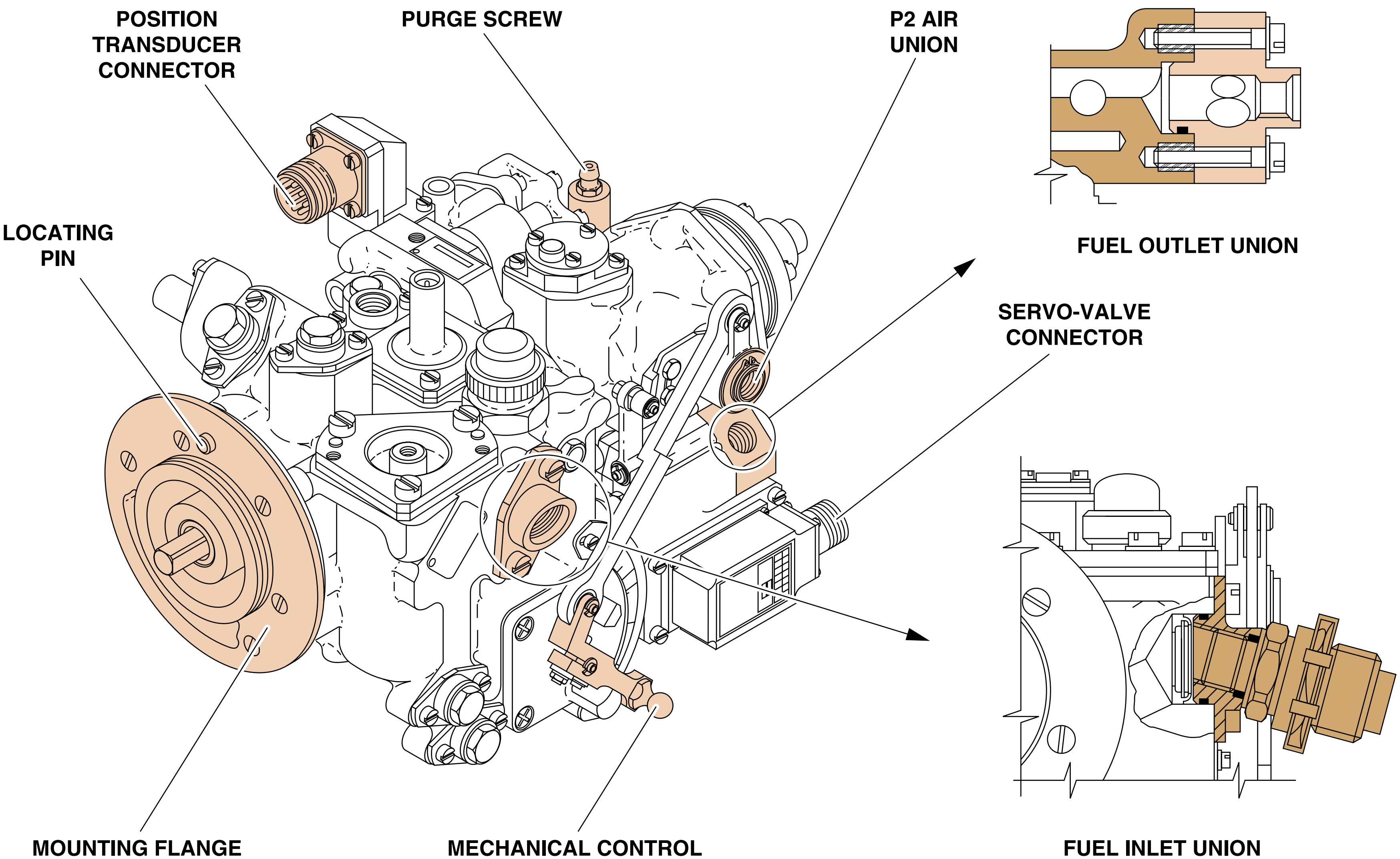
- Fuel inlet union : self sealing union screwed into the FCU (left side)
- Fuel outlet union : union screwed into the rear of the FCU
- Fuel inlet and outlet unions to the start servo-valve
- Purge screw.

Air unions

- P2 air pressure union for the acceleration controller
- P0 air tapping union for the acceleration controller.

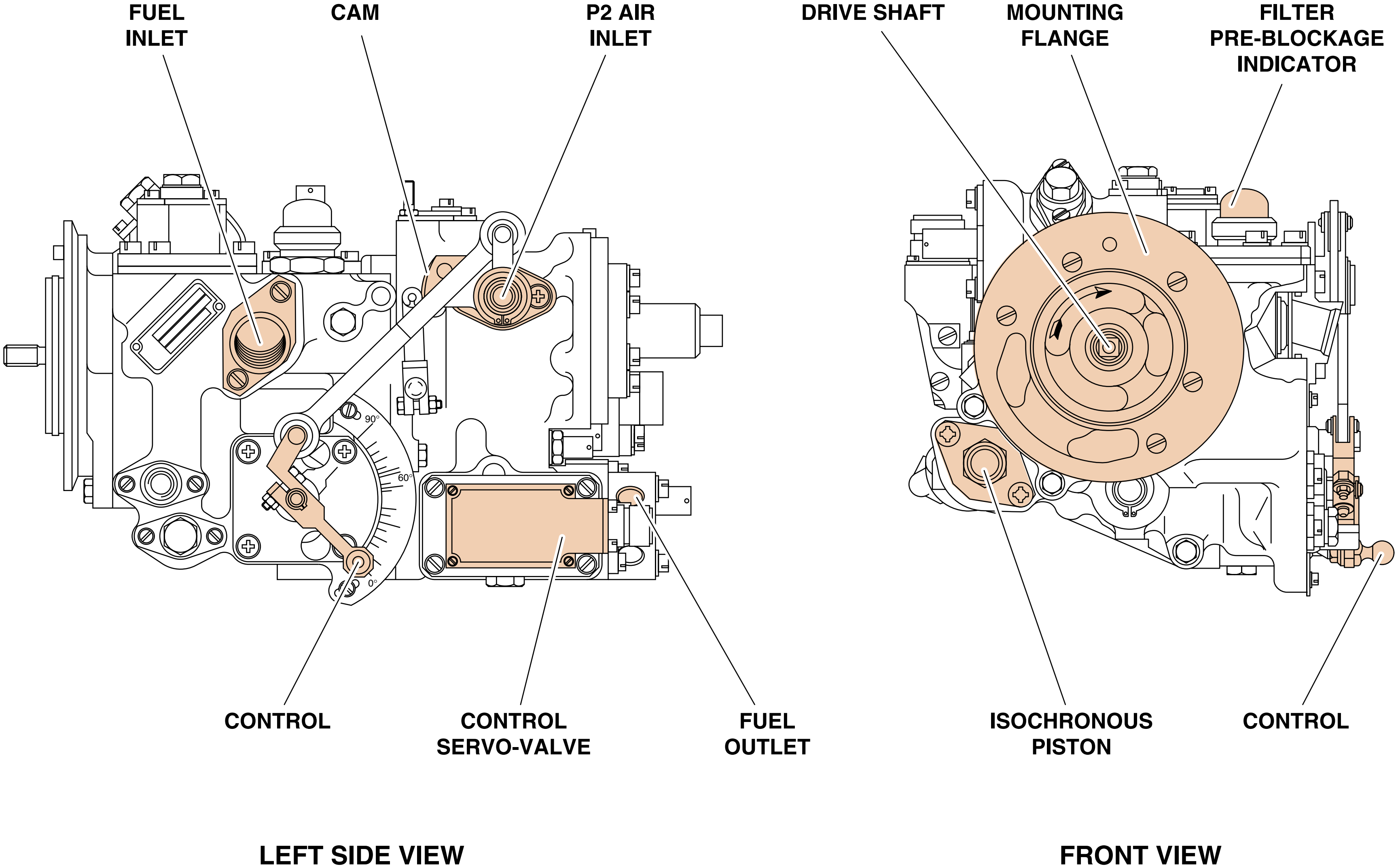
Electrical connectors

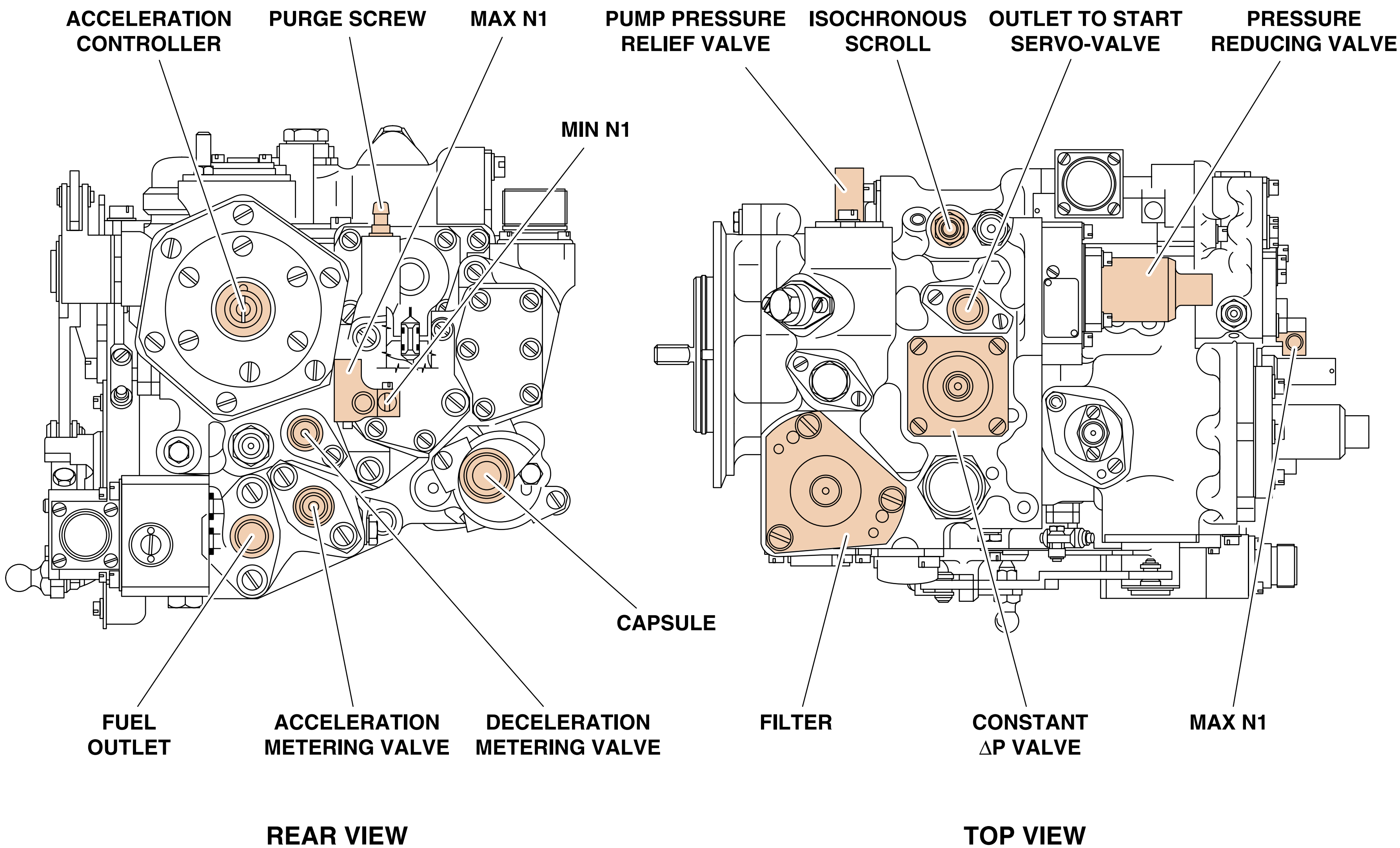
- Servo-valve connector
- Position transmitter connector.



FUEL CONTROL UNIT - INTERFACES

FUEL CONTROL UNIT - EXTERNAL VIEWS





FUEL CONTROL UNIT - EXTERNAL VIEWS

DIGITAL ENGINE CONTROL UNIT - GENERAL

Function

The DECU controls and monitors the engine operation.

Position

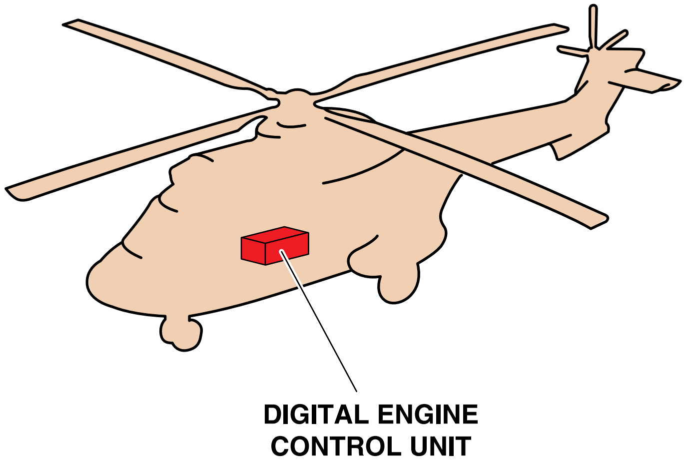
- Aircraft electrical rack.

Main characteristics

- Type : single channel digital
- Electrical supply : redundant 28 V
- Mass : ≈ 4.7 kg (10.3 lbs)
- Attachment : 4 mounting pads fitted with vibration dampers
- Quantity : one DECU per engine.

Main components

- Mounting flange of the earth braid terminal
- Electrical connectors
- Modules
- Mounting pads.



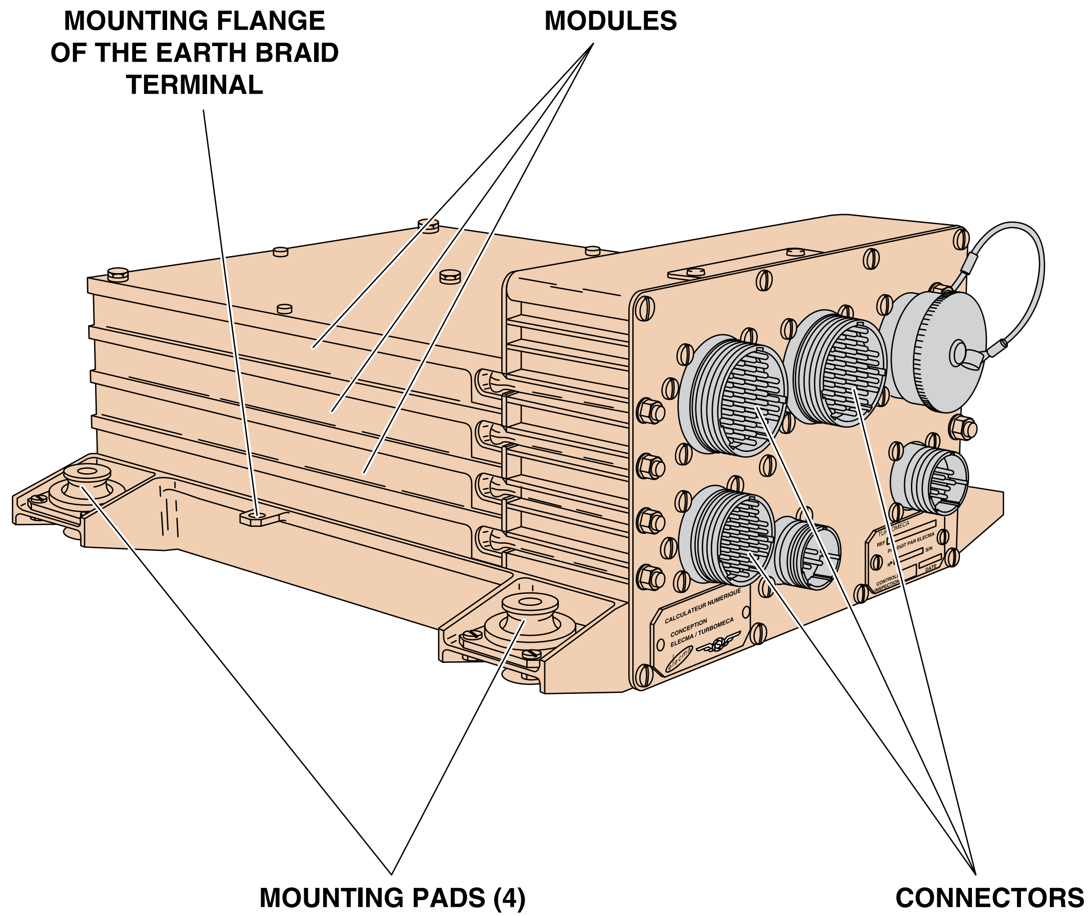
Type
Single channel digita

Electrical supply
Redundant 28 V

Mass
4.7 kg (10.3 lbs)

Attachment
4 mounting pads fitted with vibration dampers

Quantity
One DECU per engine



DIGITAL ENGINE CONTROL UNIT - GENERAL

DECU - FUNCTIONAL DESCRIPTION (1)

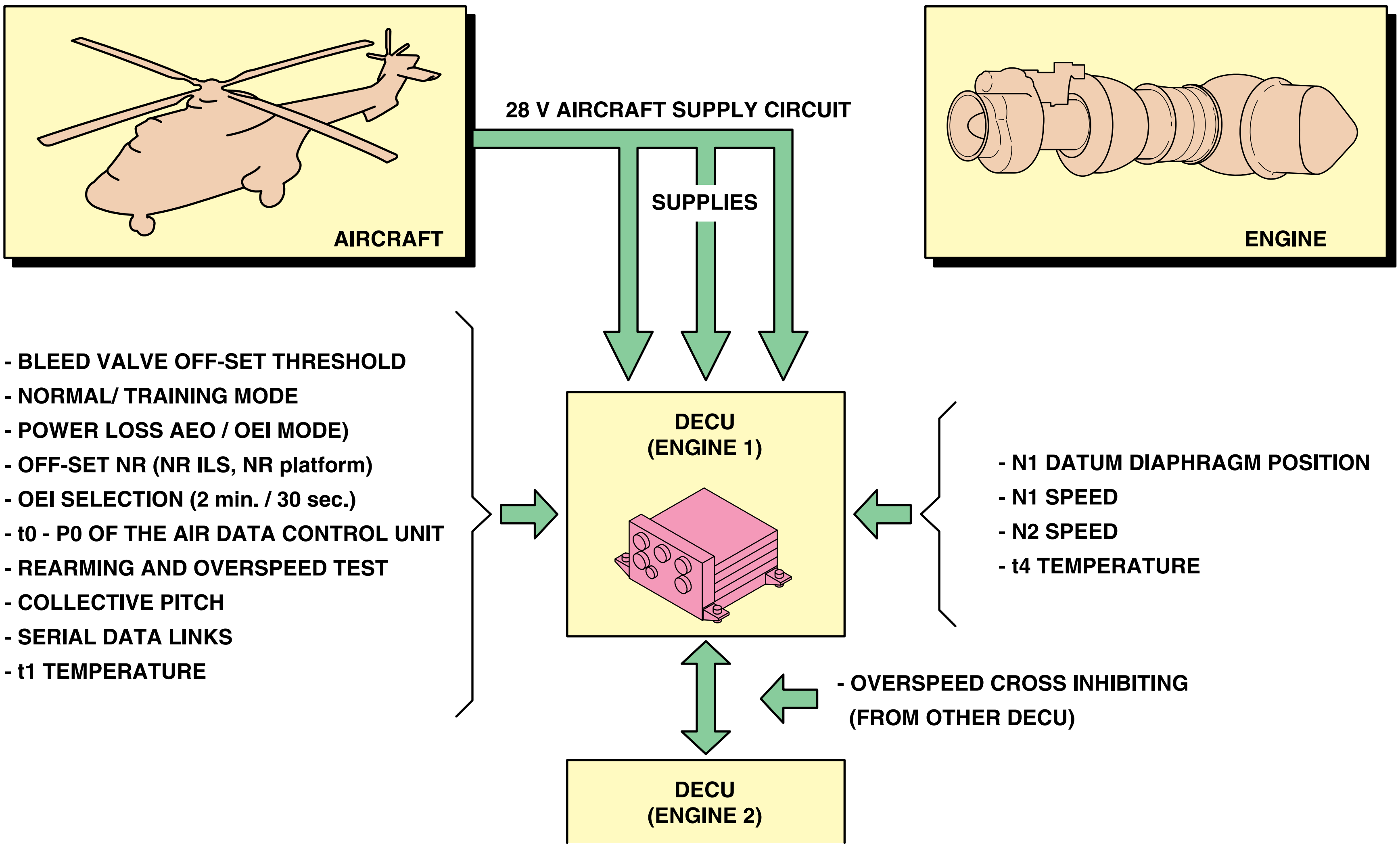
DECU inputs

From the aircraft

- 28 V supplies (main, secondary, overspeed)
- Bleed valve off-set threshold
- Power loss (automatic selection of the twin/AEO stop or single/OEI stop)
- Mode (normal, training)
- Off-set NR (NR ILS, NR platform)
- OEI selection (2 min. or 30 sec.)
- t0 and P0 of the air data control unit
- Rearming and overspeed test
- Rotor collective pitch (anticipator)
- Serial data links (RS 232 - ARINC 429)
- Health monitoring (engine 1 or 2 selection)
- t1 temperature (air intake duct).

From the engine

- Position of the N1 datum diaphragm
- N1 speed (x 1)
- N1 speed (x 2 control, x 2 overspeed)
- t4 temperature
- Overspeed cross monitoring (from other DECU).



DECU INPUTS

DECU - FUNCTIONAL DESCRIPTION (1)

DECU - FUNCTIONAL DESCRIPTION (2)

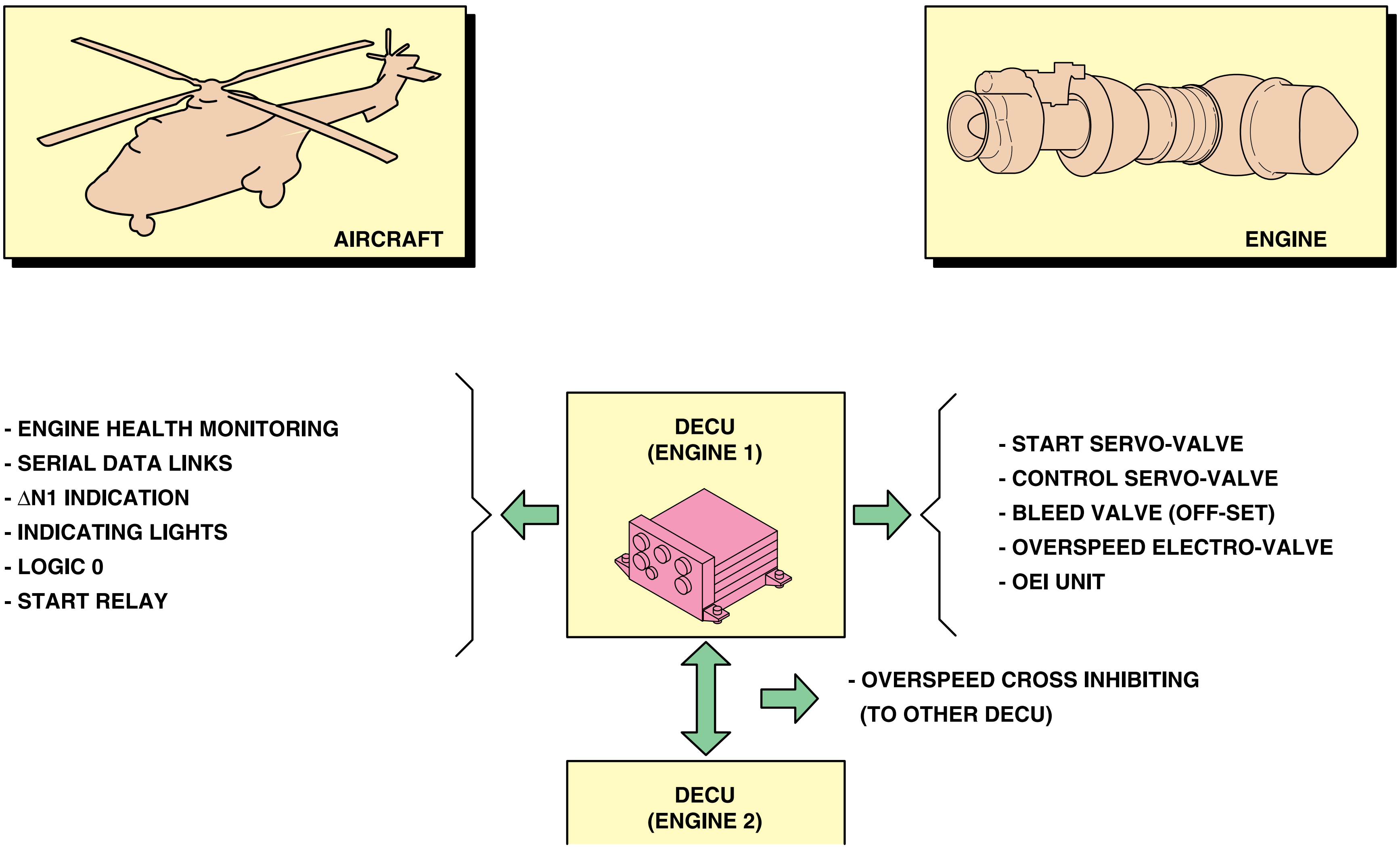
DECU outputs

To the aircraft

- Engine health monitoring
- ARINC 429 and RS 232 serial data links
- ΔN1 indication
- Indicating lights
  - Bleed valve off-set threshold
  - Overspeed arming
  - Redundancy and minor failure
  - Major failure
  - Training mode
  - Overspeed test
  - OEI indicating light
- Logic 0
- Start relay.

To the engine

- Start servo-valve
- Bleed valve (off-set threshold)
- Overspeed electro-valve
- OEI unit
- Overspeed cross inhibiting
- Control servo-valve.



DECU OUTPUTS

DECU - FUNCTIONAL DESCRIPTION (2)

DECU - FUNCTIONAL DESCRIPTION (3)

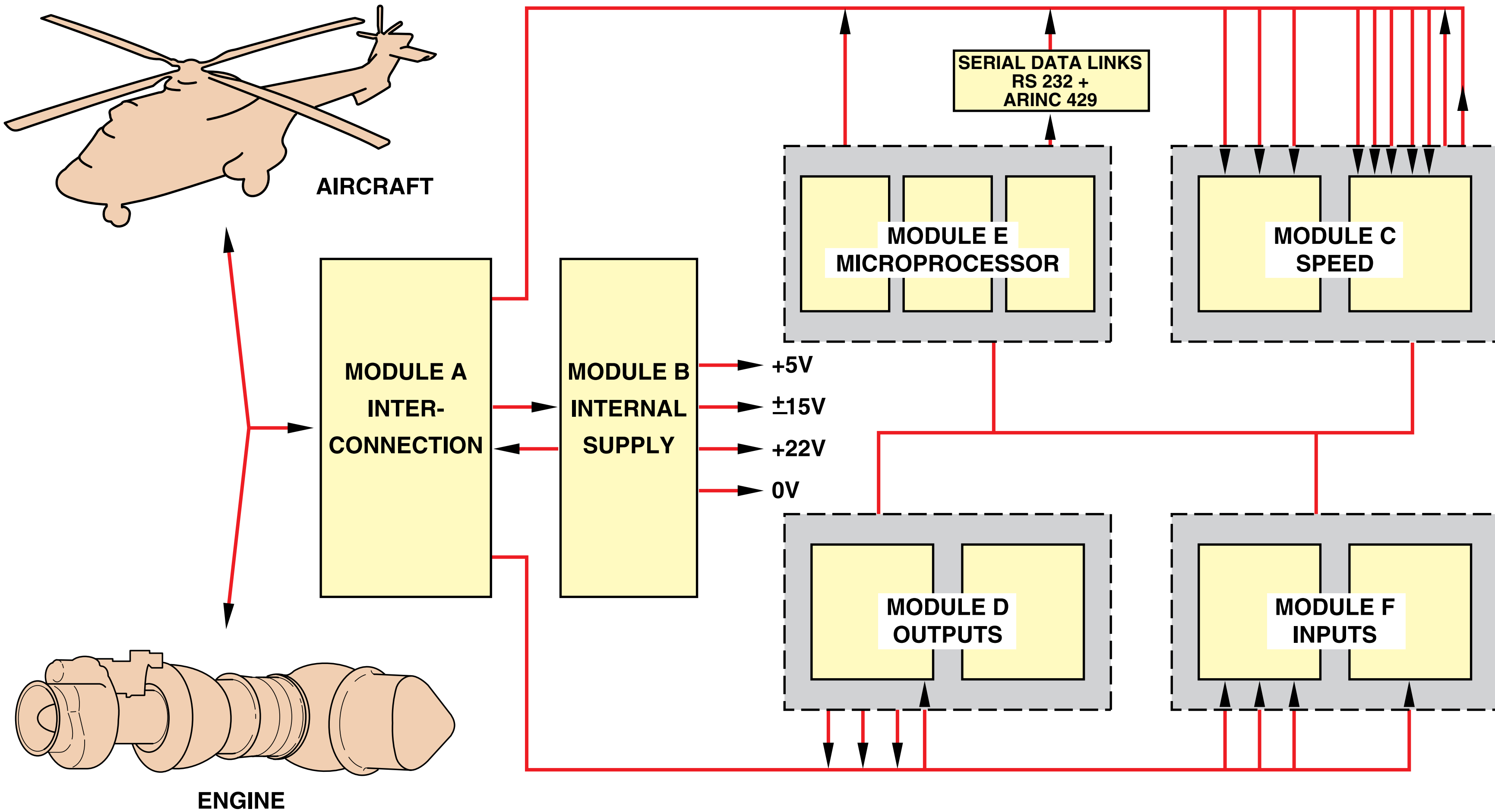
DECU layout

The DECU includes 6 interchangeable modules :

- Interconnection module : A
- Supply module : B
- Speed module : C
- Output module : D
- Processor module : E
- Input module : F

and connectors J1 to J6 :

- J1-J5 : engine connectors
- J2-J3-J4 : helicopter connectors
- J6 : test connector.



DECU LAYOUT

DECU - FUNCTIONAL DESCRIPTION (3)

DECU - FUNCTIONAL DESCRIPTION (4)

Module A - Interconnection module

This module includes the electrical connections :

- Between the different modules
- Between the engine and the DECU
- Between the helicopter and the DECU.

It also provides protection against lightning and electromagnetic interference (EMI).

- J1-J5 : engine connectors
- J2-J3-J4 : helicopter connectors
- J6 : test connector.

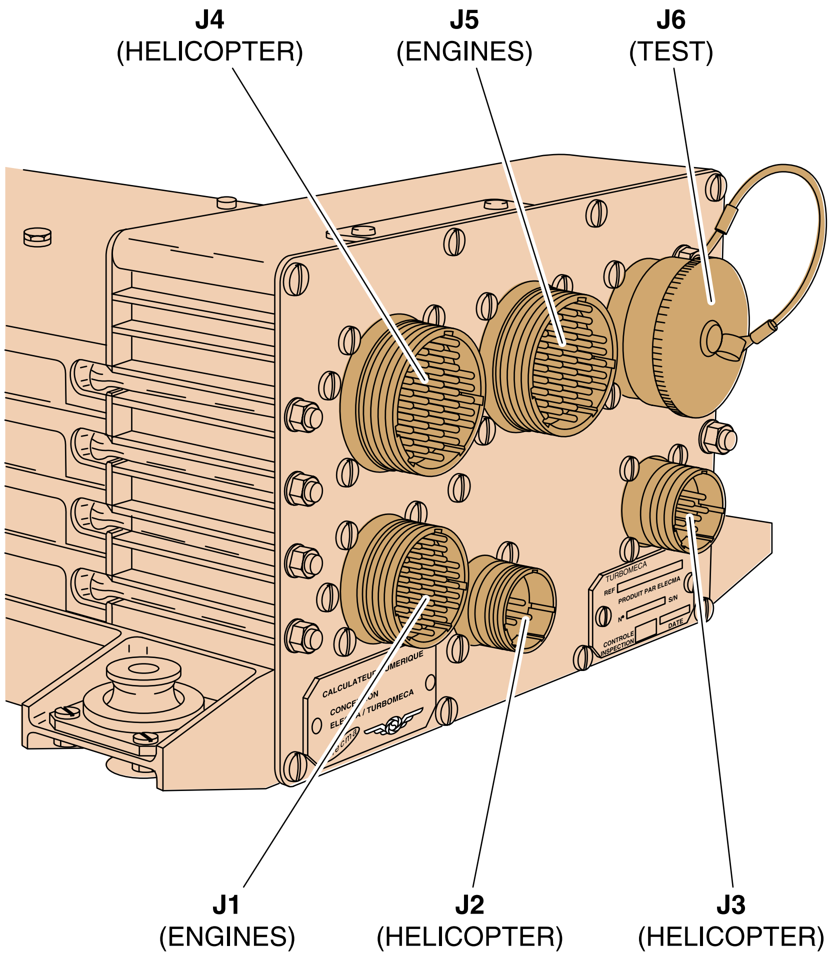
Module B - Supply module

This module provides the various internal supplies required for the DECU operation :

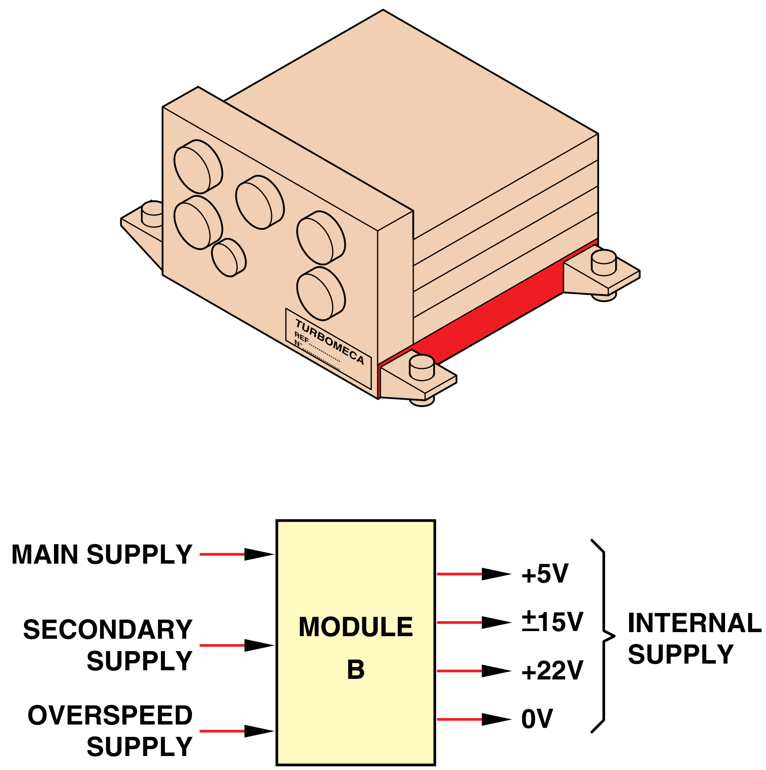
- +5V
- ±15V
- +22V
- 0V ("logic zero").

There are three separate power supplies used for the fuel flow control and the power turbine overspeed safety :

- Main supply
- Secondary supply
- Overspeed supply.



INTERCONNECTION



SUPPLY

DECU - FUNCTIONAL DESCRIPTION (4)

DECU - FUNCTIONAL DESCRIPTION (5)

Module C - Speed module

This module ensures the following functions :

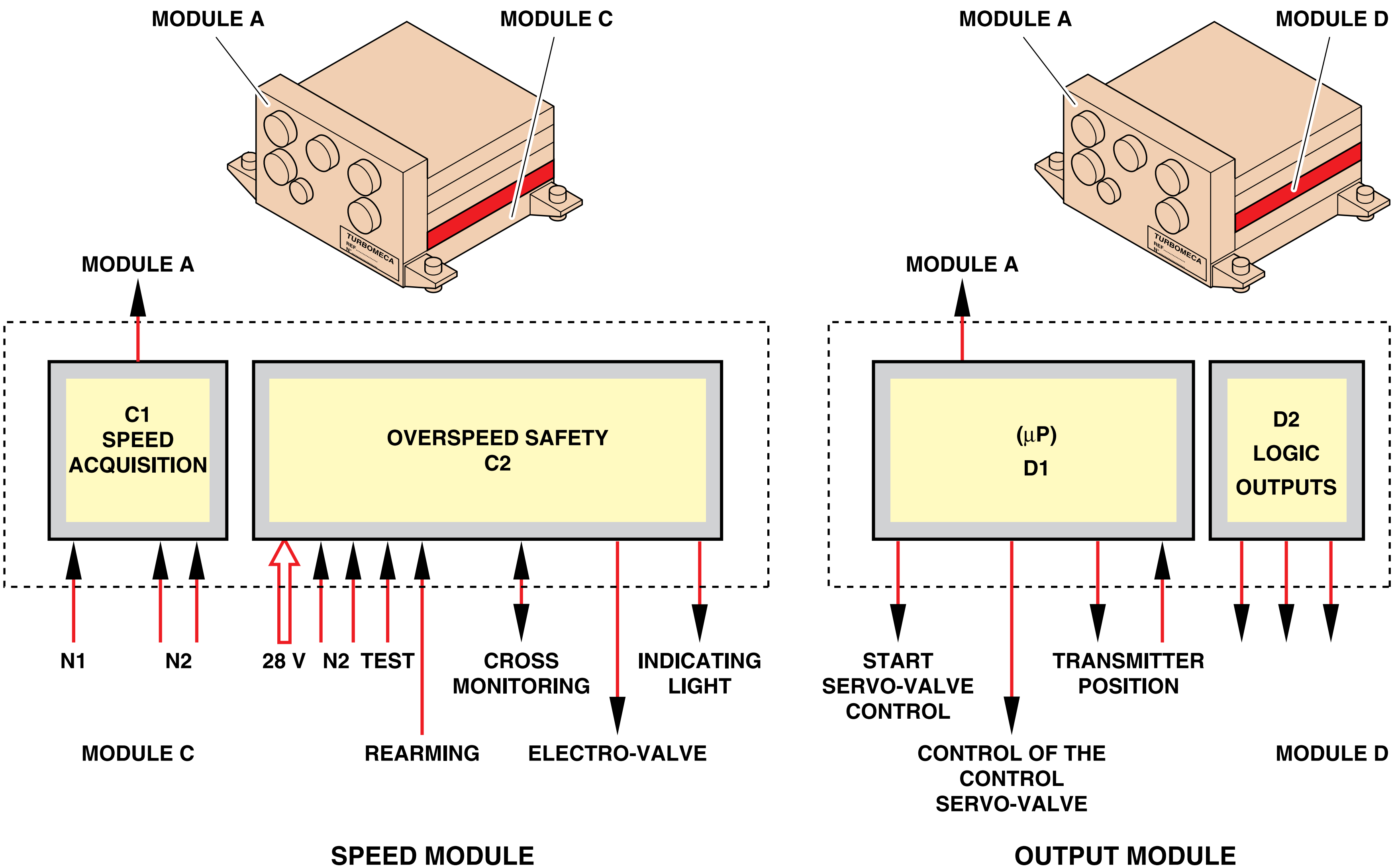
- Acquisition and processing of the N1 and N2 speed signals
- Overspeed safety (the overspeed module has its own power supply).

Note *: Refer to the following page for the details of the overspeed system.*

Module D - Output module

This module is designed around a 6809 micro-processor and includes memory circuits such as RAM, REPROM… for the control of the servo-valves and the processing of the position signal of the N1 datum diaphragm.

This module also processes the logic outputs (relays, indicating lights…).



DECU - FUNCTIONAL DESCRIPTION (5)

DECU - FUNCTIONAL DESCRIPTION (6)

Overspeed safety

The power turbine safety system provides an immediate and automatic shut-down of the engine in case of power turbine overspeed (≈ 121.5 % N2).

This system requires a very quick response and a high reliability.

Overspeed condition

The measurement is ensured by two electro-magnetic sensors : F'2 and F'3.

The detection is ensured by two detectors (N = 121.5 %) which supply a different polarity to the relay V through the auxiliary contacts of the other DECU (cross monitoring).

The relay V energised, it permits the supply of the relay S-S' which moves the 6 contacts to the overspeed position :

- Relay X supply to prevent the illumination of the indicating light during engine shut-down
- Supply of the flasher (the indicating light flashes)
- Supply of the overspeed electro-valve (immediate engine shut-down)
- Start inhibition
- Inhibition of the other engines' overspeed system.

Note 1 *: During engine shut-down, the relay V returns to rest but the relay S remains in the overspeed position.*

Note 2 *: The accurate threshold is 121.5 ± 1.5 %.*

Rearming

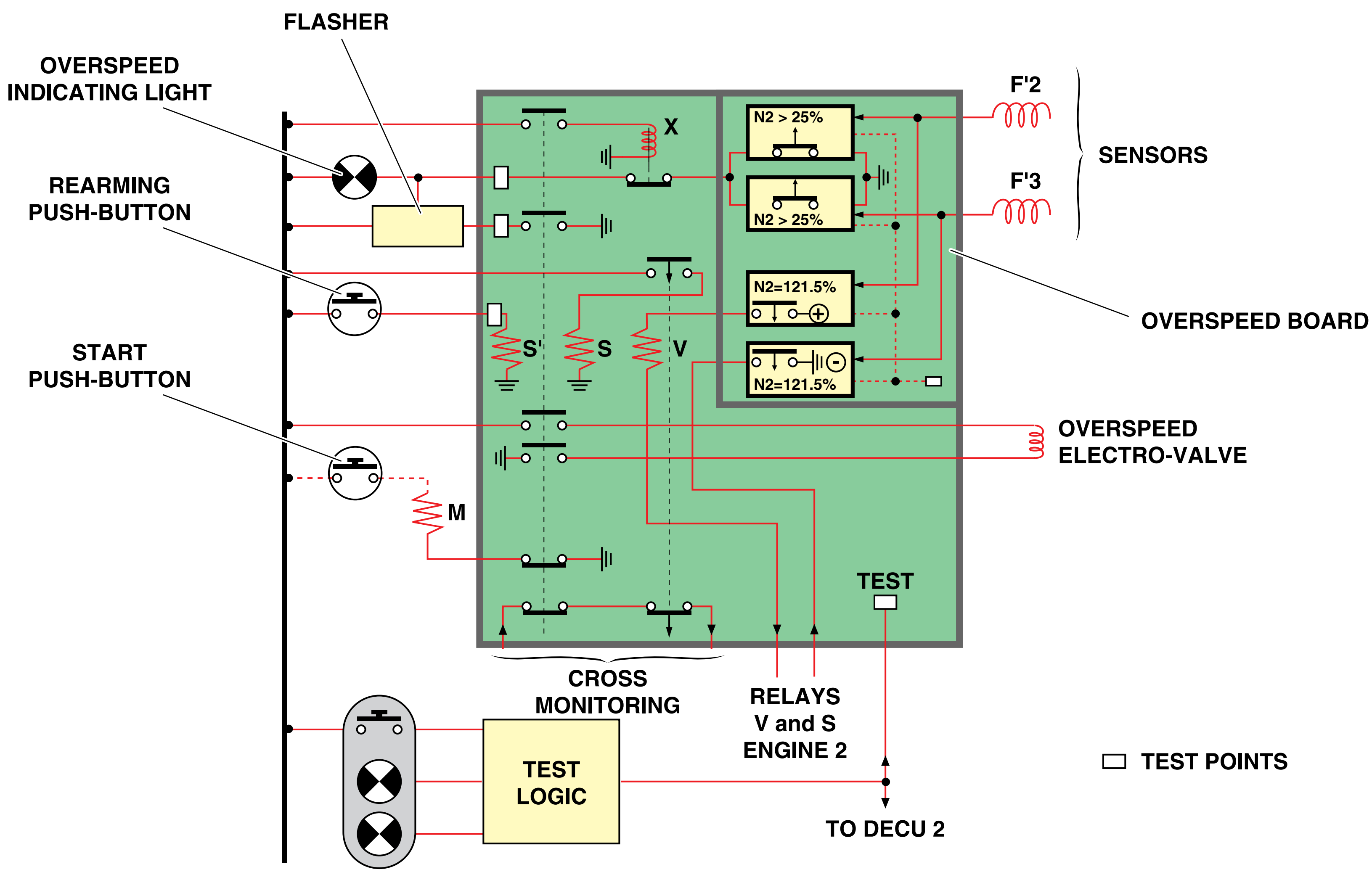
When the push-button is pressed, the solenoid S' of the bi-stable relay S-S' is supplied : the system returns to the "normal" position.

Test

There are two types of test on this system :

- Automatic test : the indicating light is illuminated when the system is energised and goes out when the engine reaches 25 % N2
- Periodic test : this is operated with the engine stopped. The test push-button is pressed and the failure or correct indicating light comes on at the end of the test.

  This test is inoperative during flight, due to the presence of the actual F'2 and F'3 signals (N2 > … %).



OVERSPEED SAFETY

DECU - FUNCTIONAL DESCRIPTION (6)

DECU - FUNCTIONAL DESCRIPTION (7)

Module E - Processor module

This is the main module of the DECU. It is designed around a 6809 micro-processor, programmed in assembler.

This module also includes memory circuits (REPROM, RAM, NOVRAM) and serial data links.

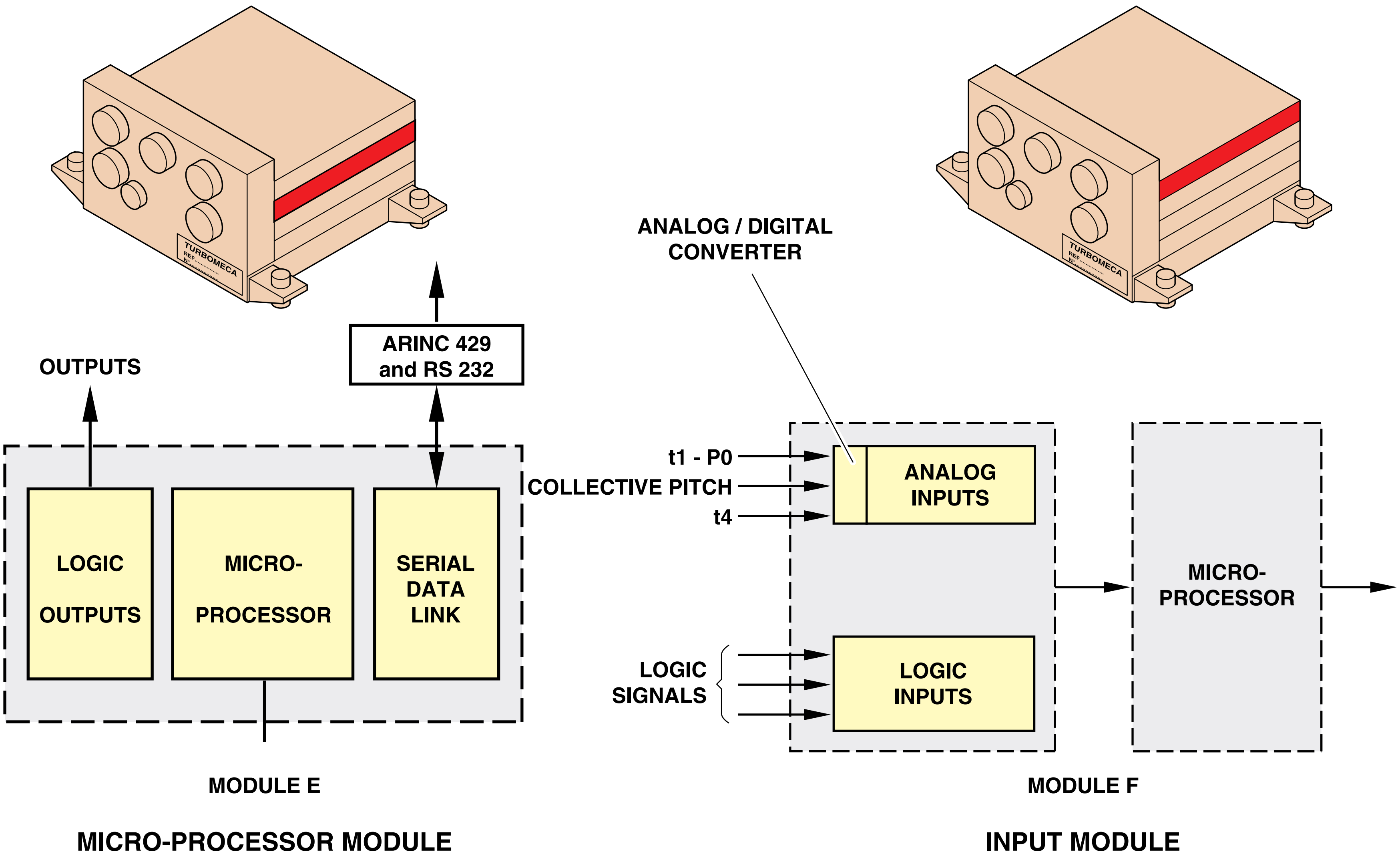
Logic outputs to :

- Starter
- OEI flag
- Training indicating light
- OEI indicating lights
- Failures
- Bleed valve control.

Module F - Input module

This module includes :

- Analog inputs (t0, P0, collective pitch). An analog-digital converter transforms these inputs
- Logic inputs which are supplied by the selectors :
  - Training/Normal
  - 30 sec. or 2 min. OEI
  - Power loss (AEO/OEI)
  - Bleed valve off-set threshold
  - Serial data links
  - Off-set NR (NR, LS, NR platform).



DECU - FUNCTIONAL DESCRIPTION (7)

OEI UNIT - GENERAL

Function

This OEI unit provides :

- The pilot with information about the OEI 30 sec. rating (indicating light on instrument panel)
- Signals for maintenance by indicating which engine operated in the OEI 30 sec. rating.

Position

- Engine lower part, on the heat exchanger support.

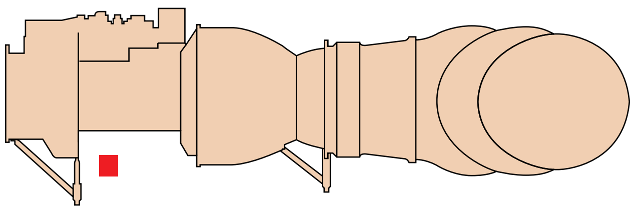
Main characteristics

- Type : electronic components, and bi-stable relay
- Connection : to the DECU.

Main components

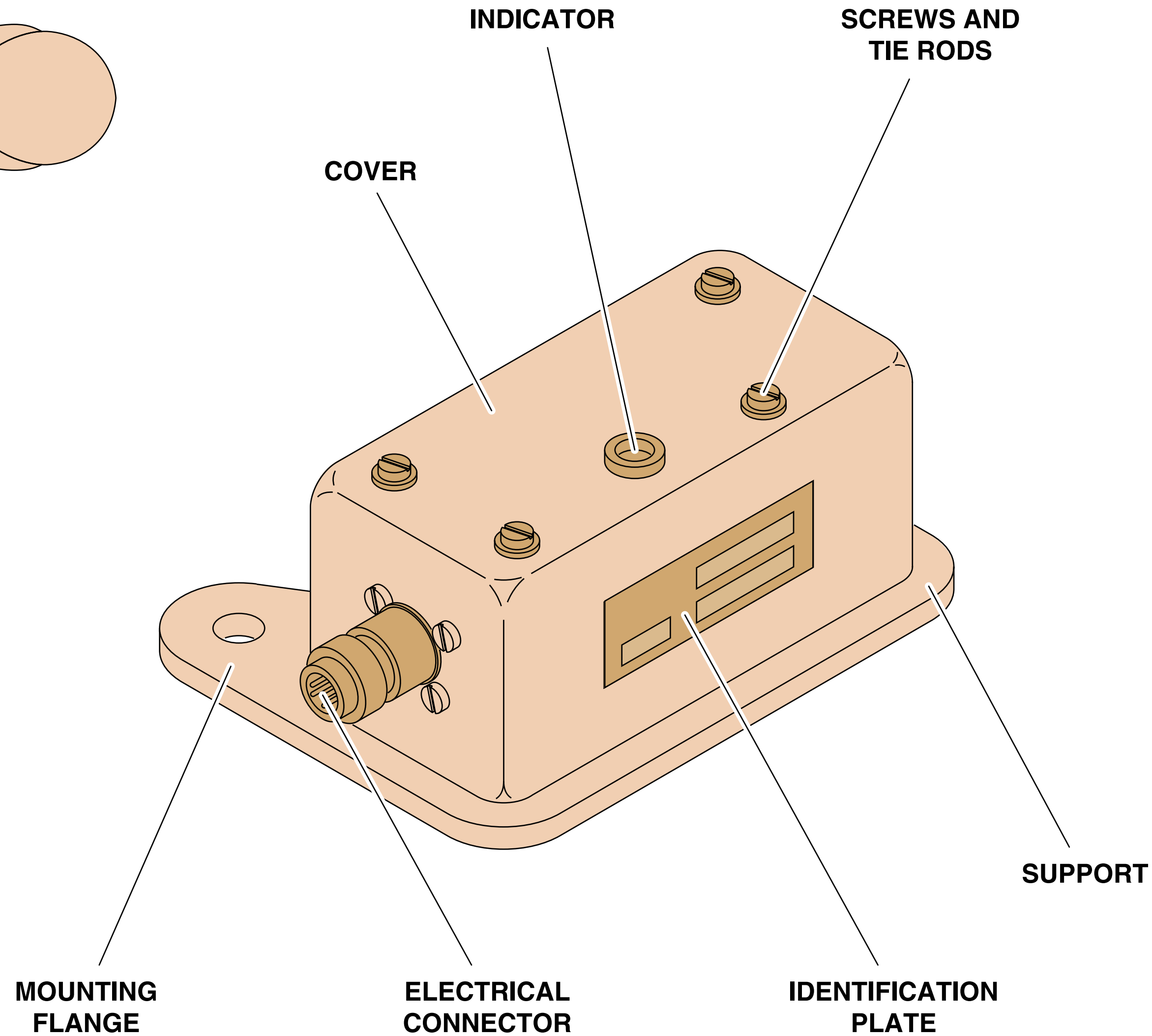
- Support and mounting flange
- Cover with screws and tie-rods
- OEI indicator
- Electrical connector.

Note *: OEI : One Engine inoperative.*
The OEI indication is also mentioned in the chapter "INDICATING SYSTEM".



Type
Electronic components

Connection
To the DECU



OEI UNIT - GENERAL

OEI UNIT - DESCRIPTION - OPERATION

Description

The unit includes :

- A bi-stable relay
- A magnetic indicator (white and black flag)
- A reset device.

It is connected to the DECU and supplies an OEI indicating light on the instrument panel.

General operation

In case of a failure which energises the NG DIFF and PWR indicating lights, the power control unit provides an OEI arming signal to the 2 DECUs.

As soon as one engine operates in the OEI 30 sec. range (N1 > OEI 2 min.) the corresponding DECU provides a signal for the corresponding OEI unit.

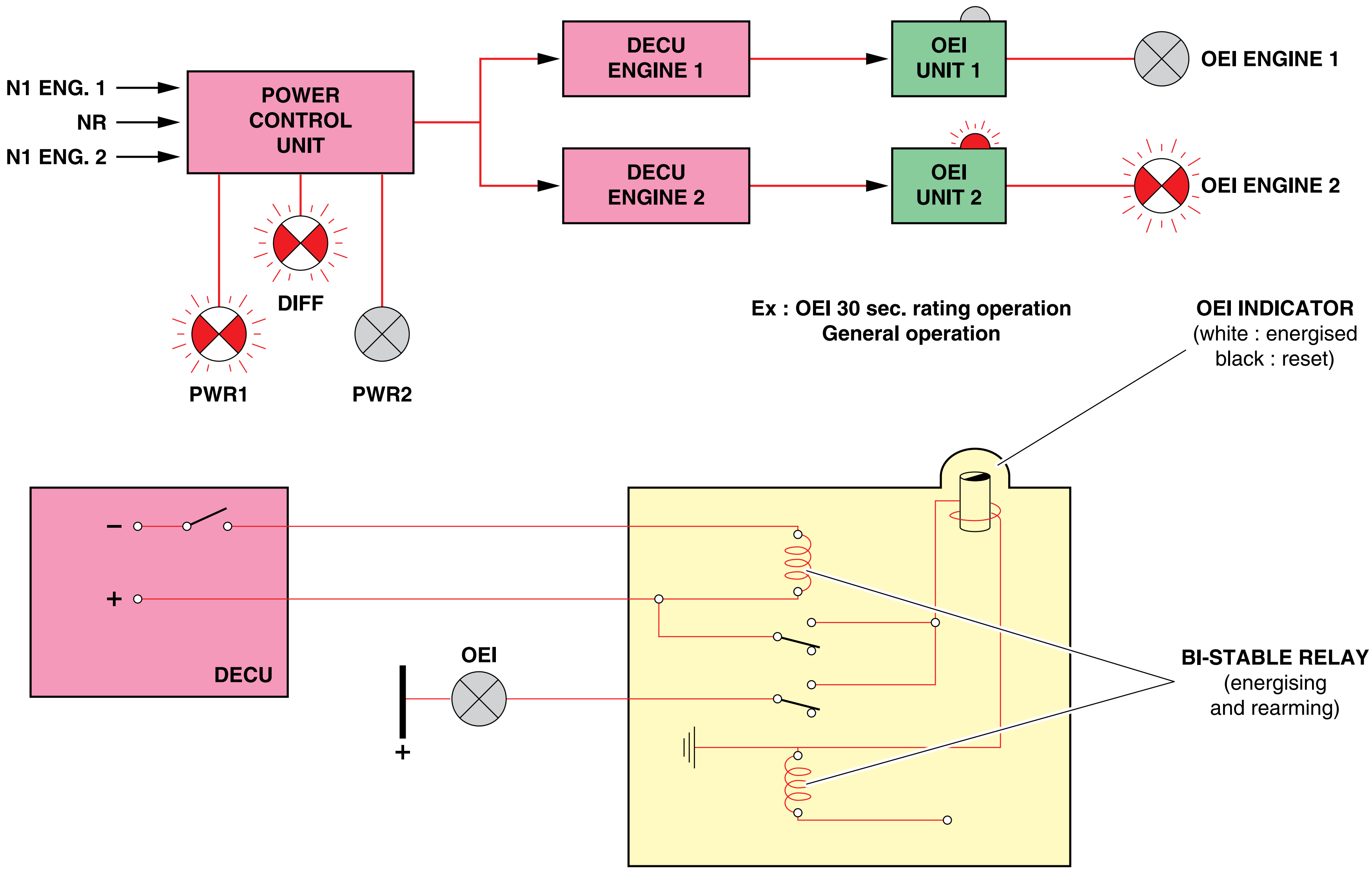
The OEI unit supplies the OEI flag on the unit and supplies the OEI indicating light which flashes on the overhead panel.

Operation of the OEI unit

At power on, the DECU supplies the OEI unit (+28 VDC).

In case of OEI selection (and after a given operating time in OEI 30 sec.), the DECU generates a negative signal to the OEI unit. The bi-stable relay is energised and the flag indicator becomes white, and the indicating light flashes on the overhead panel.

To reset the OEI circuit, the other solenoid of the bi-stable relay must be energised. This operation must be carried out in a specific work-shop.



OEI UNIT - DESCRIPTION - OPERATION

GENERAL OPERATION (1)

This part deals with the general operation of the complete system, during the different phases.

System at rest

The engine is stopped, there is no pressure in the system and the electrical system is de-energised :

- The pump is stopped (its pressure relief valve is "closed")
- The ΔP valve is "closed"
- The start injector electro-valve is "closed"
- The overspeed and drain valve :
  - Fuel supply cut off and injection wheel drain
  - Check valve "closed"
  - Overspeed electro-valve "closed"
- The starting device is de-energised (0 mA), flap valve "closed"
- The N2 governor servo-valve is de-energised (0 mA, flap valve in neutral position).

The control is considered to be set to "STOP" and the two manual valves are therefore in the "closed" position. The cam maintains the valves closed.

Operation during starting

Control

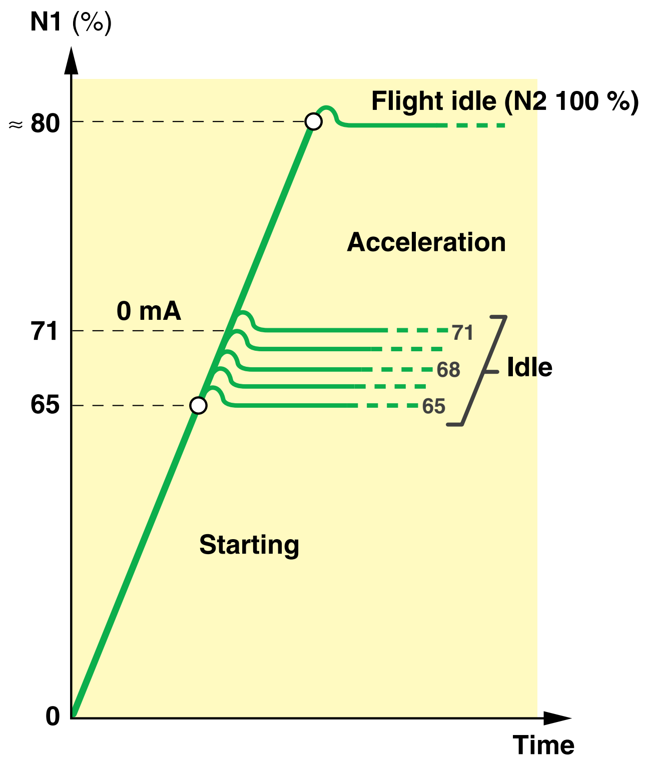
- The electrical power is on
- The start servo-valve is set to 2 mA
- The booster pump operates
- The control lever is set to the start position
- The start push-button is pressed.

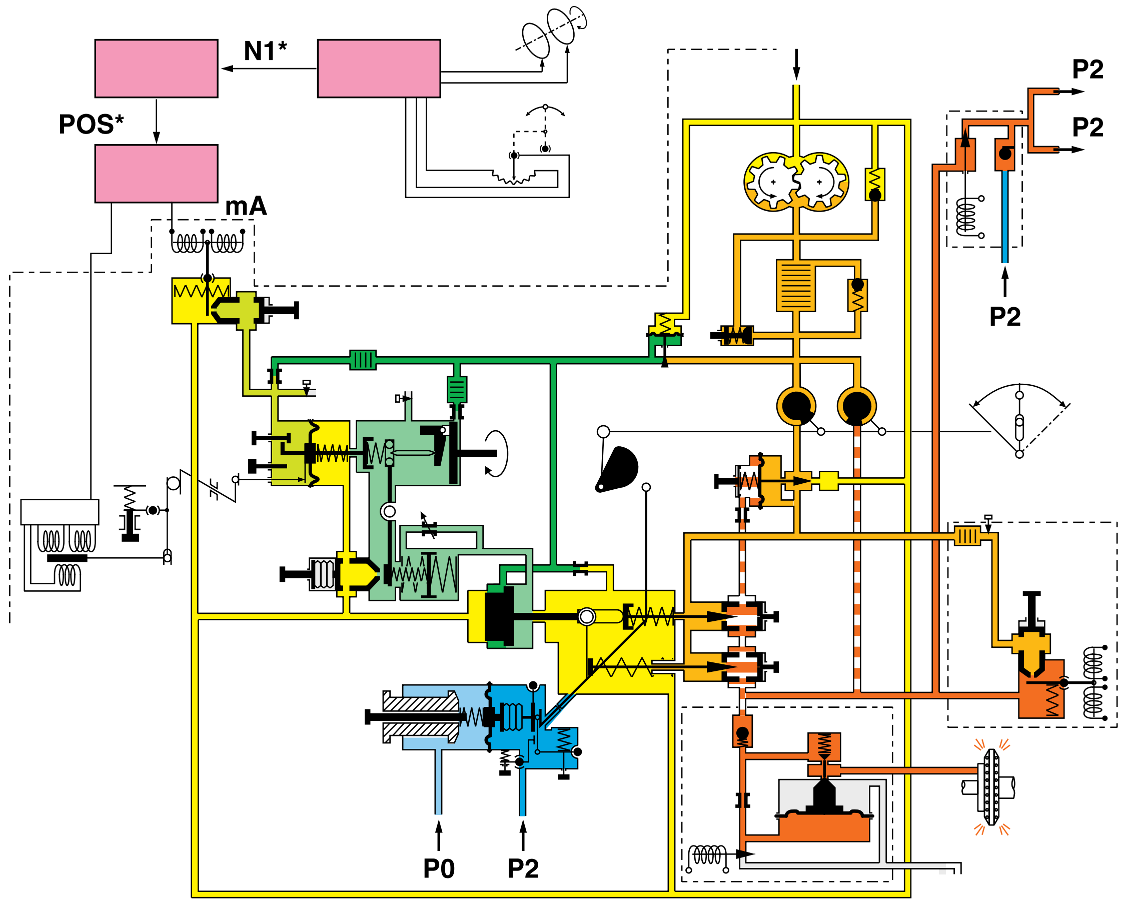
Sequence

- The starter and ignition are energised, the start injector electro-valve is energised "open"
- N1↗, Pr↗ : injector supply
- Pr > 220 kPa (31.9 PSI), pressurising valve opens : injection wheel supply. Drain and overspeed valve open
- Q↗ according to N and t4 (starting device servo-valve)
- N1 ≈ 45 % : the starter and the ignition are cut-off, the start injector servo-valve closes ; and the injectors are ventilated with P2 air
- N1 ≈ 68 % : idle control by the starting device.

During this phase, the constant ΔP valve and the control system components operate. As the nominal N2 has not been reached, the control system is not "in equilibrium". The metering needles are in a position which depends on the angle of the throttle lever and on the acceleration controller.

Note : *Pr : fuel pressure*
The sequence can be stopped by carrying out a normal shut-down : by returning the lever to "fully closed".





REST - STARTING - STABILISED RATING

GENERAL OPERATION (1)

GENERAL OPERATION (1) (continued)

Operation during acceleration

The acceleration is obtained by moving the control lever from the "start" position to the "flight" position :

- The main valve progressively opens
- The cam changes the acceleration controller setting.

The fuel flow (not determined by the starting device, but by the Fuel Control Unit) increases, N1 increases, N2 increases (according to the applied load).

When N2 reaches its nominal value, the control system operates (N2 governor ⇒ N1 governor ⇒ Q).

The nominal operating position (or flight position) is considered really reached when the control is "fully open" (52°). The main valve is "open", and the flow is determined by the control system.

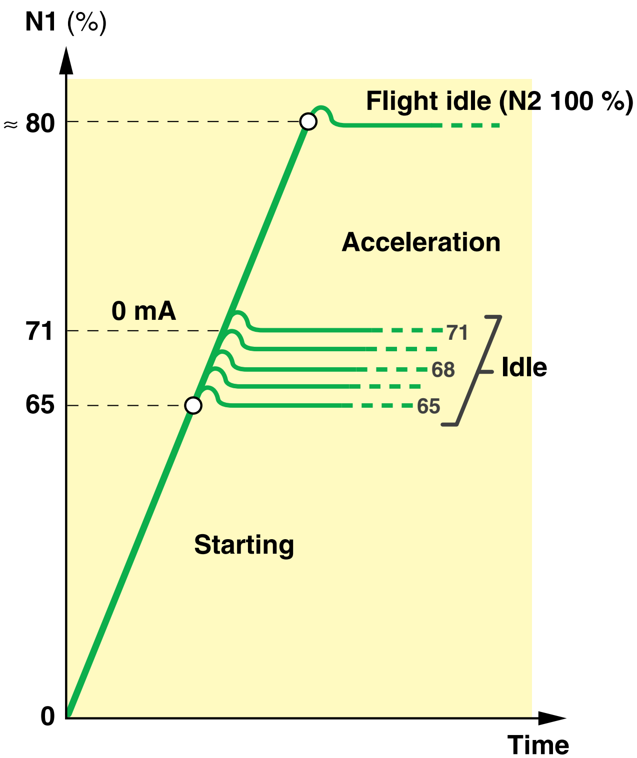
Operation at stabilised rating

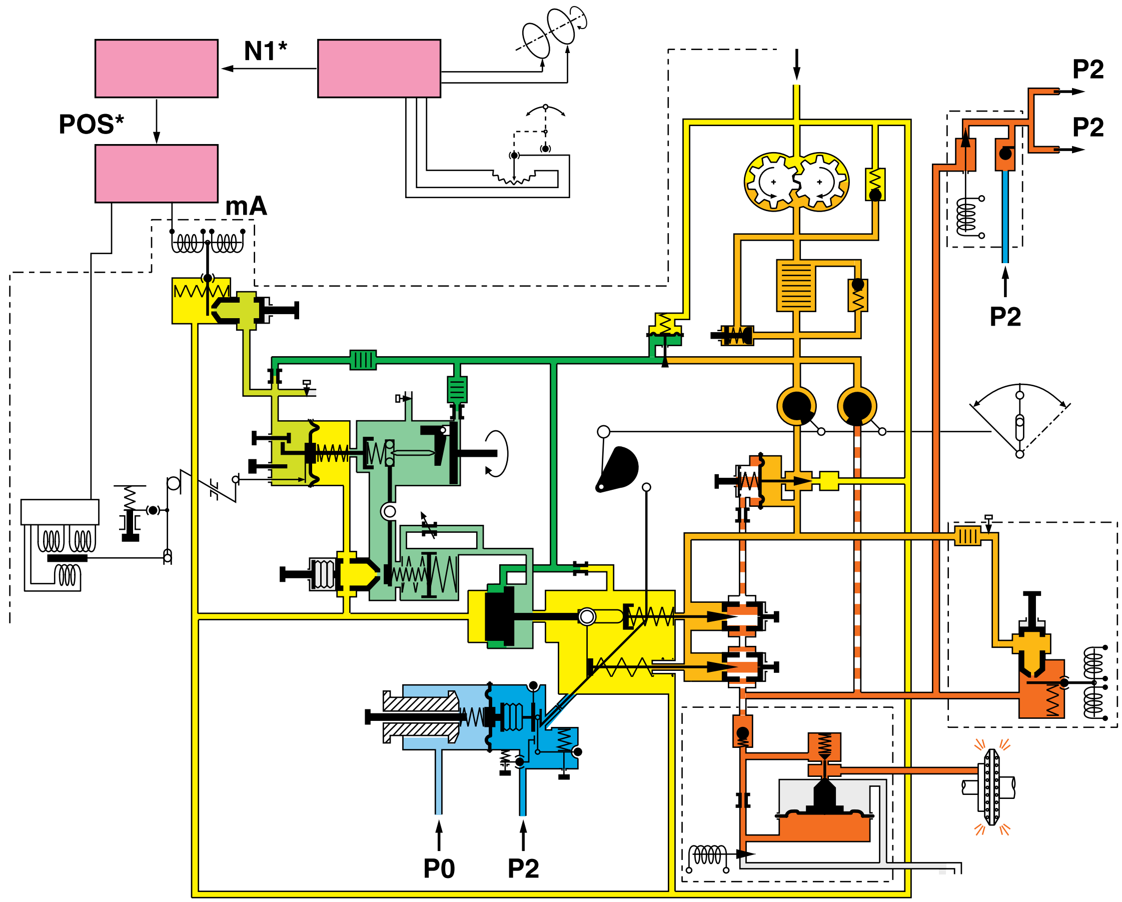
All the following parameters are stable : P2, Q, t3, N1, W, N2.

Position of the components :

- Pump valve "closed"
- Main valve "fully open"
- Constant ΔP valve in "control mode"
- Pressure reducing valve in "control mode"
- N2 and N1 governors in "equilibrium"
- Acceleration controller is operating according to P2 pressure (clearance between the fork and the metering valve)
- Metering needles in "Control mode" (S1 + S2).

The pump supplies fuel under pressure, the flow is determined by the metering needles position, and the excess fuel is returned to the pump inlet by the constant ΔP valve.





ACCELERATION
GENERAL OPERATION (1)

GENERAL OPERATION - GENERAL (2)

Operation at transient ratings - General

A transient rating is characterised by the variation of one of the operating parameters.

All these parameters are "linked", and the variation of any of them causes the other to vary. The control system detects the variation and meters the fuel flow to restore the equilibrium.

The most common case of transient operation occurs when a load is applied to the power turbine (helicopter rotor pitch).

The principle is : N2 detection, generation of a new N1 datum setting, control of the flow with acceleration control, return to equilibrium.

The diagram N1/N2 network provides an illustration of the entire envelope covered by the control system, between min N1 and max N1 and between min θ and max θ.

For a given collective pitch, the speed control is carried out on a static droop line (intrinsic static droop of the Fuel Control Unit). Each stabilised point is defined by a θ, an N2 and an N1.

In reality, the point depends on the necessary power, which depends not only on the pitch θ, but also on the flight and atmospheric conditions.

Under θ variation in transient conditions, the system successively passes from one line to another, which means that there is a change in N1 and N2 speeds. In reality, there is a transitory variation of N2 which then stabilizes at a slightly different value (the static droop is not only eliminated, but in fact slightly over-compensated).

We can note the following characteristic points :

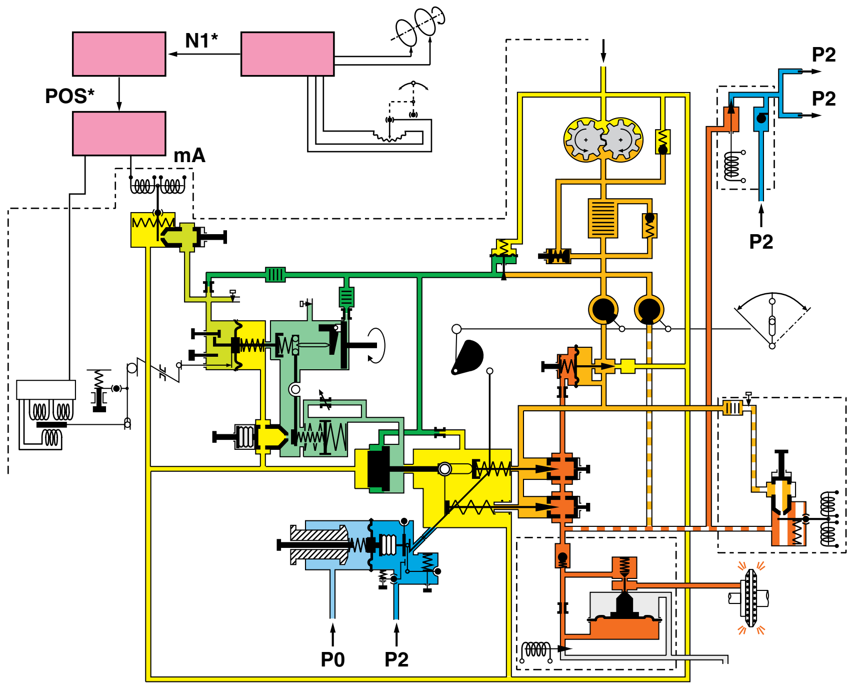
65 % N1 . Minimum controlled speed. This limit is practically never reached, due to the fact that on a helicopter, the engine and rotor become desynchronised beforehand.

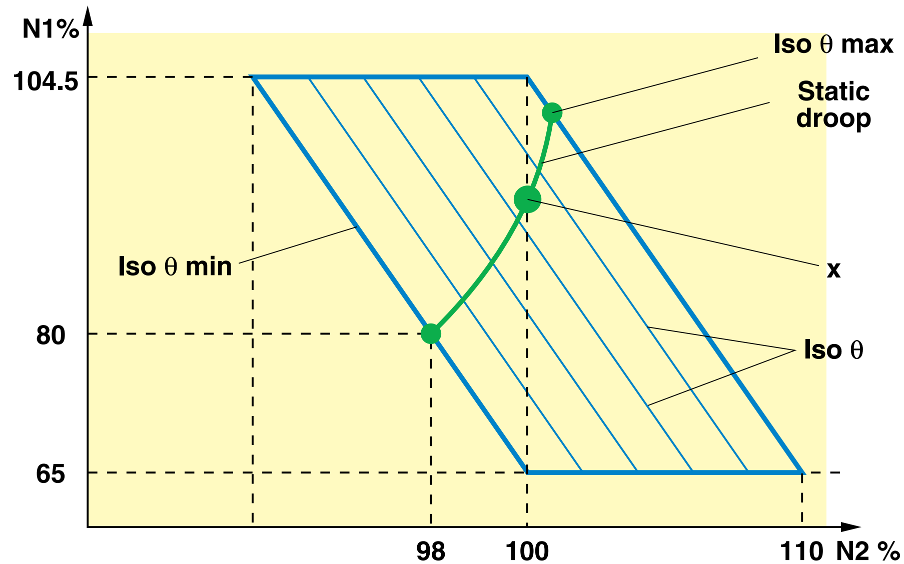
70 % N1 . This speed can be considered as the minimum power rating ; in other words it is the power required to drive only the compressor (the rotor is desynchronised throughout a very wide envelope).

80 % N1 . This speed is reached when the control takes-over on ground at fine pitch ; this speed, which depends on the load applied, also varies according to the circumstances (1 or 2 engines operating) (example : 1 engine = 81 %, 2 engines = 77 %).

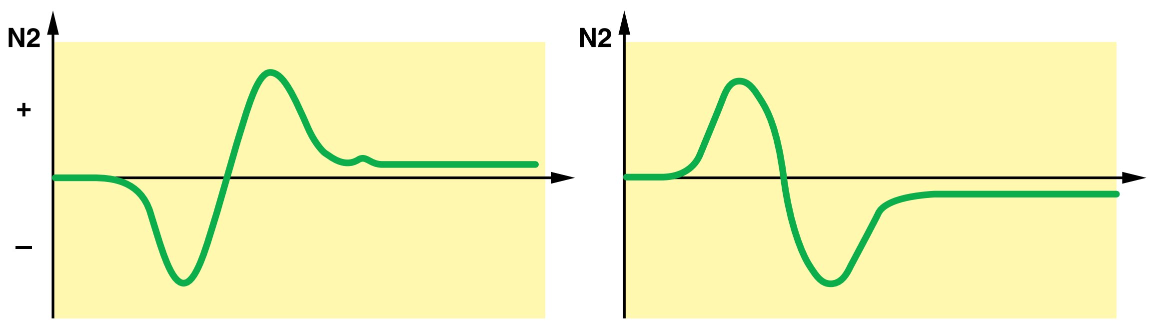
Point x .... Stabilised point x during flight (example : N1 ≈ 90 %, N2 = 100 %).

104.5 % .. Maximum controlled speed which corresponds to the maximum OEI 30 sec. rating. This limit is calculated as a function of P0 and t1. The extreme limit is the hydromechanical safety stop at about 34 650 RPM.





N1 / N2 RELATION AND STATIC DROOP



TRANSIENT VARIATION OF N2

TRANSIENT RATING

GENERAL OPERATION - GENERAL (2)

GENERAL OPERATION (3)

Transient rating - Load increase

- Rotor collective pitch increase
- The electronic system detects the pitch increase, the N2 decrease, and generates a mA signal for the servo-valve
- The servo-valve closes its flap valve ; the leak decreases, the modulated pressure increases
- The diaphragm moves and sets an increased N1 datum
- The gas generator governor flap valve closes, the leak decreases, the modulated pressure increases
- The working piston moves, the metering valve opens to the stop of the acceleration governor (instantaneous increase)
- The flow increases, P2 increases, the governor enables the acceleration to continue : the ΔP tends to decrease, but the ΔP valve closes in order to return the ΔP to its nominal value
- The power supplied by the gas generator increases and balances the required torque ; the nominal N2 is restored, and the complete system returns to equilibrium.

Evolution of parameters

θ - **Collective pitch** : increase from min to max almost instantly

N2 - **Power turbine speed** : transient decrease and rapid return to nominal speed after a slight overshoot and a slight overcompensation of the static droop

N1 - **Gas generator speed** : speed increase and stabilisation after a slight overshoot

t - **Time in seconds**

Image of a load increase

t = 0 - "Start". Collective pitch control

θ ↗ - The pitch increases

W^1 >W - The resisting torque becomes higher than the drive torque

N2 ↘ - The power turbine rotation speed decreases

(G) - The N2 governor detects the 2 signals and sends a datum value to the N1 governor which increases the fuel flow Q

Q ↗ - Instantaneous flow step

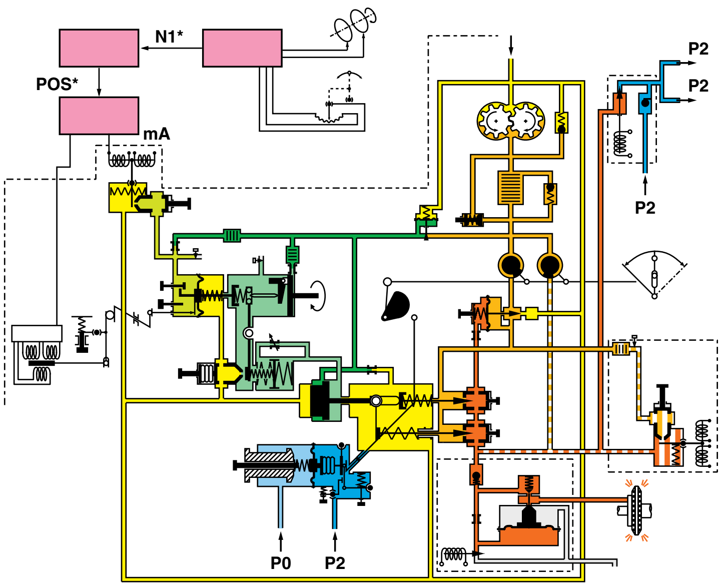
P2 ↗ - The compressor outlet pressure increases

(AC) - The acceleration controller enables the acceleration to continue

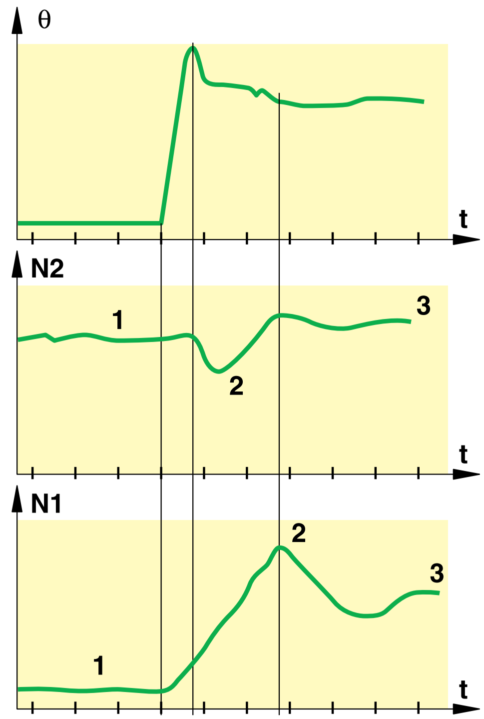
(Combustion) - The fuel flow Q to the combustion chamber increases

N1 - Increases, the output power W increases, the N2 speed stops decreasing and returns to its nominal value when the equilibrium between torques, W^1 = W, is achieved

t = 4 seconds End of transient



TRANSIENT RATING
LOAD INCREASE
(operation, image of the control system loop, evolution of parameters)



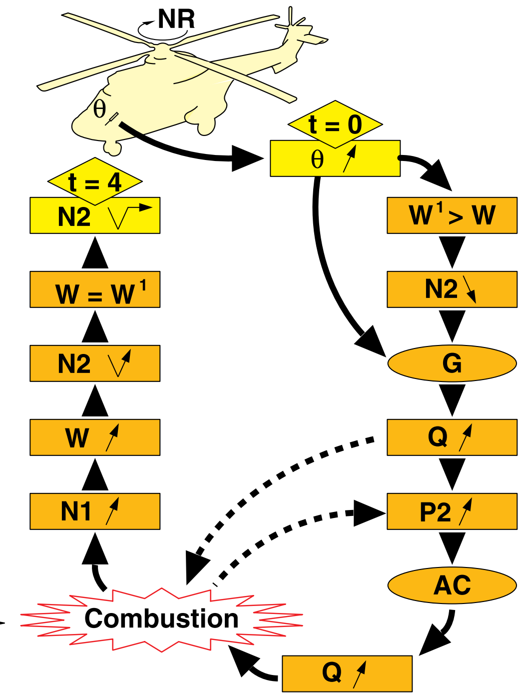
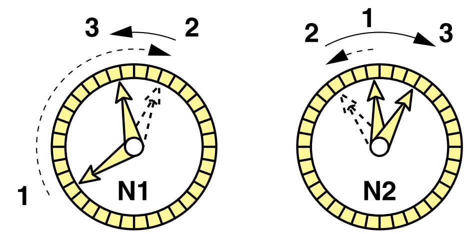


IMAGE OF A LOAD INCREASE



EVOLUTION OF PARAMETERS

GENERAL OPERATION (3)

GENERAL OPERATION (4)

Transient rating - Load increase

- Rotor collective pitch decrease
- The electronic system detects the pitch decrease and the N2 increase, and generates a mA signal for the servo-valve
- The servo-valve opens its flap valve ; the leak increases, the modulated pressure decreases
- The diaphragm moves and defines a decreased N1 datum which is sent to the DECU
- The working piston moves and closes the metering valve
- The flow decreases, P2 decreases, the governor limits the deceleration through the 2nd metering needle, as a function of P2 ; the ΔP tends to increase, but the valve operates in order to return the ΔP to its value
- The power supplied by the gas generator decreases and adapts itself to the required torque ; the nominal N2 is restored, and the complete system returns to equilibrium.

Evolution of parameters

θ - **Collective pitch** : rapid decrease of pitch

N2 - **Power turbine speed** : transient increase and return to nominal speed (to within the static droop)

N1 - **Gas generator speed** : speed decrease and stabilisation

t - **Time in seconds**

Image of load decrease

t = 0 - "Start". Collective pitch movement

θ ↘ - The pitch decreases

W¹ <W - The resisting torque becomes lower than the drive torque

N2 ↗ - The power turbine rotation speed increases

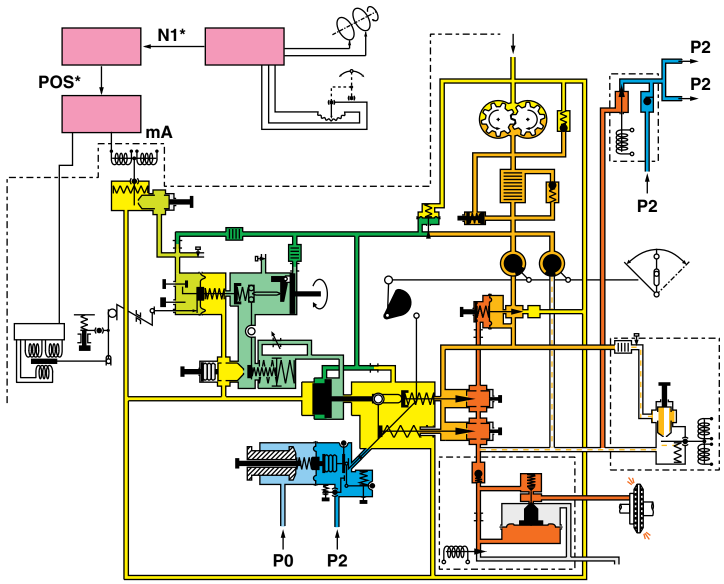
(G) - The governor detects and decreases the fuel flow Q

(AC) - The acceleration controller enables the deceleration to continue according to the P2 compressor pressure

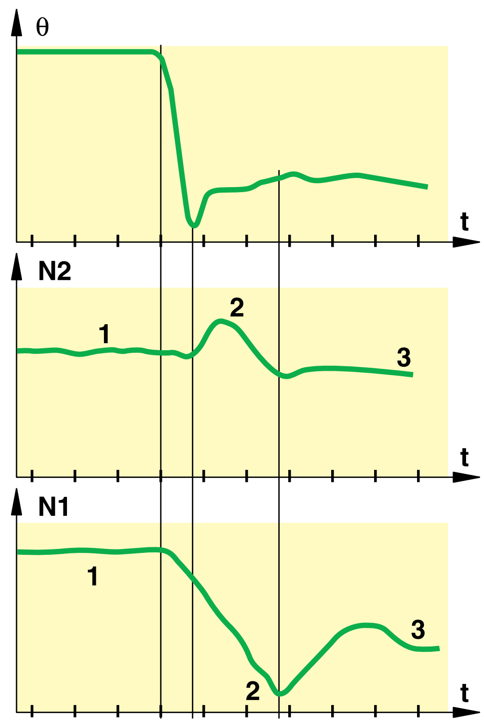
(Combustion) - The fuel flow Q to the combustion chamber decreases

N1 - Decreases, the output power W decreases, the N2 speed returns to its nominal value

t = 4 seconds **End of transient**



TRANSIENT RATING
LOAD DECREASE
(operation, image of the control system loop, evolution of parameters)



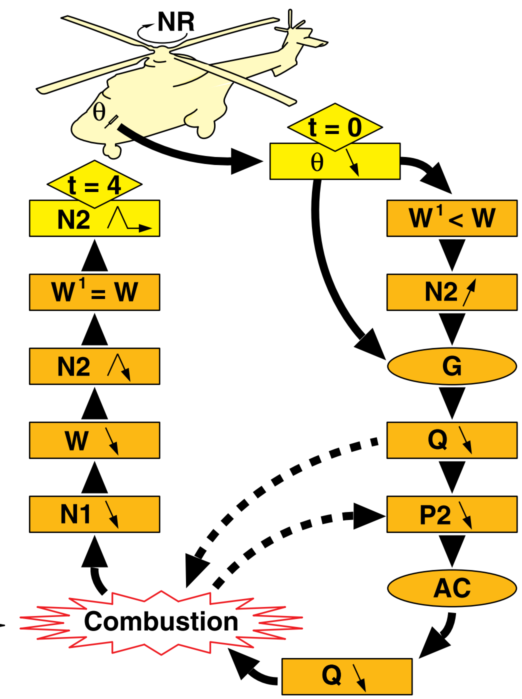
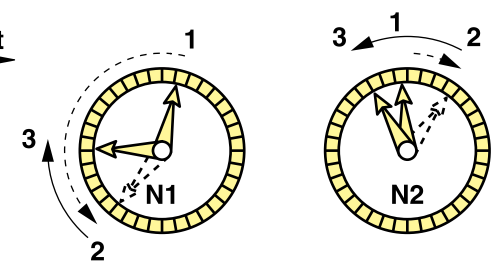


IMAGE OF A LOAD DECREASE



EVOLUTION OF PARAMETERS

GENERAL OPERATION (4)

GENERAL OPERATION (5)

Operation during engine shut-down

- Deceleration by means of the control lever, from "flight" position to rapid reduction notch
- When the lever is moved, it acts on the FCU (acceleration controller) and on the flow metering needles (S1+S2)
- The lever is set to the "stop" position (fully closed), the valve is completely "shut", the engine stops (N1↘, N2↘, t4↘ …)
- The drain and overspeed valve moves to the drain position (the fuel is cut-off and the injection wheel is purged).

Operation during manual starting

- To carry out a manual procedure, the starting device has to be closed (manually or automatically)
- The fuel flow is then not determined by the start servo-valve but by the control lever position
- The start push-button is kept pressed until approximately 45 % N1
- The control lever is then displaced until the nominal governed speed is reached.

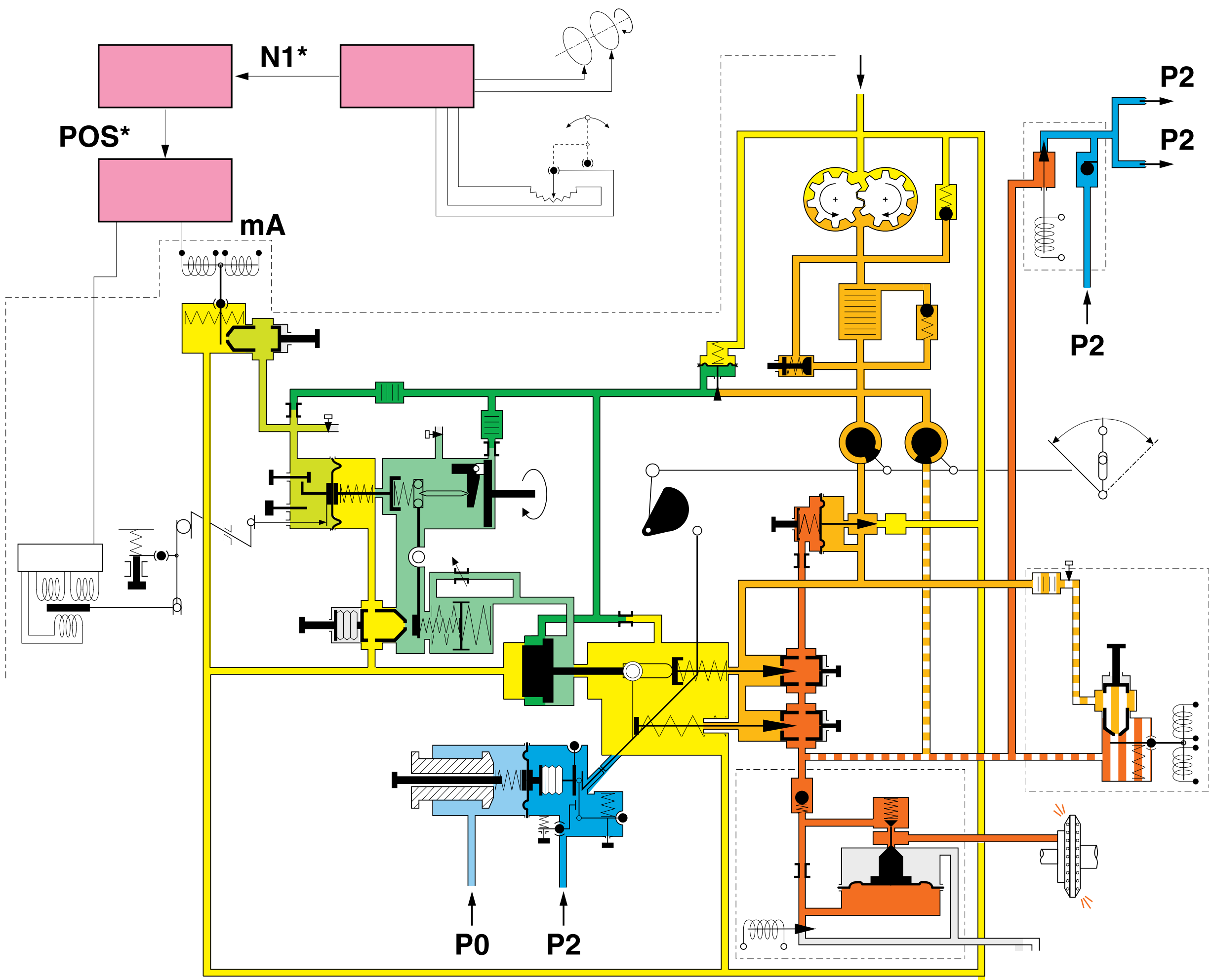
Note *: There is no governed idle speed.*

Operation during a manual engine control

In case of a fuel control failure, it is possible to achieve the engine control in the conventional way.

- Insufficient fuel flow : the control lever is moved to the emergency range (62° - 90°), the emergency valve opens and fuel by-passes the control system (limited max flow)
- Excessive fuel flow (or instability) : the control lever is moved to the starting range (52° - 32°), the main valve closes (the emergency valve obviously remains closed).

In a twin-engine configuration, the defective engine is set to a fixed power ; the other engine adapts to the conditions.



ENGINE SHUT-DOWN - MANUAL STARTING - "emergency" MANUAL CONTROL

GENERAL OPERATION (5)

GENERAL OPERATION (6)

Operation in "training" mode

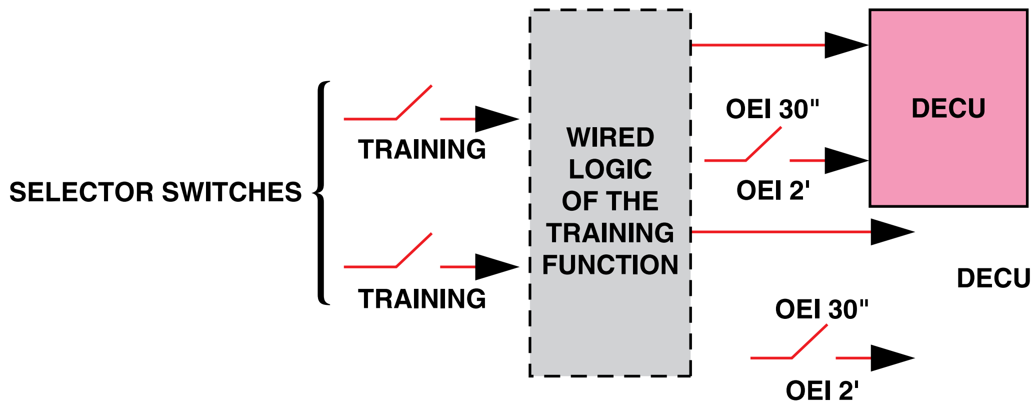
For the operation in training mode, there is a selector switch for each engine which is connected to the two engine DECUs. This switch permits the selection of the training mode on one of the two engines :

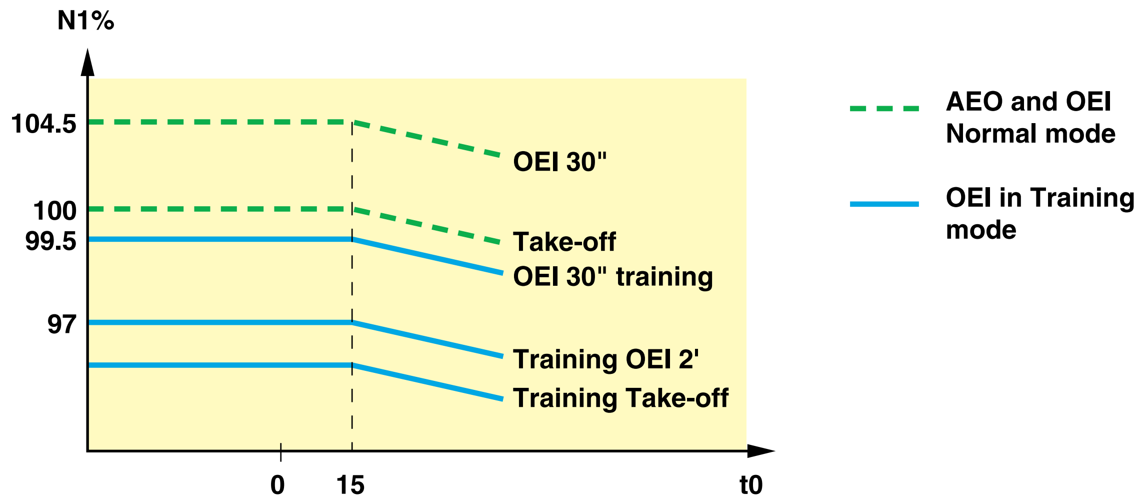
- The training mode is used with a lightly loaded helicopter

- On the selected engine, the rating is automatically reduced to idle rating (≈ 90 % of N2)

- On the second engine, the OEI 30 sec. and 2 min. OEI ratings are automatically limited by the DECU. These training ratings are lower than the AEO take-off rating (99.5 % of N1). Thus, the training is safely achieved with the ability to return to normal mode at any time.

Note *: The training mode indication is the same as an effective engine failure, but the maintenance counters are not activated.*





LIMITS OF THE "training" RATINGS

GENERAL OPERATION (6)

8 - CONTROL AND INDICATION

MANUAL CONTROL SYSTEM - GENERAL

Functions

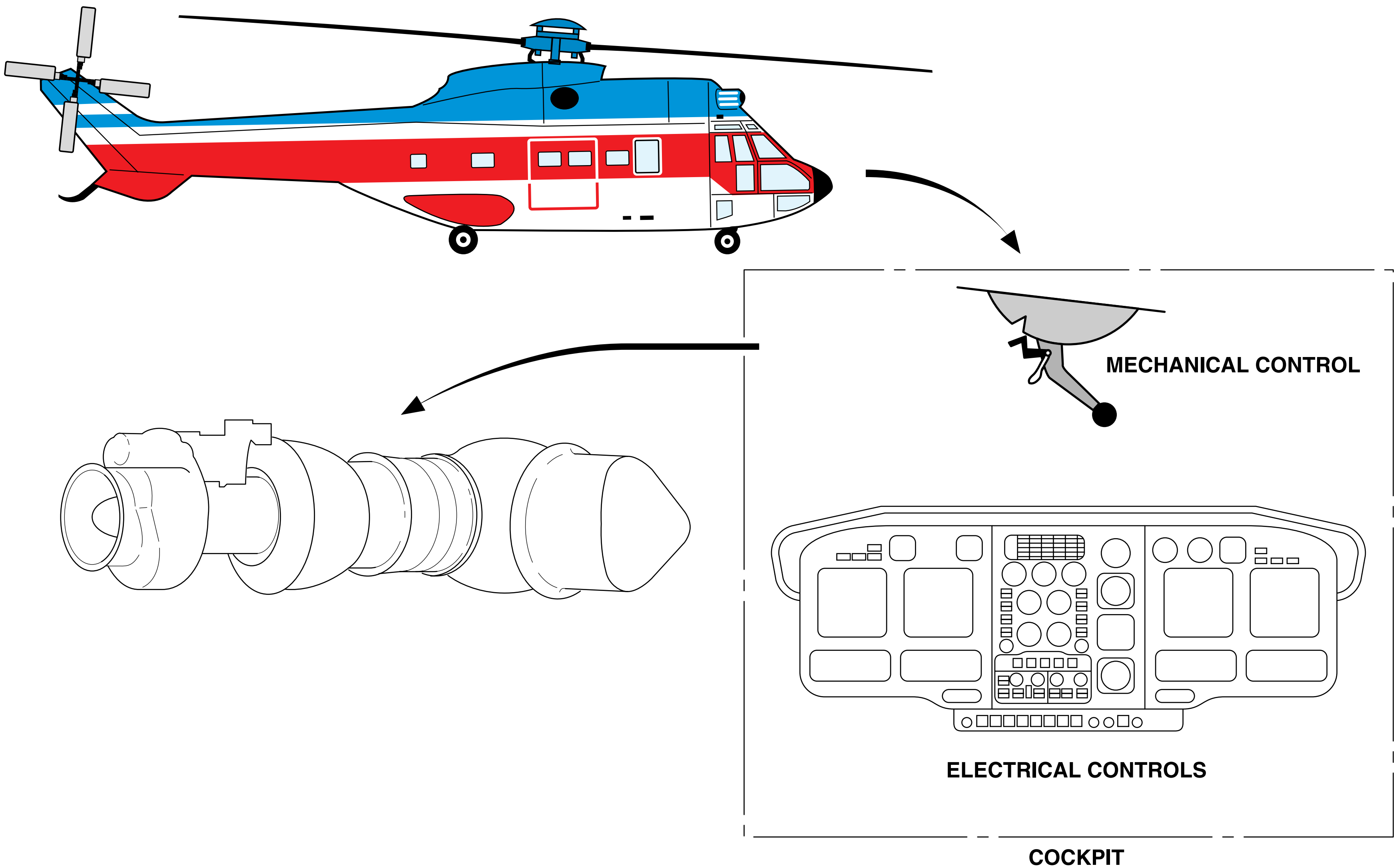
The system ensures the manual control of the engine.

Position

All the controls are located in the cockpit.

Main components

- Mechanical control (connected to the Fuel Control Unit)
- Electrical controls (switches, push buttons).



MANUAL CONTROL SYSTEM - GENERAL

MANUAL CONTROL SYSTEM - MECHANICAL CONTROL

Description

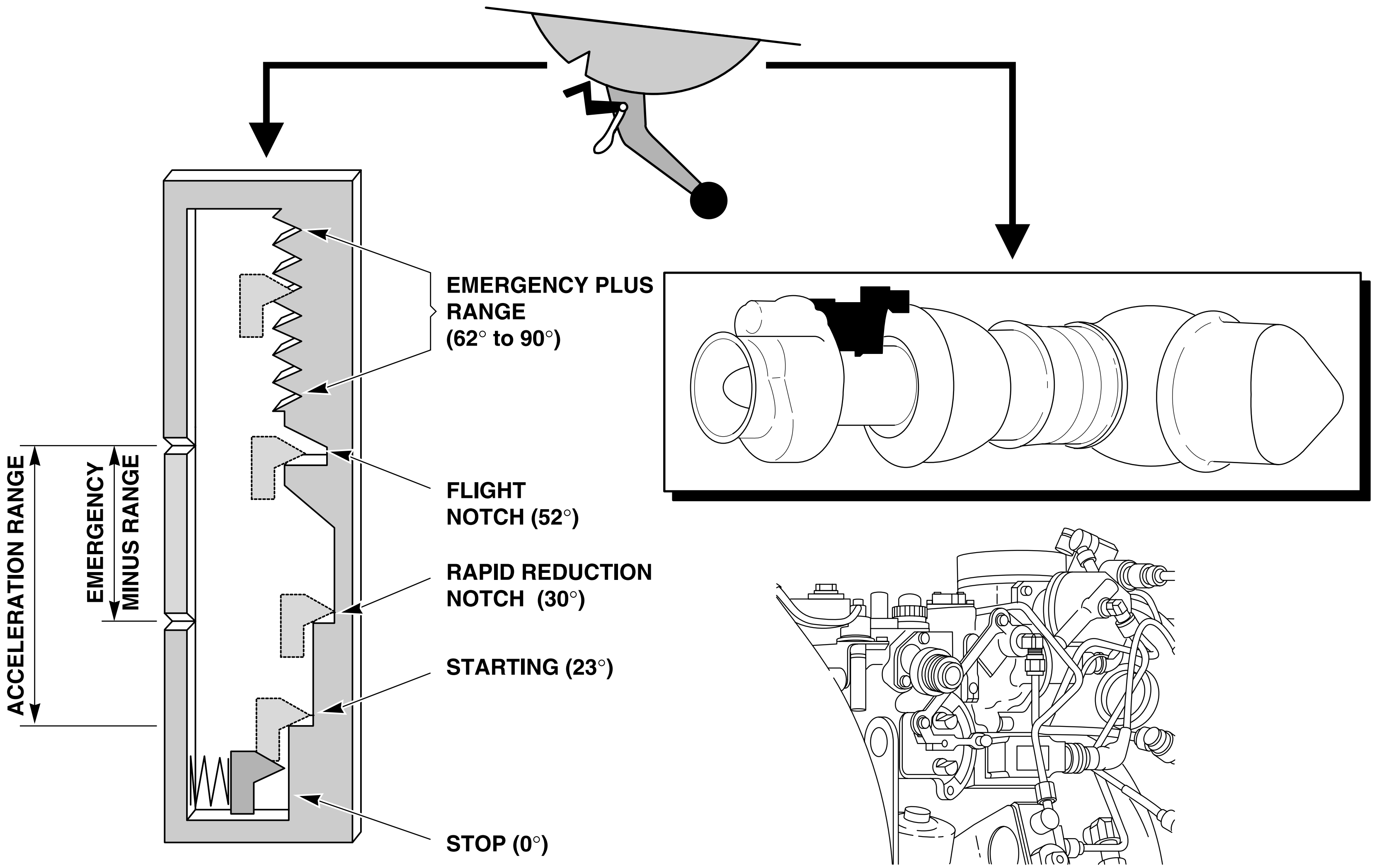
This control is used, for starting, for acceleration from start idle to flight idle and to stop the engine.

It is also used for manual control of the engine, for manual starting or in the event of failure of the automatic control system.

The control lever, located at the upper part of the cockpit, is connected by cable to the Fuel Control Unit. The adjustment of this connection is carried out following the aircraft maintenance manual instructions.

Positions of the control

- **Stop** : control fully closed (0°), both valves of the fuel control unit closed
- **Starting** : control in a notch (23°) which corresponds to the partial opening of the main valve
- **Rapid reduction notch** : mechanical stop to avoid flame out during deceleration (stop which can be overridden by mechanical device)
- **Flight notch** : control fully open (52°) which corresponds to the full opening of the main valve (automatic control of the fuel flow)
- **Emergency plus range** : between 62° and 90° after flight notch overriding. The range corresponds to the progressive opening of the auxiliary valve (manual control of the fuel flow in by-pass of the metering unit)
- **Emergency minus range** : between the flight notch and the rapid reduction notch. The range corresponds to a partial closing of main valve (manual control of the flow decrease)
- **Acceleration range** : between starting and flight. Acceleration and deceleration range of the engine. Can be also used for manual starting.



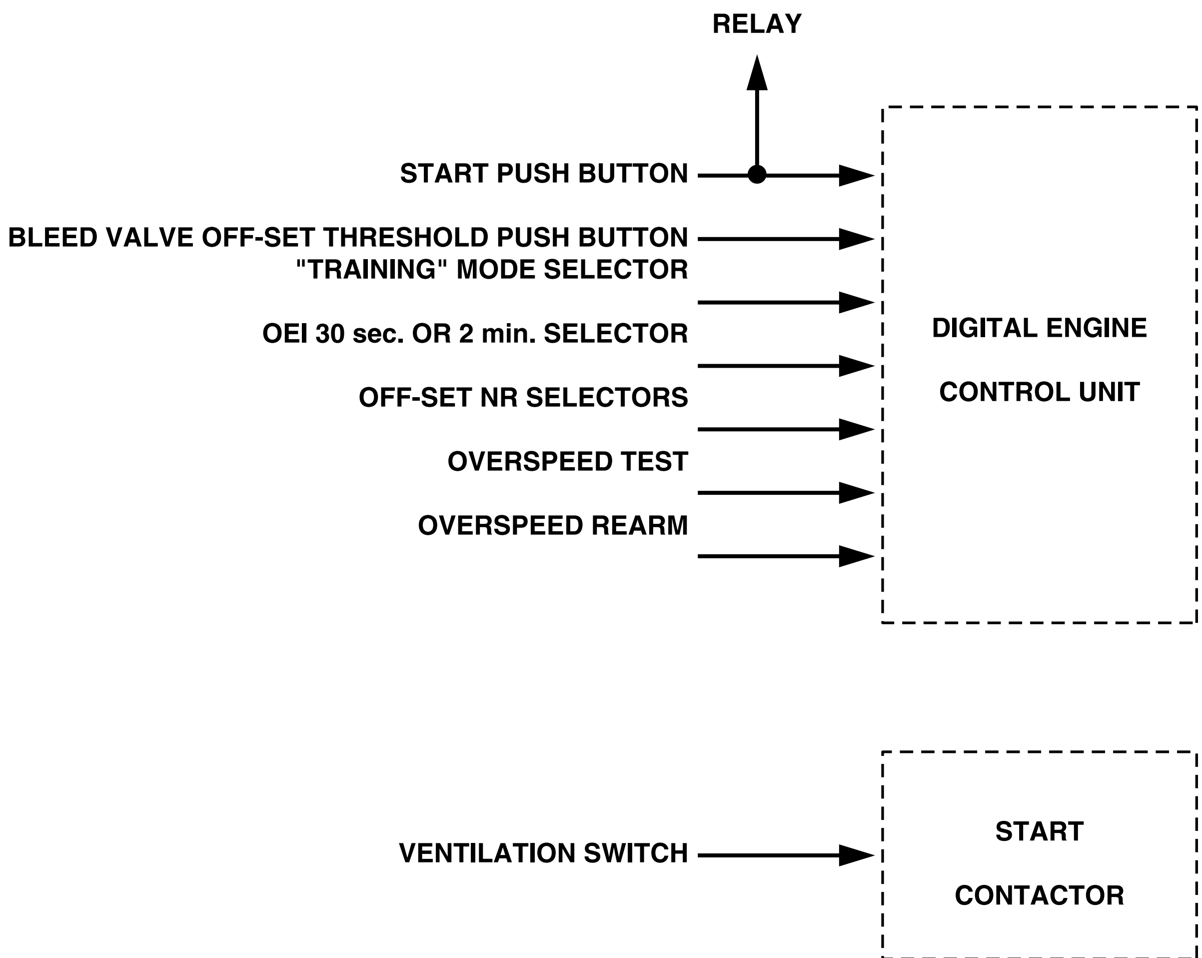
MANUAL CONTROL SYSTEM - MECHANICAL CONTROL

MANUAL CONTROL SYSTEM - ELECTRICAL CONTROLS

Description

The following are connected to the DECU :

- Start push-button
- Bleed valve "off-set threshold" push button (hovering with ground effect, with a strong tail wind)
- "Training mode" selector (for pilot training in OEI mode)
- OEI 30 sec. or 2 min. selector
- Off-set NR selectors (NR platform)
- Overspeed test
- Overspeed rearming.
- A "ventilation" switch which supplies the starter contactor (operation on ground, essentially in maintenance with limited operating time).



MANUAL CONTROL SYSTEM - ELECTRICAL CONTROLS

INDICATING SYSTEM

Functions

The indicating system provides the following functions :

- It allows the pilot to check that the engine is operating within operating limits
- It detects faults or abnormal evolution of parameters
- It verifies certain operating phases.

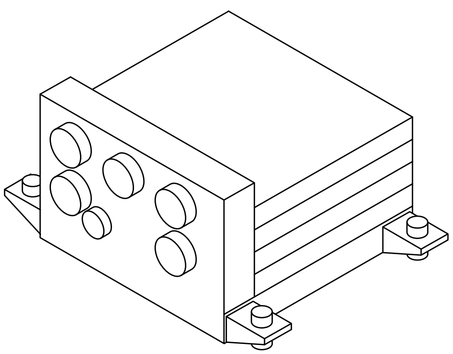
Note *: In fact there are operating parameters (N1, ΔN1 and torque) and monitoring parameters (N2, t4, oil pressure and temperature).*

Miscellaneous indications

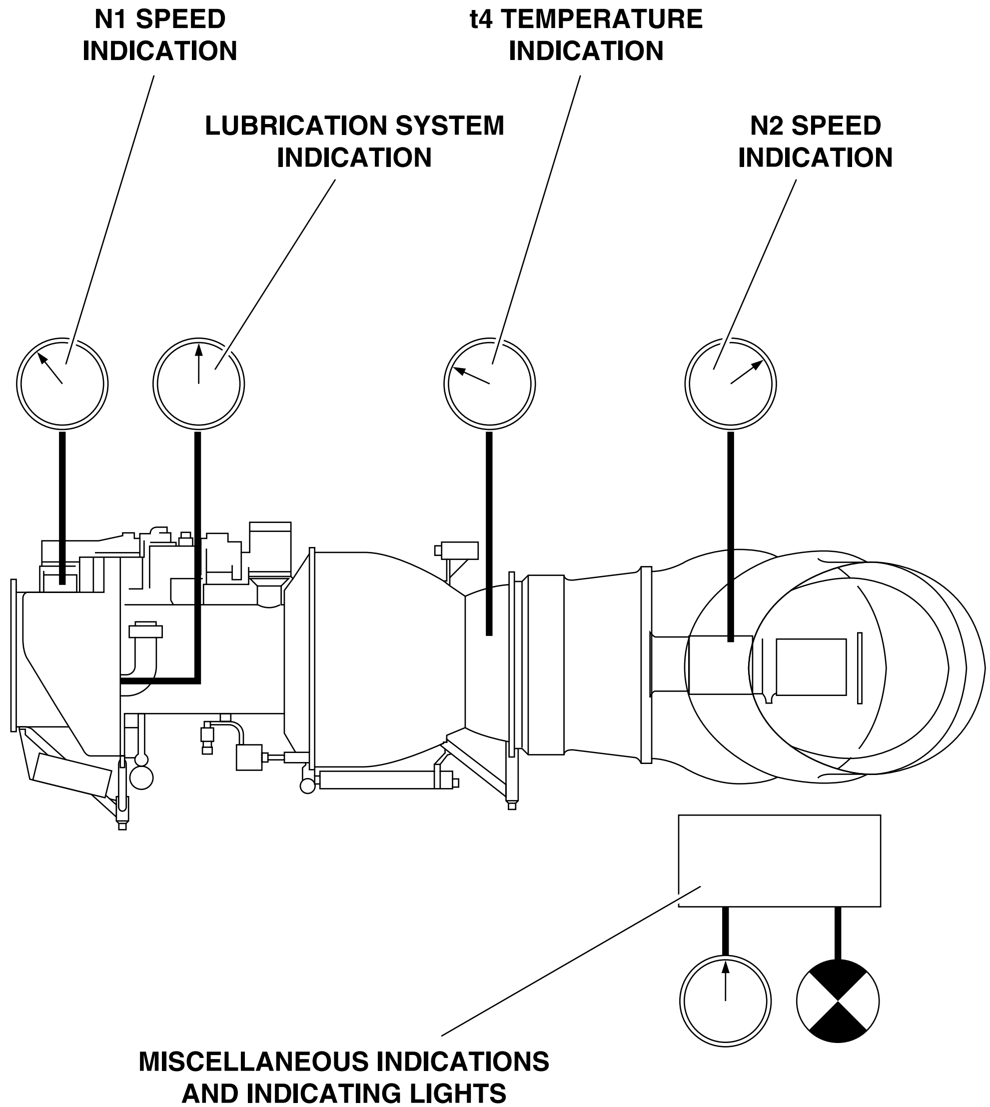
- Gas generator rotation speed (N1) indication
- Power turbine rotation speed (N2) indication
- Turbine gas temperature (t4) indication
- Engine torque indication
- Lubrication oil system indication (refer to chapter "OIL SYSTEM")
- Power loss indication
- Cycle counter
- Maintenance control unit
- Miscellaneous indications.

Note *: Refer to the various systems for the description and operation.*

FUNCTIONS
To ensure that the engine operates within determined limits To detect a fault or an abnormal change of parameters To check certain operating phases



DECU



INDICATING SYSTEM

SPEED INDICATION

Function

Two indicating systems measure the rotation speeds of the gas generator (N1) and the power turbine (N2).

Main characteristics

- Type : phonic wheel and electro-magnetic sensor
- Sensor signal : frequency proportional to the rotation speed
- Indication : digital in percentage.

Main components

- N1 speed sensors
- N2 speed sensors
- Connections with the DECU and the Fuel Control Unit
- Connections with the indicator.

Description

Refer to pages 8.12 to 8.19.

General operation

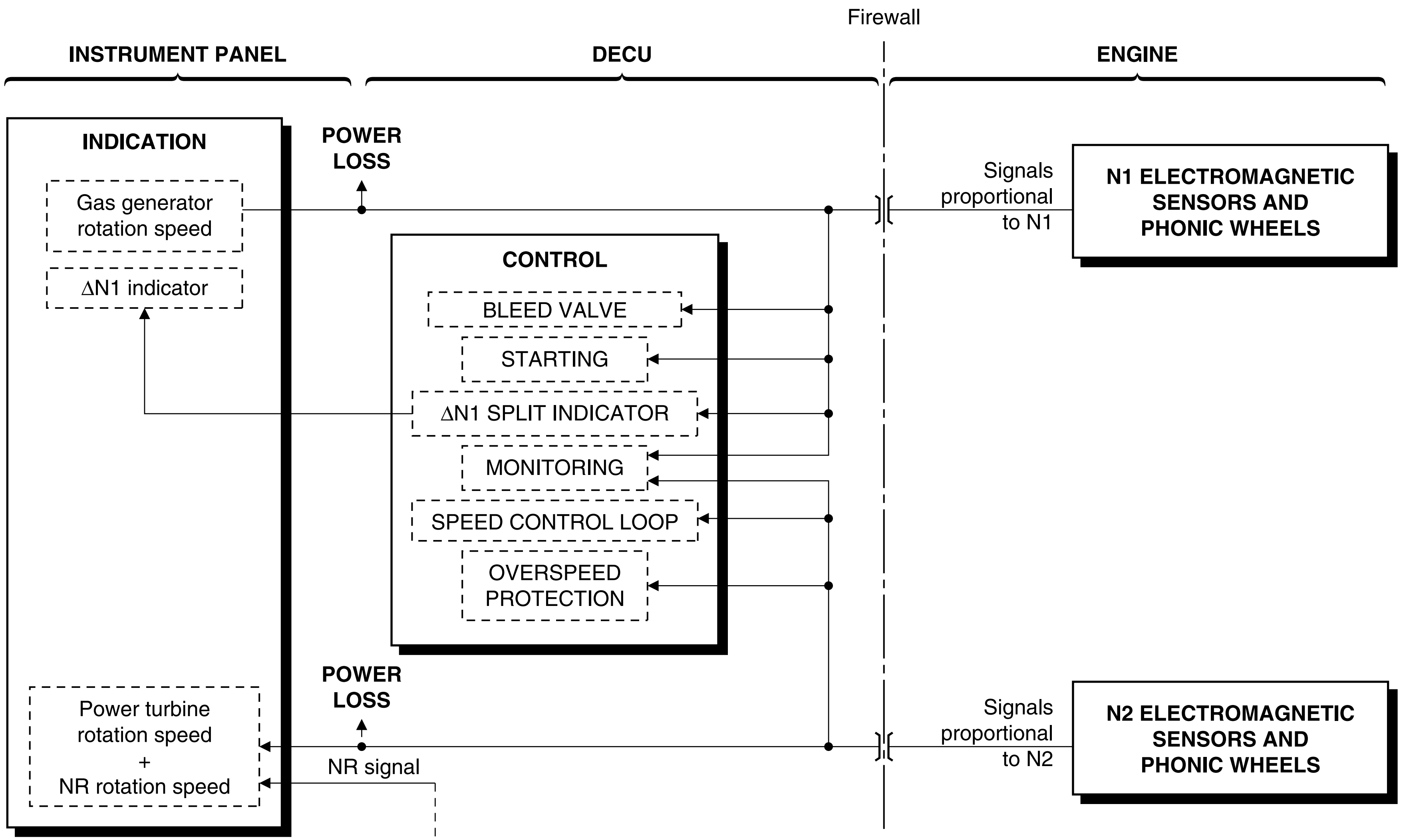
The gas generator rotation speed (N1) signal is used for :

- Starting control and bleed valve control in off-set mode
- Indication (N1 and ΔN1)
- Engine monitoring (power loss, cycles, health).

The N1 speed is an operating parameter as it reflects the engine power and serves to determine the limit ratings.

The power turbine rotation speed (N2) signal is used for :

- Engine control (speed control loop and overspeed protection)
- Indication (associated with the NR rotation speed indication)
- Engine monitoring (power loss, cycle counter).



SPEED INDICATION

GAS GENERATOR SPEED SENSORS - GENERAL

Function

The sensors measure the rotation speed of the gas generator rotating assembly.

Position

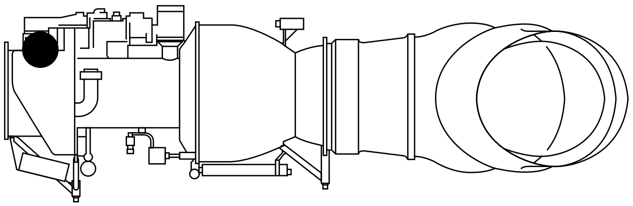
- In the accessory gearbox.

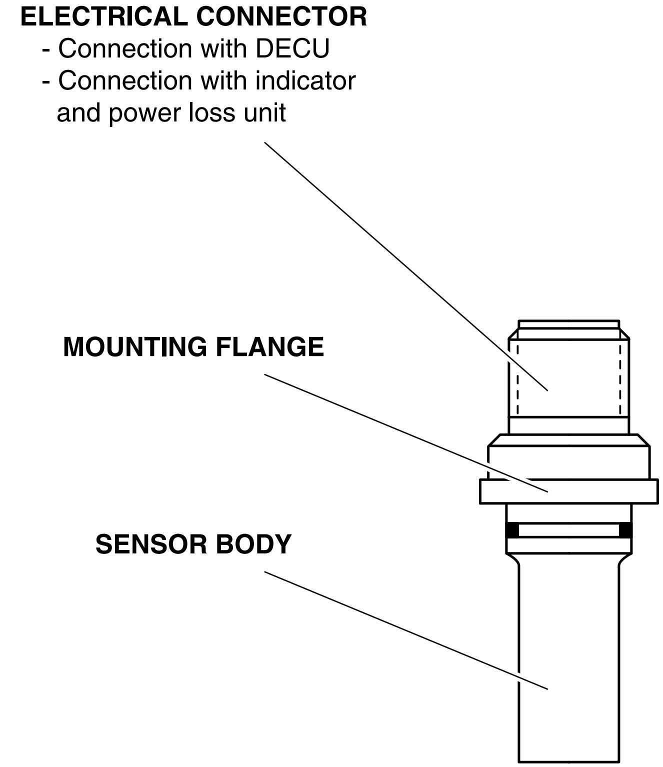
Main characteristics

- Quantity : 1 double sensor
- Type : electromagnetic
- Phonic wheel : starter drive gear
- Double sensor :
  - Two equal frequencies F and F' (F = 0,2344 N1 ; N1 = 4,2645741 F) F = 7782,08 Hz for 33200 RPM
  - The voltage across the terminals of each sensor is between 1.5 and 7 Volts.

Main components

- Phonic wheel (in the accessory gearbox)
- Sensor body
- Electrical connector (connection with DECU for starting N1, compressor bleed valve and split indicator ; direct connection with speed indicator and power loss unit).





Quantity
1 double sensor

Type
Electromagnetic

Phonic wheel
Starter drive gear

Signal
7782,08 Hz for 33200 RPM

GAS GENERATOR SPEED SENSORS - GENERAL

GAS GENERATOR SPEED SENSORS - FUNCTIONAL DESCRIPTION

Functional description

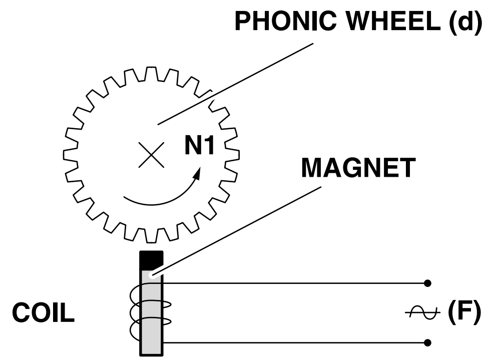
The rotation of the phonic wheel (starter drive gear) produces a pseudo-sinusoidal alternating voltage in the sensor.

The frequency of this alternating voltage is proportional to the rotation speed and the number of teeth on the phonic wheel.

$$F\ (Hz) = \frac{\text{Number of teeth x speed N (RPM)}}{60}$$

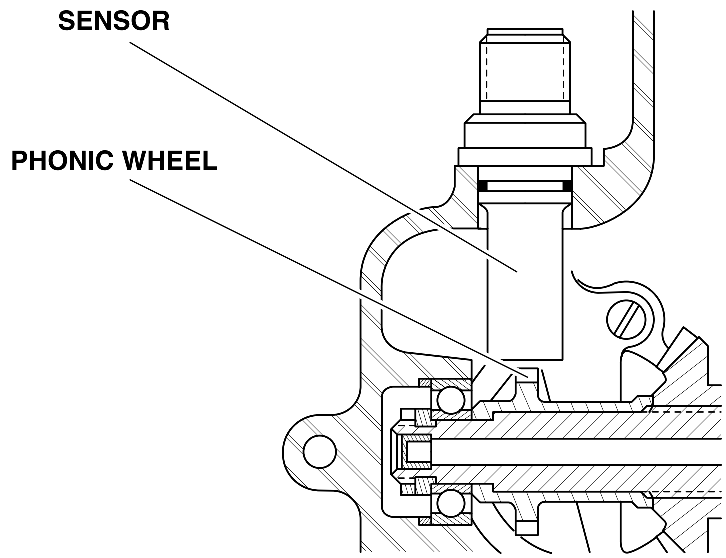
At 33200 RPM (N1), the frequency is 7782,08 Hz.

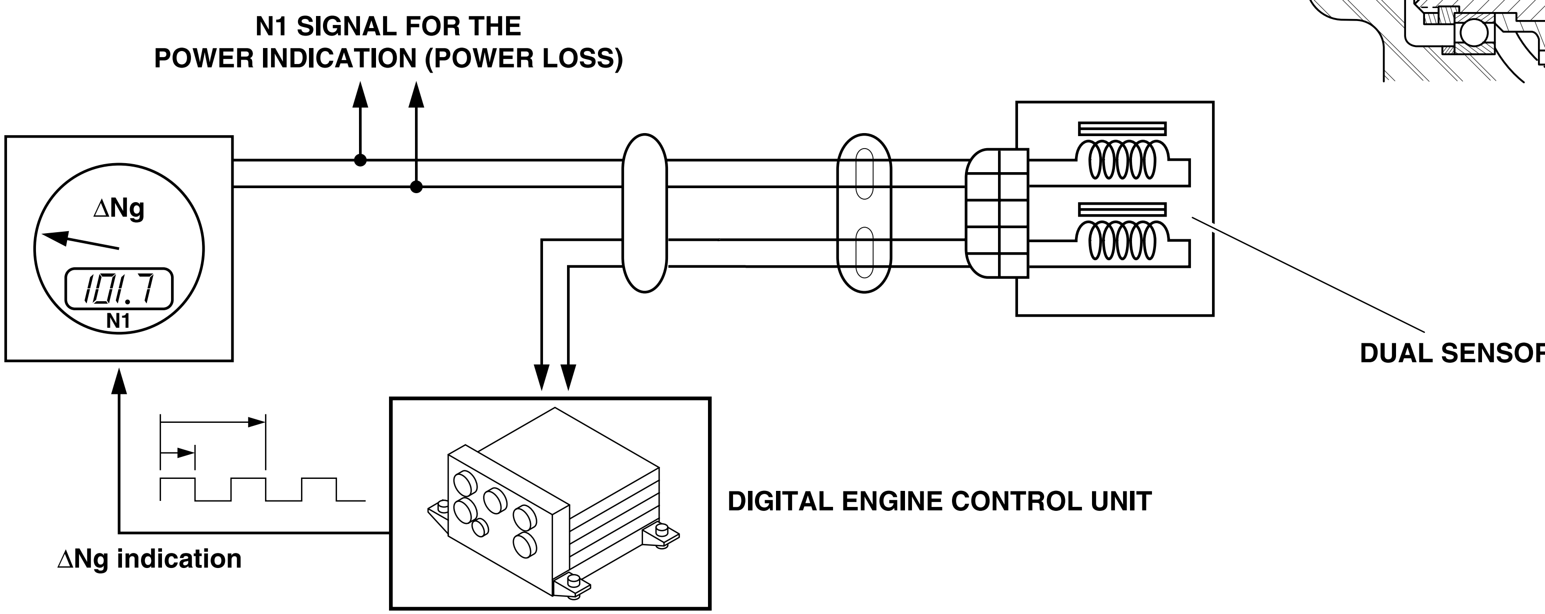
The outputs from the N1 sensor are transmitted to the speed indicator on the instrument panel and to the DECU ; they are used for start fuel flow control, bleed valve control in off-set mode, split indicator and DECU.



$$F = \frac{N \times d}{60}$$

PRINCIPLE OF SPEED MEASUREMENT





FUNCTIONAL DESCRIPTION

GAS GENERATOR SPEED SENSORS

POWER TURBINE SPEED SENSORS - GENERAL

Function

The sensors measure the power turbine rotation speed.

Position

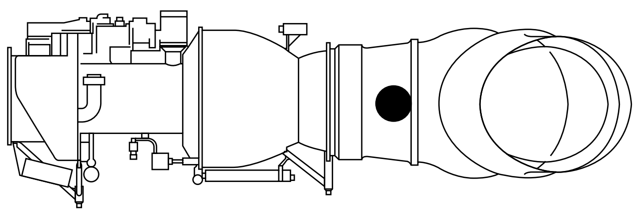
- Power turbine shaft.

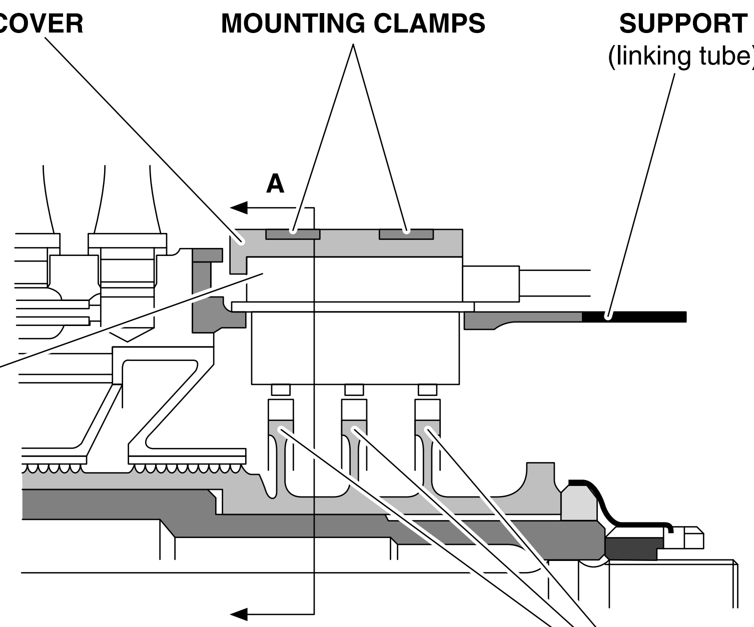
Main characteristics

- Quantity : 2 identical triple sensors (interchangeable)
- Type : electromagnetic
- 3 phonic wheels : on the power turbine shaft
- Signal at 100 % N2 :
  - 13777 Hz for F1 and F1'
  - 17987 Hz for F2 and F2'
  - 21048 Hz for F3 and F3'
- Number of teeth of the phonic wheels :
  - Front wheel : 47 teeth (F2)
  - Central wheel : 36 teeth (F1)
  - Rear wheel : 55 teeth (F3).

Main components

- Phonic wheels (in module M05)
- Sensor bodies and harnesses
- Mounting flanges and covers
- Electrical connector (connection with DECU for power turbine speed control, overspeed safety, power loss indication and power turbine rotation speed indication).



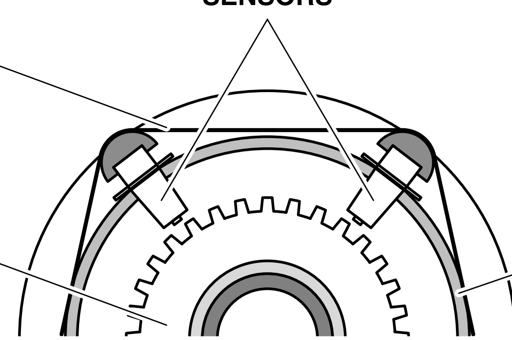


Quantity
2 identical sensors

Type
Electromagnetic

Phonic wheels
On power turbine shaft

Signal (100% N2)
F1 = F1' = 13777 Hz
F2 = F2' = 17987 Hz
F3 = F3' = 21048 Hz



A - A'

POWER TURBINE SPEED SENSORS - GENERAL

POWER TURBINE SPEED SENSORS - FUNCTIONAL DESCRIPTION

Functional description

The rotation of the phonic wheel (power turbine shaft) produces a pseudo-sinusoidal alternating voltage in the sensor.

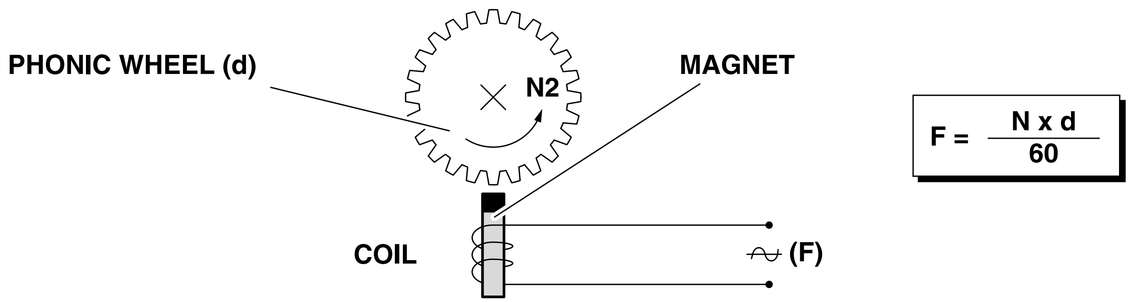
The frequency of this alternating voltage is proportional to the rotation speed and the number of teeth on the phonic wheel.

$$F\ (Hz) = \frac{\text{Number of teeth x speed N2}}{60}$$

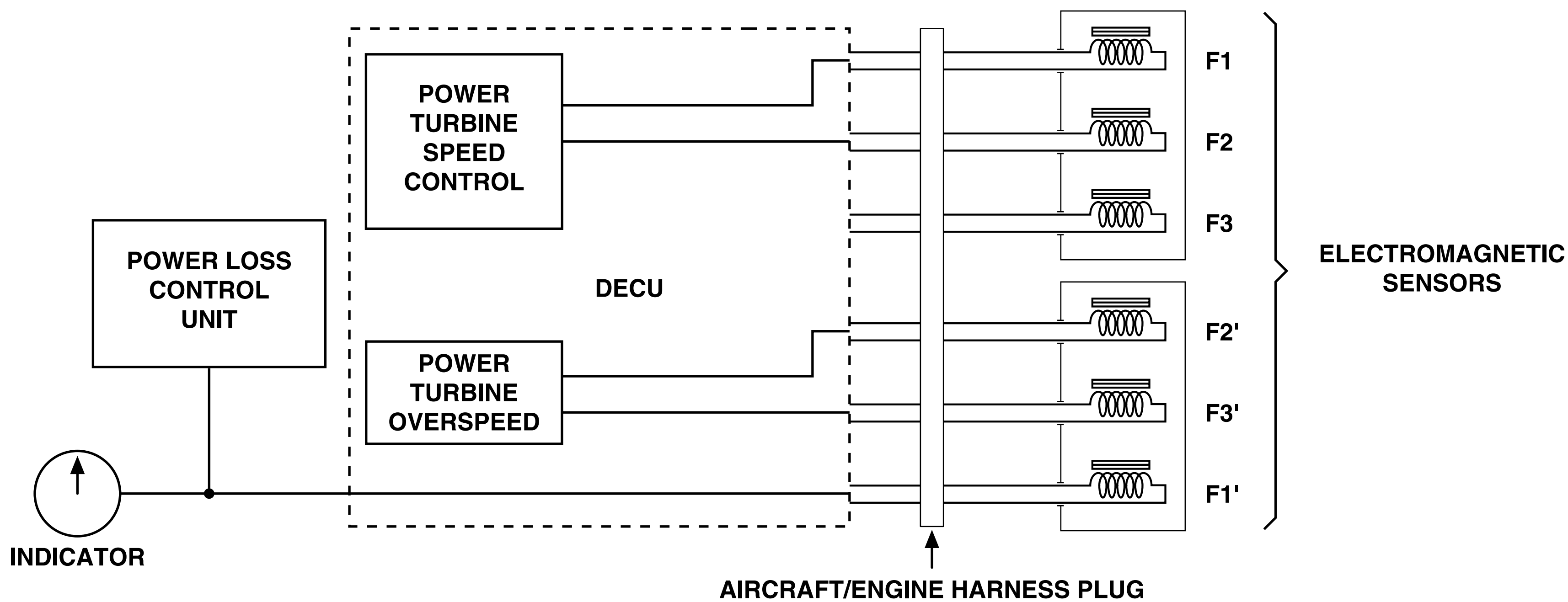
For 22962 RPM (100 % N2), the frequency (F1) is 13777 Hz for the power turbine speed indication.

The outputs from the N2 sensor are transmitted to the DECU which distributes :

- F1 - F2 : power turbine speed control
- F2' - F3' : power turbine overspeed safety
- F1' : power turbine speed indicator and power loss control unit
- F3 : not used.



PRINCIPLE OF SPEED MEASUREMENT



FUNCTIONAL DESCRIPTION
POWER TURBINE SPEED SENSORS

GAS TEMPERATURE INDICATION

Function

This system provides an indication of the gas temperature (t4) at the gas generator turbine outlet.

Main characteristics

- Type : pyrometric device with thermocouple probes
- Indication : degree Celsius.

Main components

- Probes
- Conformation box
- Indicator

Description

Refer to following pages.

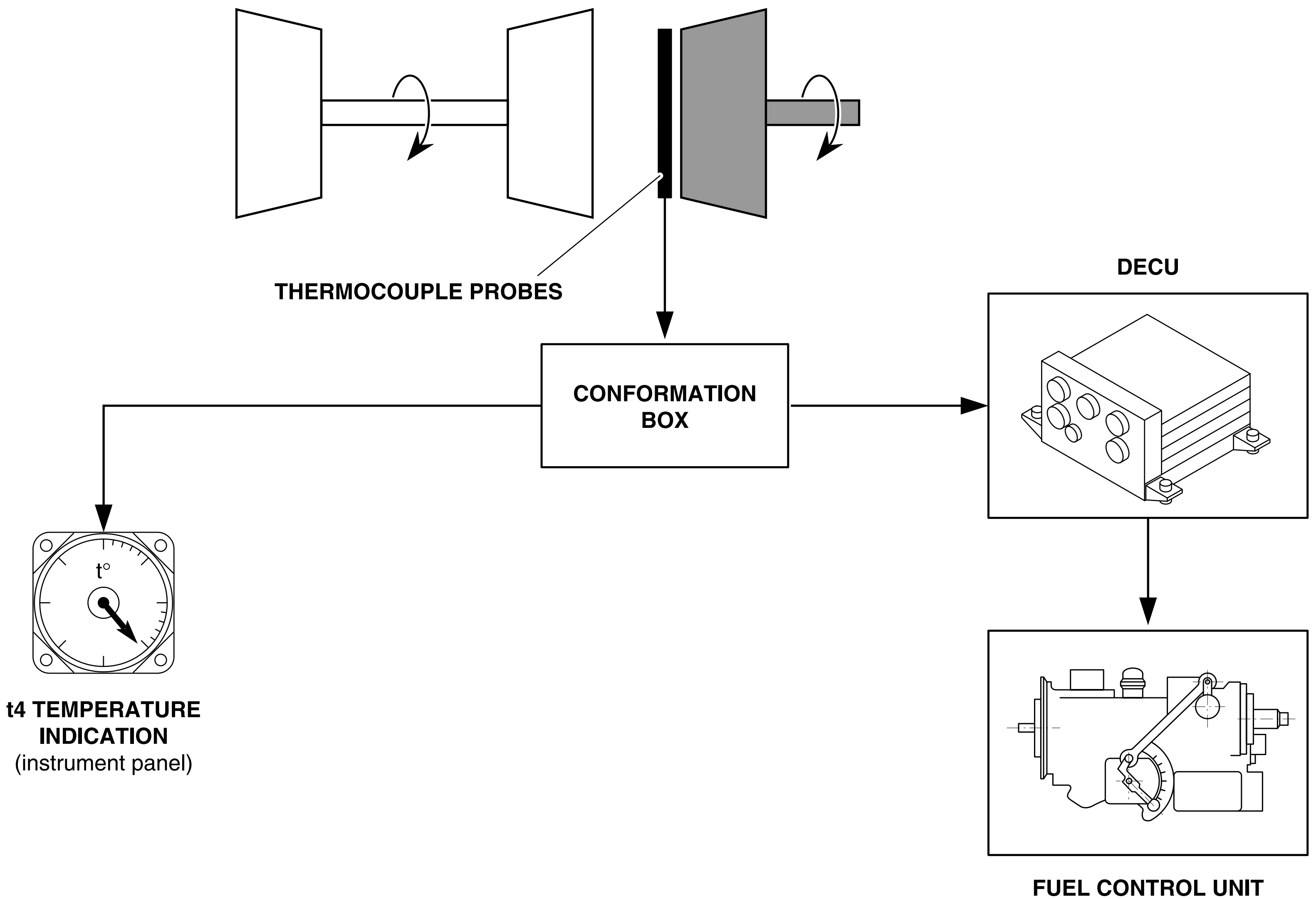
General operation

The gas temperature (t4) is an operating parameter, particularly during engine starting.

The signal from the thermocouples is used for :

- Engine control (starting fuel flow control)
- Indication
- Engine health calculation.

The conformation box provides the connection point between the thermocouples, the indicator and the DECU.



GAS TEMPERATURE INDICATION

THERMOCOUPLE PROBES - GENERAL

Function

The thermocouples (thermocouple probes) measure the gas temperature (t4) at the gas generator outlet.

Position

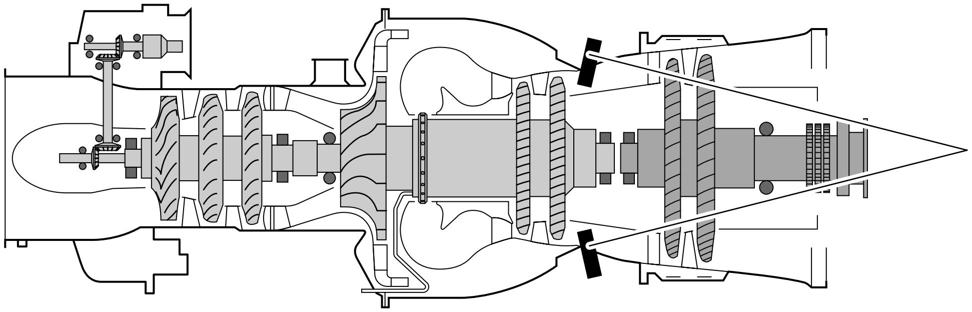
- On the gas generator outlet diffuser.

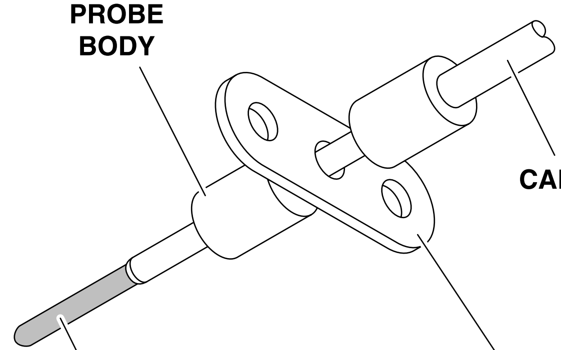
Main characteristics

- Type : Chromel-Alumel
- Quantity : 4 double probes (8 double probes after TU164)
- Alumel conductor : magnetic, negative polarity
- Chromel conductor : non magnetic, positive polarity
- Connection : to the conformation box in parallel.

Main components

- For each probe :
  - Probe (sheath and Chromel-Alumel junction)
  - Mounting flange
  - Probe body
  - Cable (connection with the conformation box).





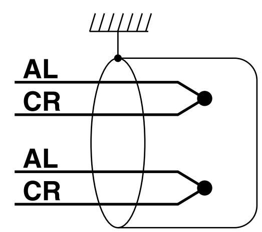
Type
Chromel - Alumel

Quantity
4 double probes
(8 double probes after TU164)

Alumel wire
Magnetic, negative polarity

Chromel wire
Non-magnetic, positive polarity

Connection
To the conformation box, in parallel



THERMOCOUPLE PROBES - GENERAL

THERMOCOUPLE PROBES - FUNCTIONAL DESCRIPTION

Functional description

The thermocouple probes are identical. They are positioned in the gas flow to give a homogeneous measurement.

Each probe contains a junction with Chromel-Alumel wires soldered together.

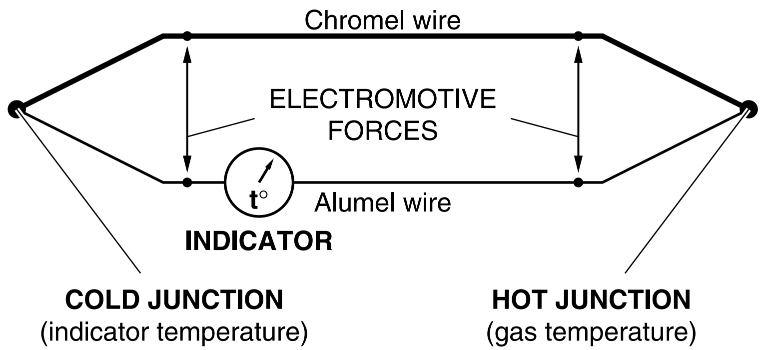
A thermocouple produces an electromotive force which is proportional to the temperature difference between the hot and cold junctions.

This voltage is supplied, via the conformation box to :

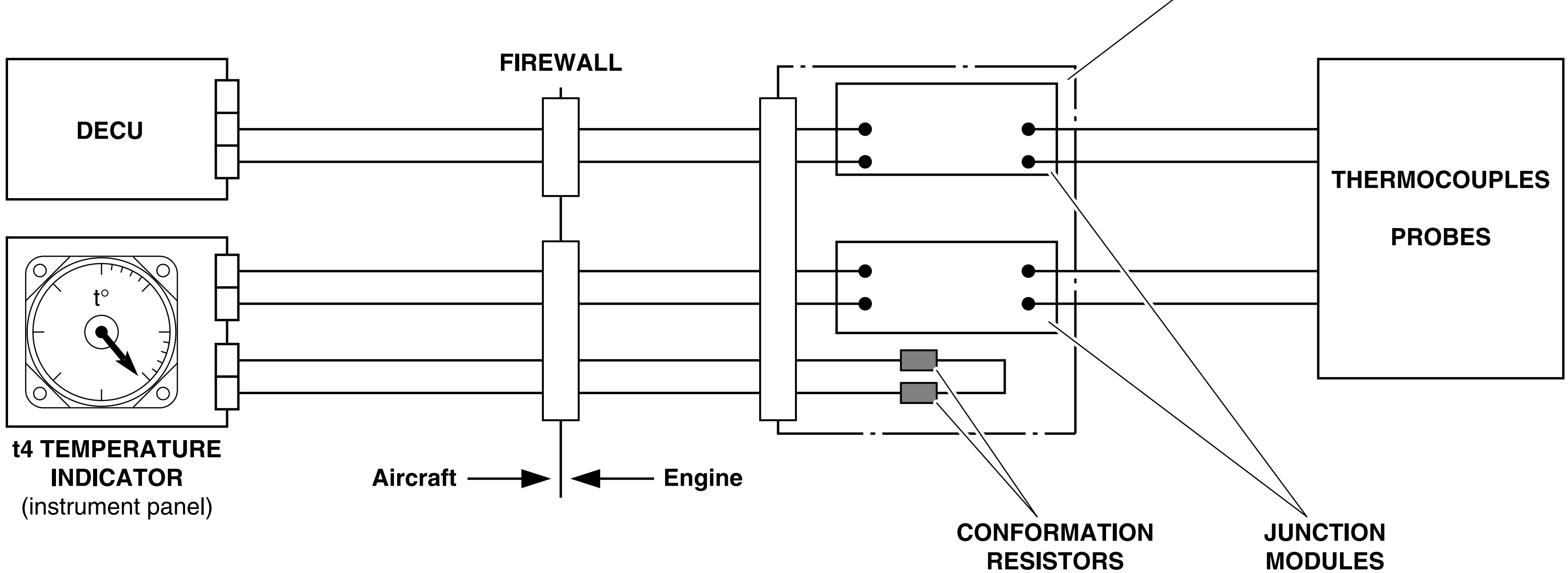
- The DECU (for start fuel flow control)

- The gas temperature indicator (millivoltmeter graduated in degrees Celsius).

The probes are connected in parallel. The reading obtained is an average temperature.



THERMOCOUPLE PRINCIPLE



THERMOCOUPLE PROBES - FUNCTIONAL DESCRIPTION

t4 CONFORMATION BOX - GENERAL

Function

The conformation box forms the interface between the thermocouples, and the indicator and DECU.

It also allows a corrected temperature (t4) indication for a given turbine inlet temperature.

Position

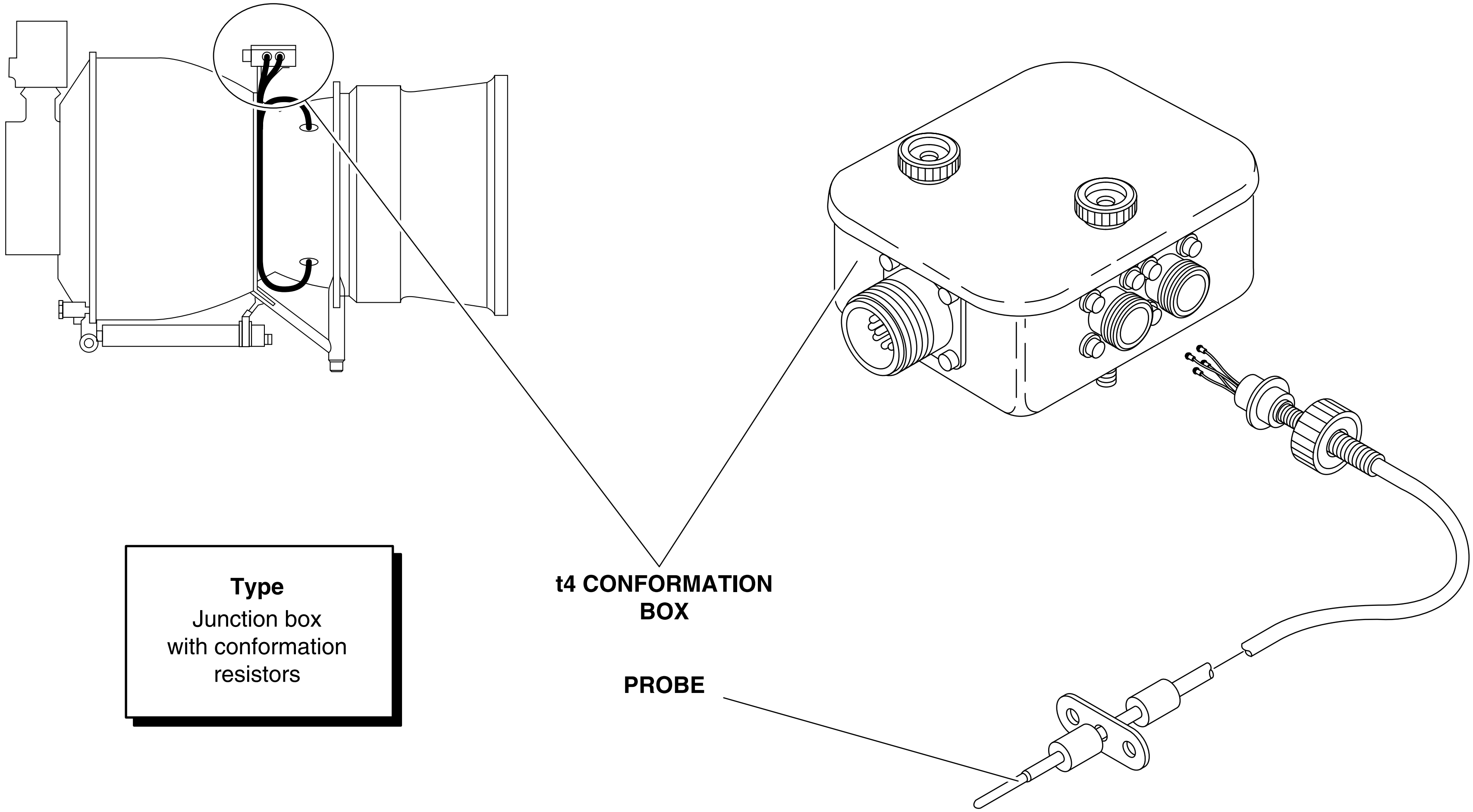
- On the upper part of the turbine casing.

Main characteristics

- Type : junction box including conformation resistors.

Main components

- Mounting flange
- Box
- Thermocouple connector
- DECU connector.



Type
Junction box
with conformation
resistors

t4 CONFORMATION BOX - GENERAL

t4 CONFORMATION BOX - DESCRIPTION - OPERATION

Description

The conformation box is mounted on a support above the combustion chamber casing, by means of 3 securing screws.

It includes the connectors :

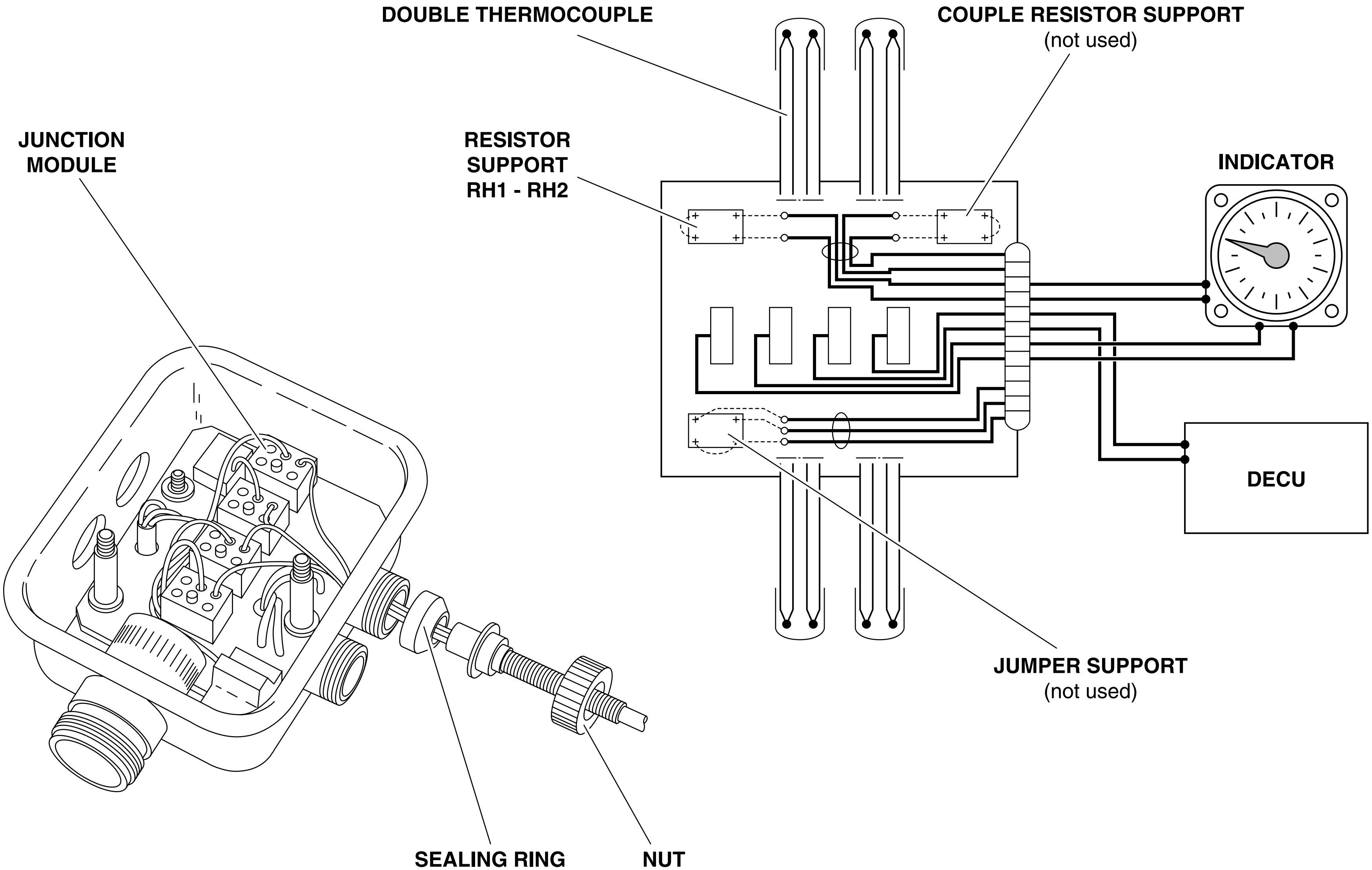
- 4 junction modules (different colours corresponding to the conductor (Cr or Al) and to the function (DECU or indication))
- 1 connection to the control harness.

The box includes :

- The connection device for the Chromel and Alumel conductors (junction modules)
- The conformation resistors.

Operation

The conformation box provides the connection point between the thermocouples, the DECU and the indicator. It contains resistors which enable a uniform t4 temperature indication for a given turbine inlet temperature (RH1 and RH2 resistors : t4 = k.t3), t4 = 680 °C (1256 °F) for t3 = 960 °C (1760 °F).



t4 CONFORMATION BOX - DESCRIPTION - OPERATION

TORQUE INDICATION

Function

The system provides an indication of the engine torque. It is located on the power transmission shaft in the main gearbox.

This system is of aircraft manufacturer responsibility and is only briefly mentioned.

Main components

- Two phonic wheels on the power transmission shaft
- Detector
- Control unit
- Indicator.

Functional description

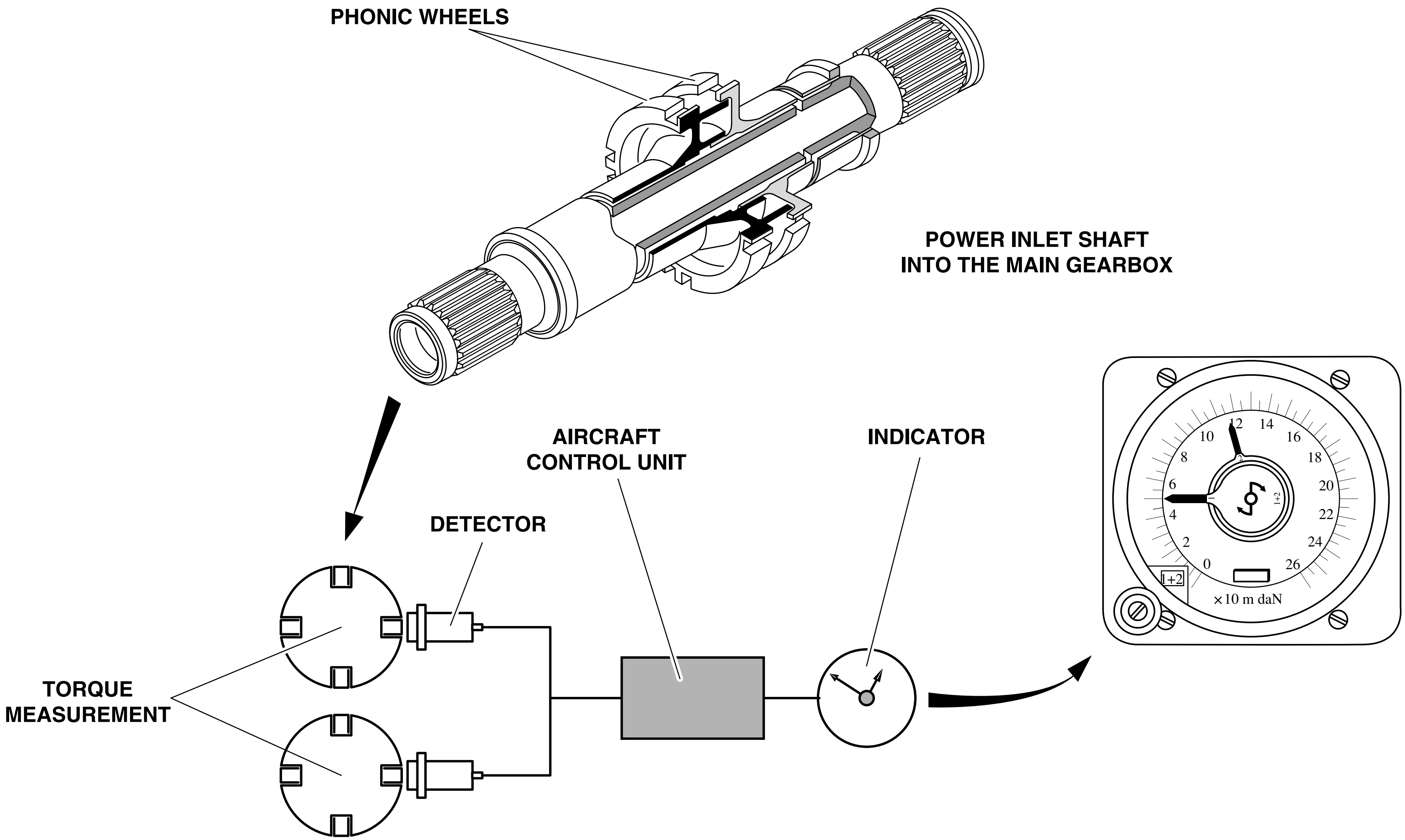
The shaft torsion causes an angular displacement of a disc with respect to another. This displacement is measured by a detector.

There are two detectors : one per input shaft in the main gearbox.

An aircraft control unit processes the detector signal which is sent to the indicator.

The indicator simultaneously shows the values of the engine 1 torque and the total torque (position 1 + 2), or the torque values of each engine (position 1).

Note : *Refer to the aircraft manual for the maximum torque limits for one or two engines.*



TORQUE INDICATION

"POWER LOSS" INDICATION - GENERAL

Function

The system (of aircraft manufacturer responsibility) indicates a control system failure or an operational failure. It basically consists of a control unit which receives a certain number of signals and outputs signals to a set of indicating lights.

The system also permits the automatic arming of the OEI stops in each DECU.

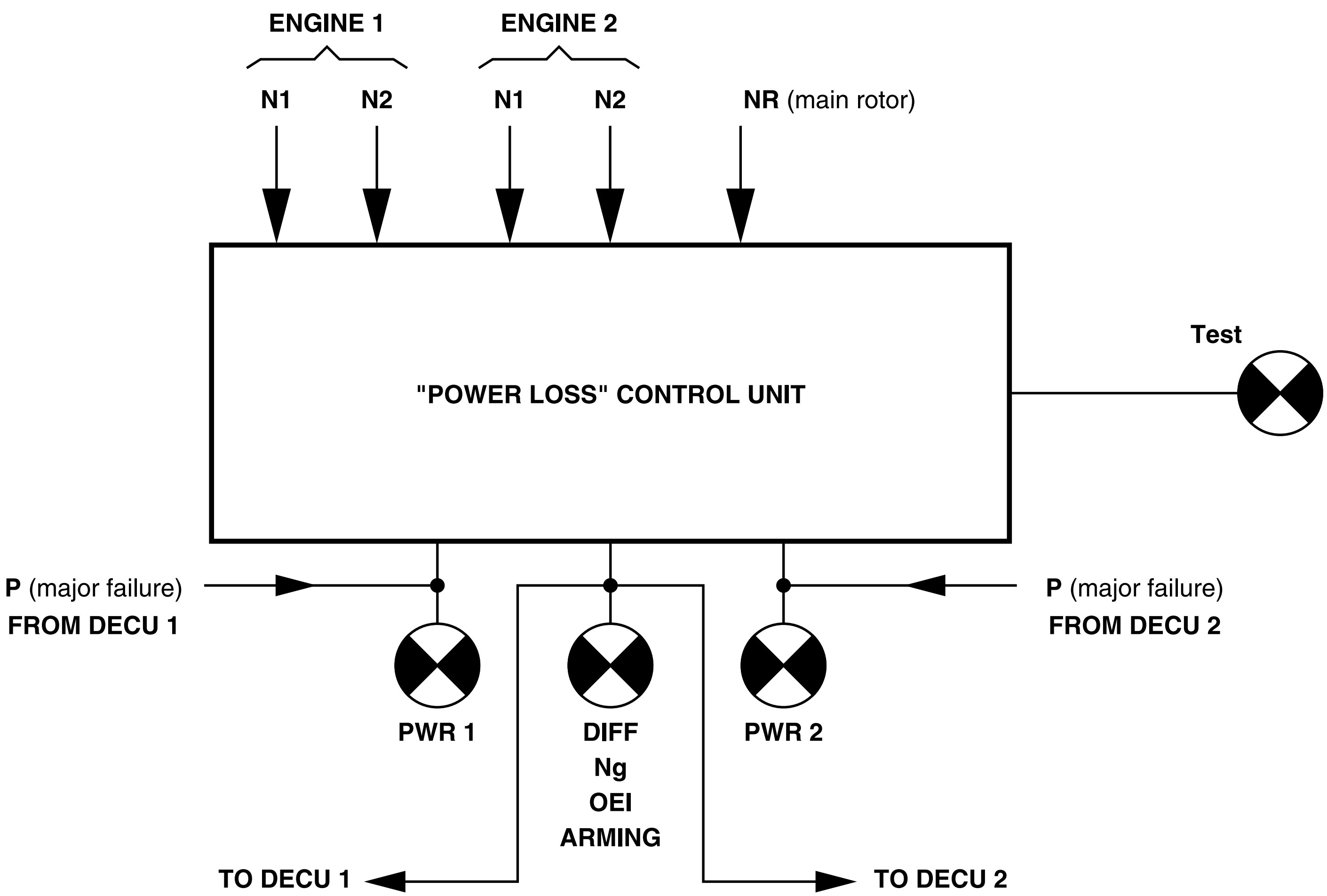
Position

Refer to aircraft manual.

Description

- Input signals :
  - N1 of engines 1 and 2
  - N2 of engines 1 and 2
  - NR of the main rotor
  - P : signal of major failure (from DECU)
- Outputs of the Control Unit :
  - PWR of engines 1 and 2
  - DIFF Ng
  - Test.

Note *: N1 = Ng and N2 = NTL.*



"POWER LOSS" INDICATION - GENERAL

"POWER LOSS" INDICATION - FUNCTIONAL DESCRIPTION

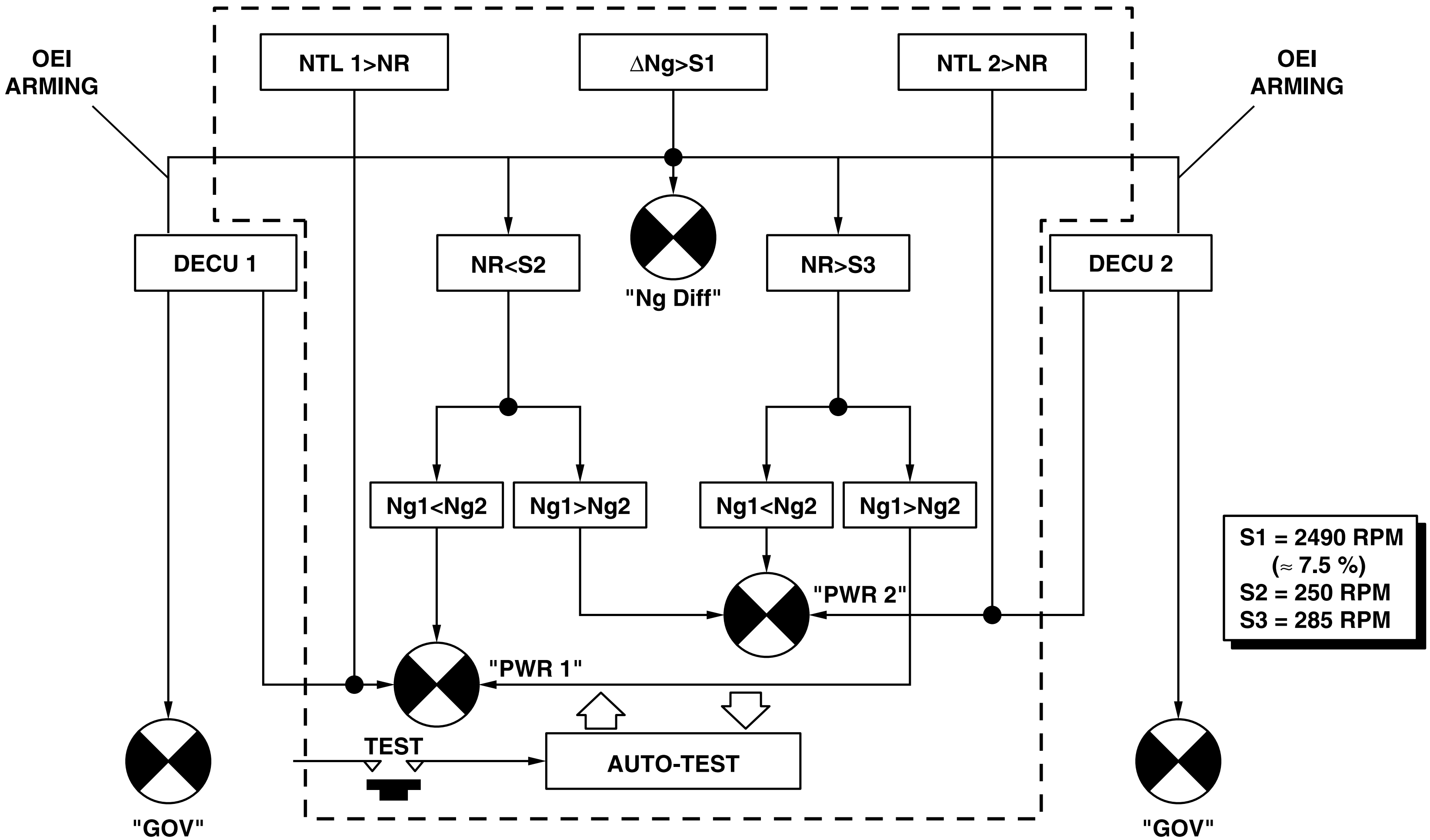
Functional description

The failure of an internal or external component (material or functional) of the control system illuminates the GOV amber light or of the PWR red light, according to the failure level (failure level discrimination : loss of redundancy, minor failure or major failure).

A difference between N2 and NR (N2 > NR : free wheel defect) illuminates the PWR red light of the corresponding engine.

A significant difference between the Ng speeds illuminates the DIFF Ng warning light and sets the OEI stops. If the difference is followed by an NR variation higher or less than a given threshold, the PWR red light of the considered defective engine illuminates.

Note : *Throttle lever on stop, the lights are inhibited (the GOV amber light is inhibited above an N2 threshold in cases of redundancy loss). Refer to the aircraft documentation for more information.*



"POWER LOSS" INDICATION - FUNCTIONAL DESCRIPTION

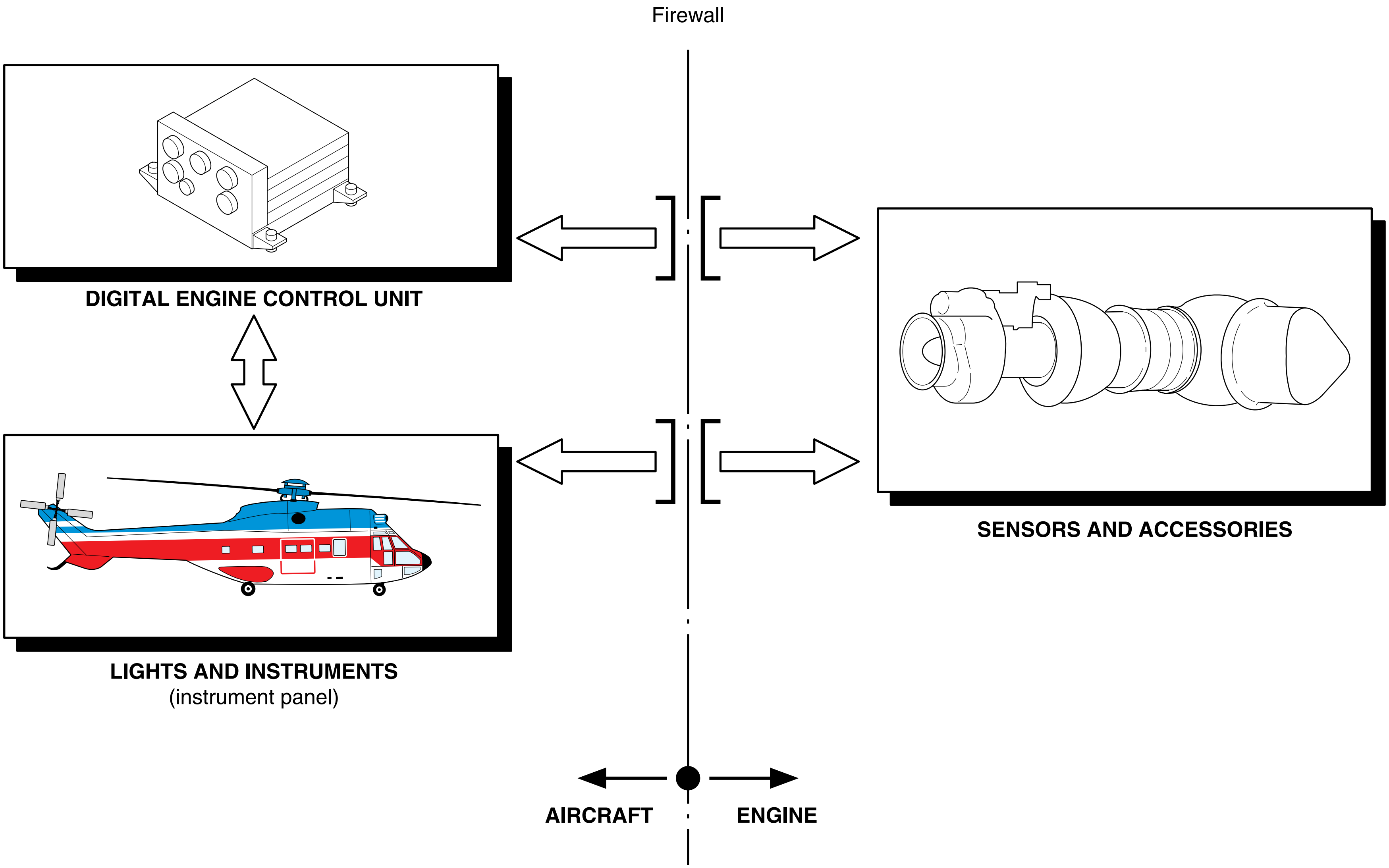
MISCELLANEOUS INDICATIONS - GENERAL

Function

The miscellaneous indications provide information on the engine operation.

Main components

- Sensors and engine accessories (refer to corresponding chapters for more information)
- Digital Engine Control Unit
- Instruments and indicators on the instrument panel :
  - Indicators
  - Instruments (particularly the ΔNg and the gas generator speed indicator).



MISCELLANEOUS INDICATIONS - GENERAL

For training purposes only

MISCELLANEOUS INDICATIONS - WARNING LIGHTS AND INDICATORS

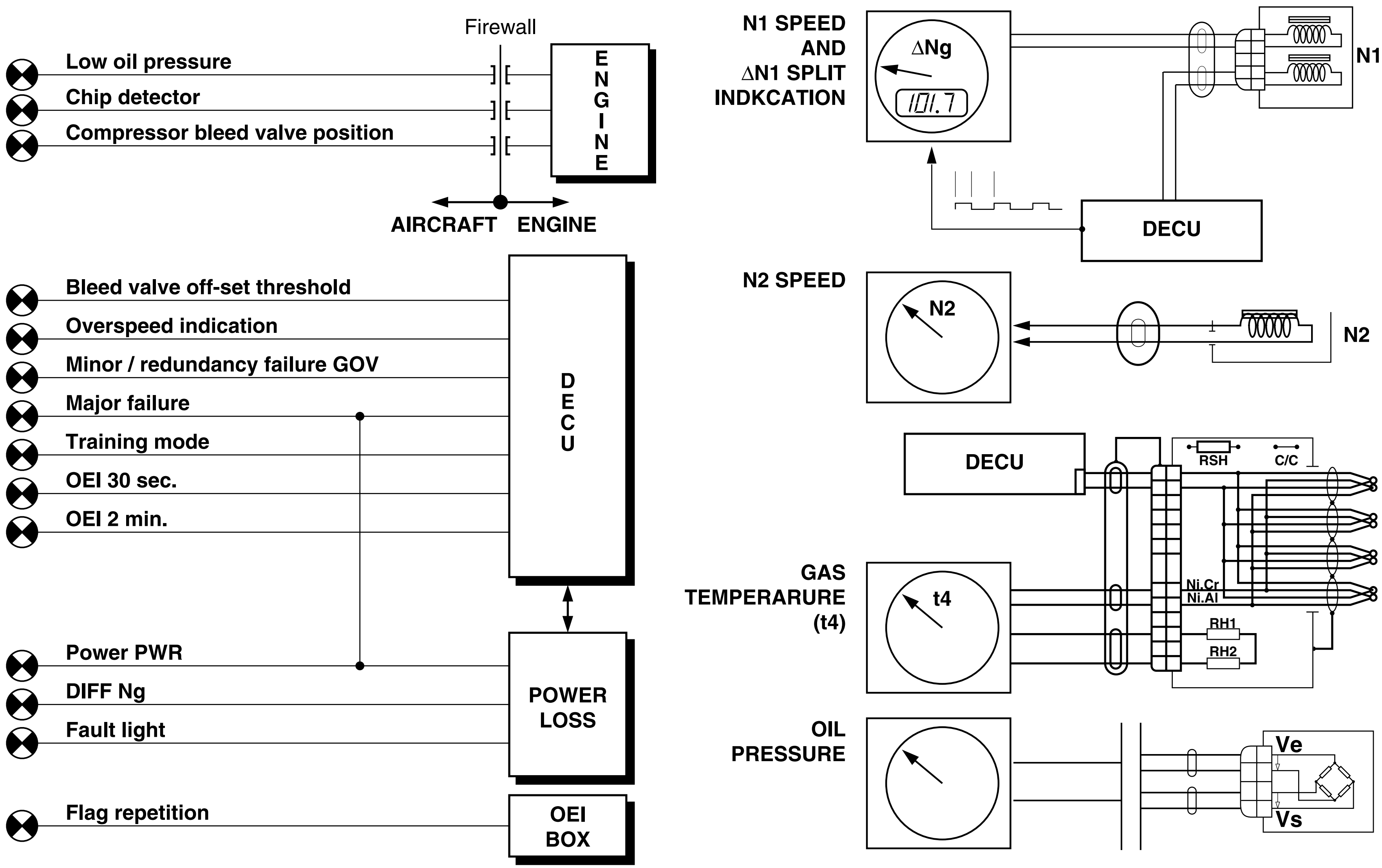
There are several warning lights and indicators which give information about the engine operation. They are the following.

Warning lights

- Low oil pressure
- Compressor bleed valve position (flag)
- Chip detector
- Bleed valve off-set threshold
- Overspeed
- Redundancy failure and minor-control system failure (GOV)
- Control system major failure (PWR)
- Training mode
- OEI 30 sec.
- OEI 2 min.
- Diff Ng
- Fault light during control unit test
- OEI box flag repetition.

Indicators

- N1 speed and ΔN1 split
- N2 speed
- Torque
- t4 gas temperature
- Oil pressure
- Oil temperature.



MISCELLANEOUS INDICATIONS - WARNING LIGHTS AND INDICATORS

MISCELLANEOUS INDICATIONS - OEI INDICATING SYSTEM

Function

This system monitors the operation of the engine (in OEI mode) when the other engine has failed.

Main components

- Power loss Control Unit
- Digital Engine Control Unit
- OEI box
- Integrated Flight Display System (IFDS).

Functional description

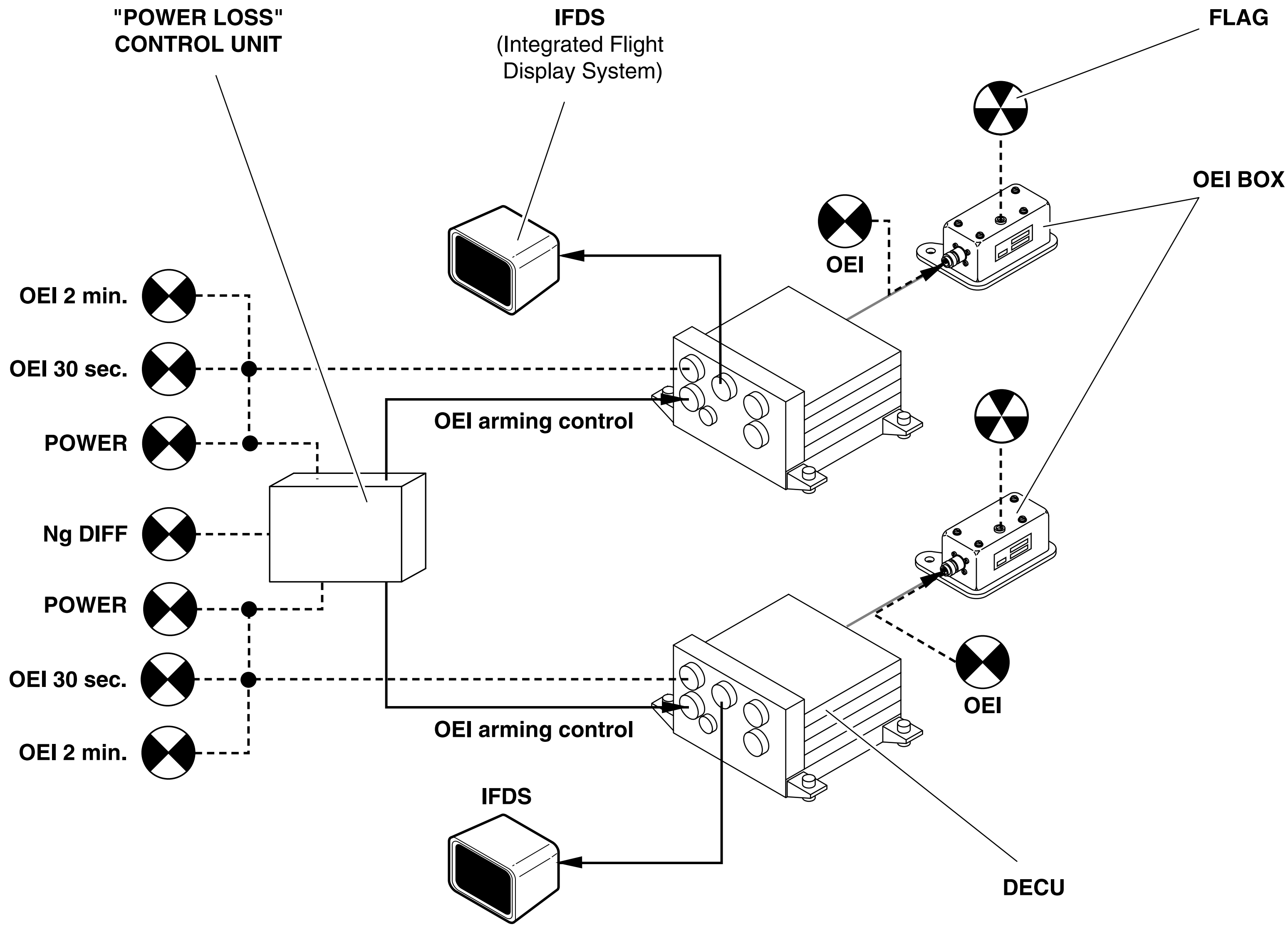
The power loss Control Unit detects an engine failure and sends a signal to the Digital Engine Control Units.

As the signal is received, it selects an OEI top rating (30 sec. or 2 min.) and supplies the corresponding OEI 30 sec. or 2 min. light on the ΔN1 indicator.

If the actual N1 exceeds a given value it starts counting the time and sends (after a given time) a signal to the OEI box. This signal energises a bi-stable relay which supplies the OEI flag on the box. The flag becomes black and the OEI light in the overhead panel flashes.

The IFDS system (Integrated Flight Display System) indicates the operating times elapsed in the various OEI ratings.

These elapsed times are calculated by the engine control unit.



MISCELLANEOUS INDICATIONS - OEI INDICATING SYSTEM

MISCELLANEOUS INDICATIONS - FIRST LIMIT INDICATOR

Function

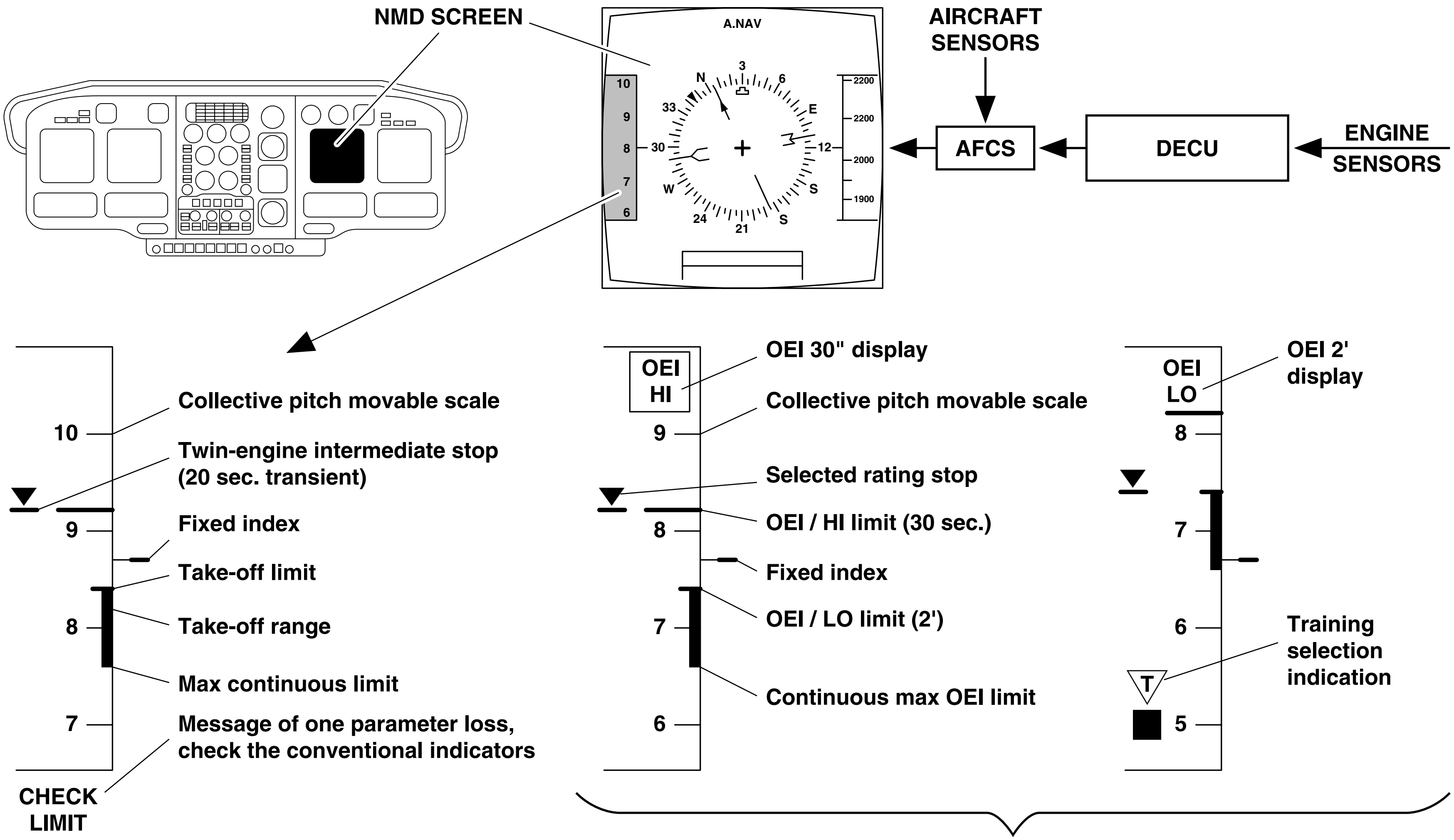
This system indicates that an engine parameter is reaching its limit.

Main components

- Navigation and Mission Display (NMD)
- AFCS (Automatic Flight Control System)
- Digital Engine Control Unit
- Aircraft and engine sensors.

Functional description

The system automatically selects among the parameters (N1, torque, t4) the one which is the nearest to its limit. It displays this parameter on a screen as a movable and graduated scale. The graduated scale moves on the screen between fixed index (limits).



OPERATION WITH TWIN-ENGINE CONFIGURATION OR AEO MODE

OPERATION WITH SINGLE ENGINE CONFIGURATION OR OEI MODE

MISCELLANEOUS INDICATIONS - FIRST LIMIT INDICATOR

MISCELLANEOUS INDICATIONS - ENGINE HEALTH MONITORING

Function

This system evaluates the engine health.

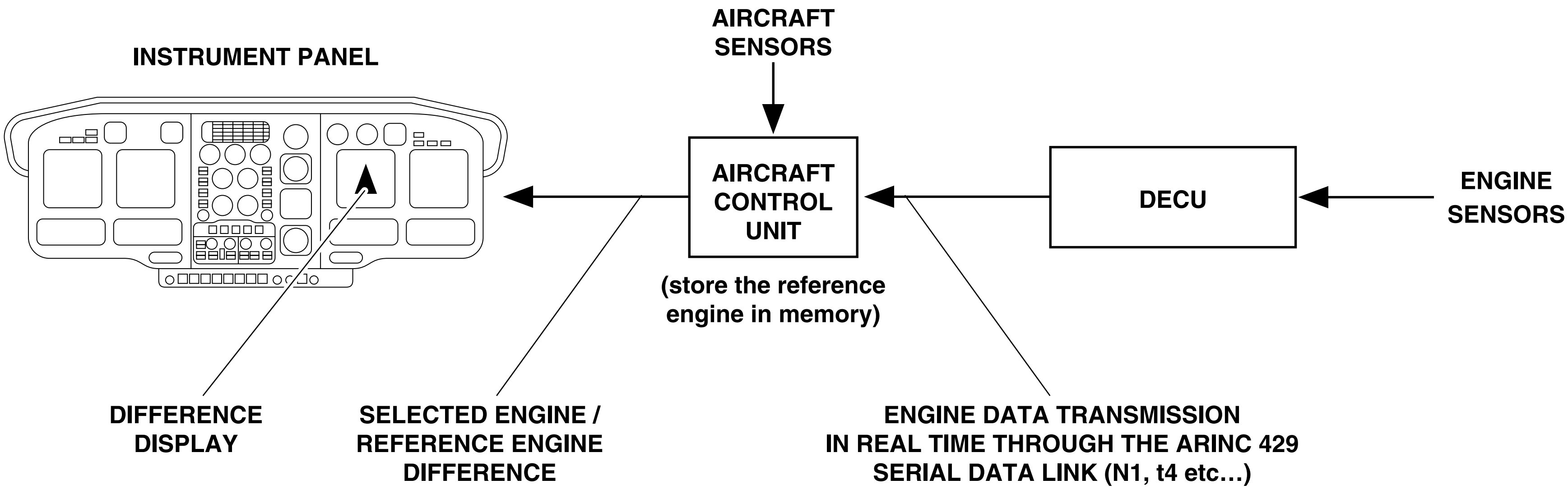
Main components

- The DECU and its ARINC 429 serial data link
- The airframe manufacturer calculation system
- The display screen and Maintenance Test Control Panel (MTCP) in the cockpit.

Functional description

The aircraft calculation system (HUMS or ACMS) stores the reference engine in memory. It compares in real time the selected engine and the reference engine.

The difference (power or thermal) is supplied to the display unit.



MISCELLANEOUS INDICATIONS - ENGINE HEALTH MONITORING

MISCELLANEOUS INDICATIONS - MAINTENANCE AID

Function

To supply the information required to evaluate operating cycles and times.

To supply the information required for troubleshooting.

Main components

- The Digital Engine Control Unit with its RS 232 serial data link
- The display screen and Maintenance Test Control Panel (MTCP) in the cockpit.

Functional description

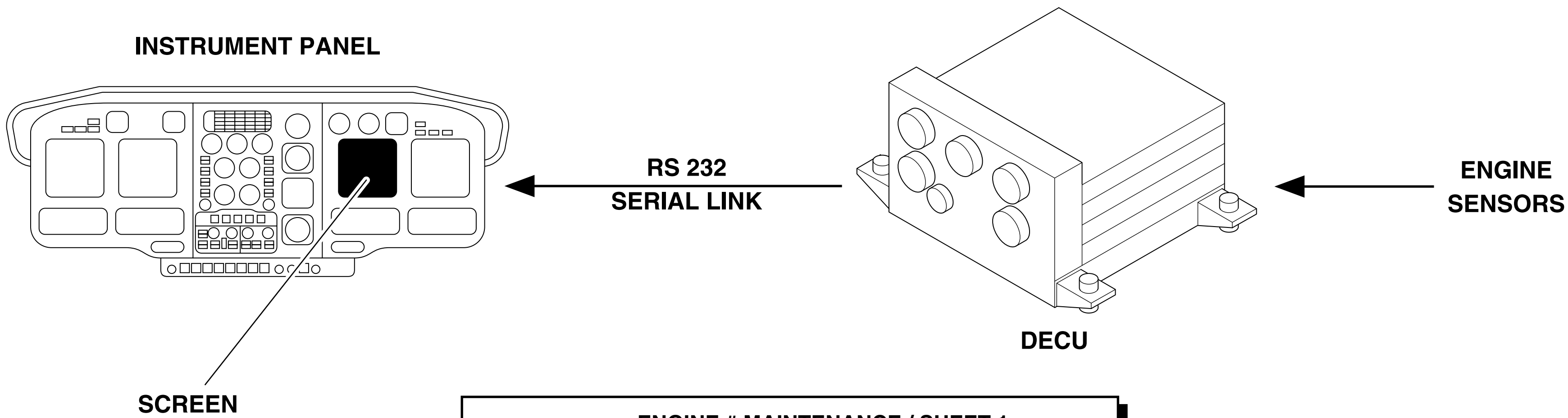
The DECU stores in memory the cycles, hours and time spent at the different ratings (OEI, take-off…).

It also stores the defects which have occurred during the last operations.

It can also display some parameters in real time, engine stopped.

The display comprises two sheets for each engine ; the engine and sheet can be selected on the MTCP :

- Sheet 1 displays :
  - Defects during the last run
  - Last run time
  - Cumulative usage parameters
- For sheet 2 refer to chapter 15.



	ENGINE # MAINTENANCE / SHEET 1	
	DEFECT DURING THE LAST RUN	
MAINT1	####	
MAINT2	####	
MAINT3	####	
LAST RUN TIME		## H ## MN ## S
	CUMULATIVE USAGE PARAMETERS	
RUN TIME		STARTS ####
TOTAL		#### H ## MN ## S
PMC < NG < MAXAEO		#### H ## MN ## S
CREEP		#### H ## MN ## S
MAXAEO < NG		#### H ## MN ## S
OEI 2MIN < NG		#### H ## MN ## S
		OEI FADEC ##
	LOW # MAINTENANCE FATIGUE COUNTS	
GENER	##, ###. #	PT ##, ###. #

EXAMPLE OF MAINTENANCE AID DISPLAY

MISCELLANEOUS INDICATIONS - MAINTENANCE AID

9 - STARTING

STARTING SYSTEM - GENERAL

Function

The starting system ensures starting (on the ground and in flight) and ventilation of the engine. It includes the following functions : cranking, fuel supply, ignition and sequential control.

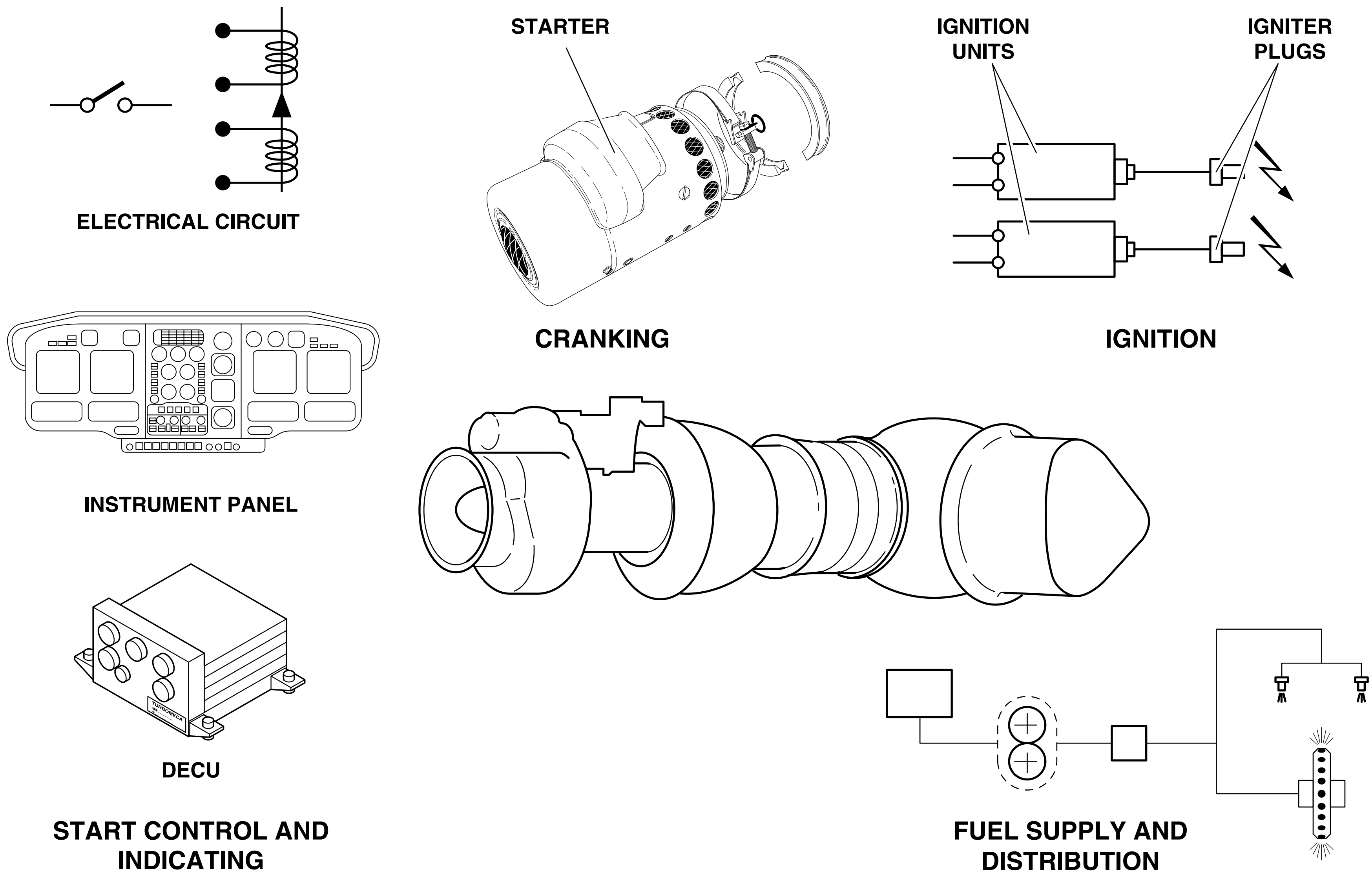
Main characteristics

- Ground starting envelope : Zp -500 m +7620 m (-1640 ft +24994 ft) at -50 °C +50 °C (-58 °F +122 °F)
- Start duration : ≈ 30 seconds
- Max ventilation time : 15 seconds
- Stabilisation time before shut-down :
  - 1 min if t0 > -10 °C (14 °F)
  - 2 min if t0 < -10 °C (14 °F)
- Run-down time : > 1 min. 55 sec. between 50 % and 0 % N1
- Max t4 during start
  - Without time limit : 750 °C (1382 °F)
  - Max overtemperature : 810 °C (1490 °F) ; 850 °C (1562 °F) if Z ≥ 6100 m (20008 ft).

Note *: Values given for information. Refer to official manuals.*

Main components

- Starter (cranking)
- Ignition system (ignition units and plugs)
- Control system (DECU and electrical circuit)
- Fuel system (supply, delivery, metering, fuel injection).



STARTING SYSTEM - GENERAL

STARTING SYSTEM - DESCRIPTION

The starting system includes the starting components, the selectors and switches, the electrical circuit and the DECU.

Starting components

- Electrical starter, to crank the rotating assembly
- Ignition units, to supply high energy current to the two igniter plugs
- Start electro-valve to supply fuel to the start injectors.

Controls

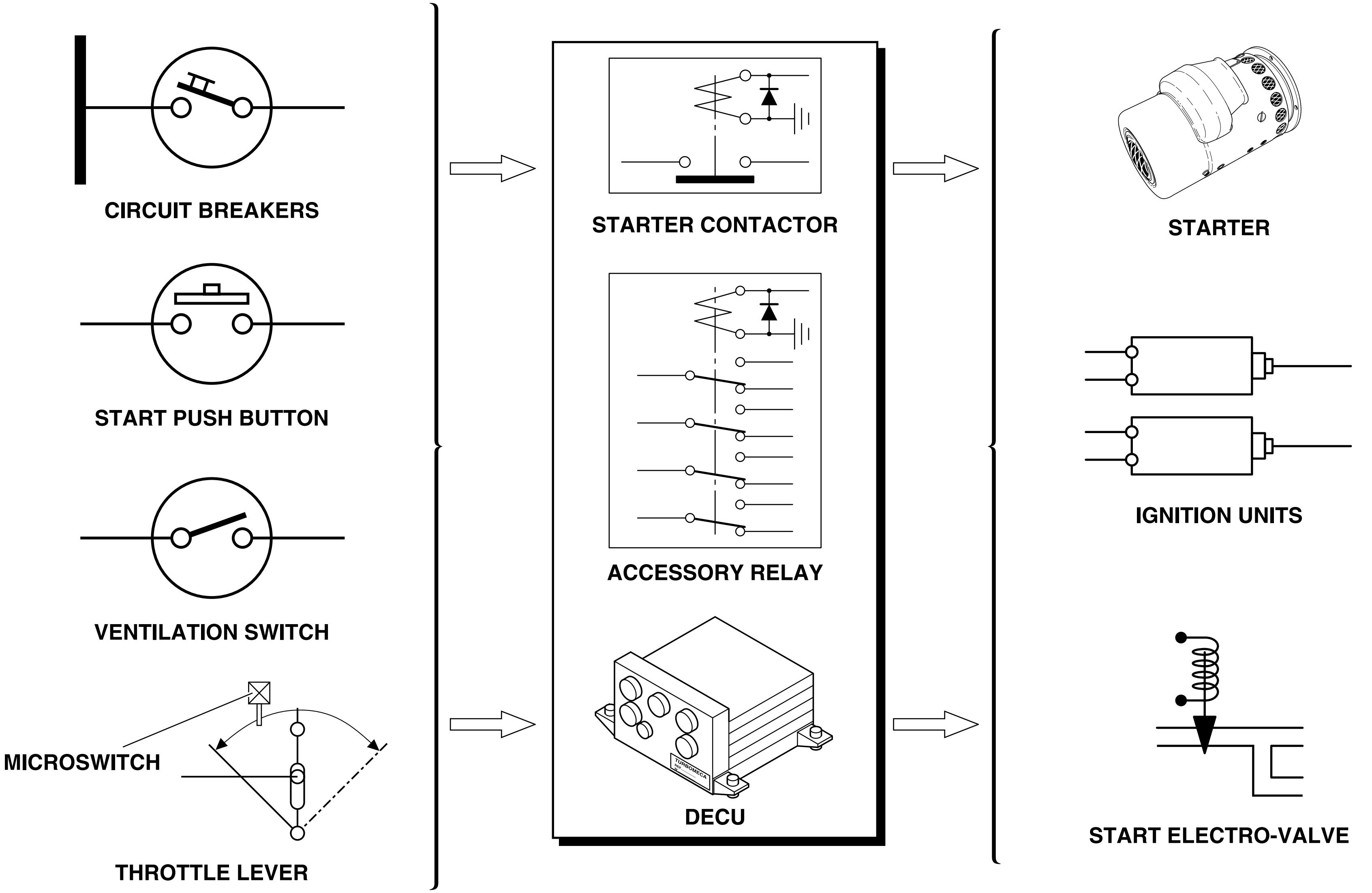
- Start selector push button
- Ventilation switch.

Electrical circuit

- Accessory relays
- Starter contactor.

DECU

- Start control
- Fuel flow control.



STARTING SYSTEM - DESCRIPTION

STARTING SYSTEM - OPERATION (1)

This section deals with operating sequences associated with the starting system : start, stop and ventilation

Start cycle

The start cycle is characterised by the evolution of the engine parameters, especially the rotation speed and the gas temperature.

The main points of the start cycle are :

- Start selection
- Self sustaining speed (de-energisation of the starter and ignition ; approx. 45 % N1)
- End of start (stabilisation at idle speed ; approx. 68 % N1).

Shut-down cycle

This cycle comprises the following points :

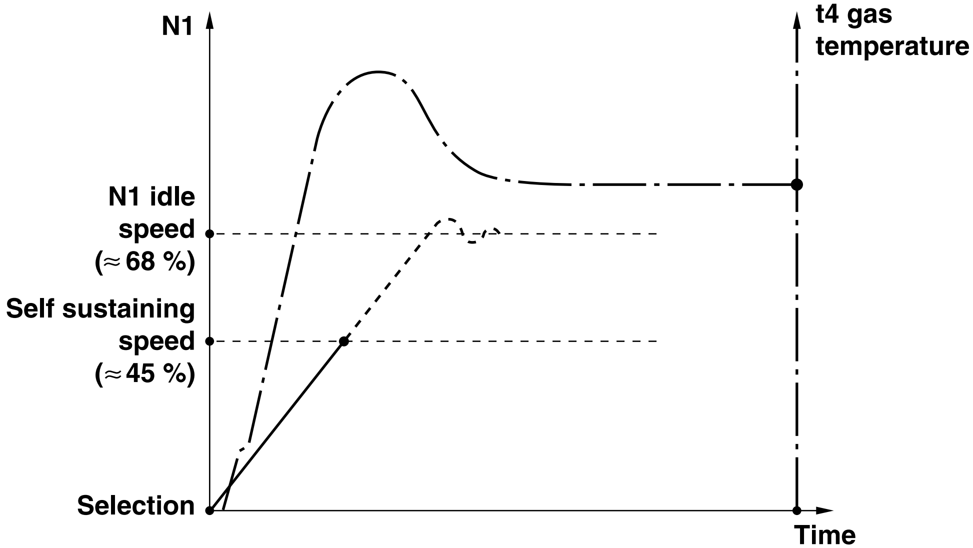
- Stabilisation
- Stop selection
- Rundown and stop.

Ventilation cycle

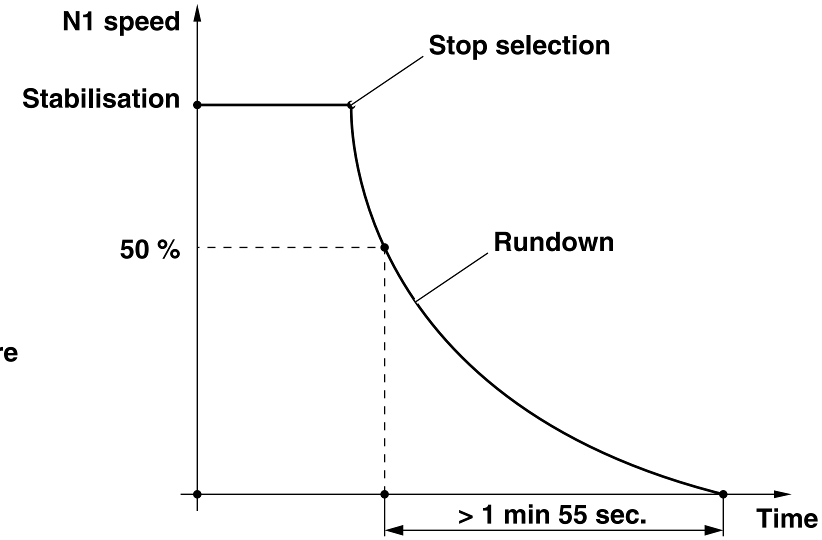
A ventilation consists of cranking the rotating assembly without supplying fuel or ignition (dry ventilation). It is used for cooling the engine or for maintenance procedures.

The cycle comprises the following phases :

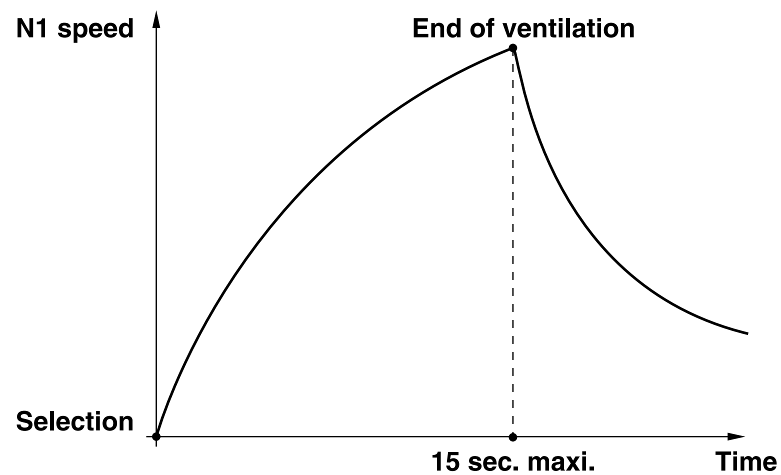
- Ventilation selection
- Cranking of the rotating assembly
- End of ventilation.



STARTING CYCLE



SHUT-DOWN CYCLE



VENTILATION CYCLE

STARTING SYSTEM - OPERATION (1)

STARTING SYSTEM - OPERATION (2)

The operating phases of the start control circuit are as follows :

"Normal" (automatic) starting

With electrical system power on, the throttle lever is set to the "starting" position and the start push-button activated (one pulse is sufficient).

The accessory relay is supplied through the circuit-breaker, the relay of the DECU and the start push button (negative through the overspeed safety circuit ; to prevent starting in overspeed configuration).

The relay "m" is self-supplied through contact N° 1 and the microswitch activated by the lever (it stays energised even after releasing the push-button).

Contact N° 2 supplies the ignition components and the start injector electro-valve.

Contact N° 3 supplies the starter relay and therefore the green indicating light and the electric starter motor.

The starting sequence takes place and when self-sustaining speed is reached, the DECU cuts the accessory relay supply and therefore all the starting accessories.

Manual (emergency) starting

This cycle is identical, except that the self supply of the accessory relay is cut off by the microswitch ; for this reason, it is necessary to hold the start push-button pressed.

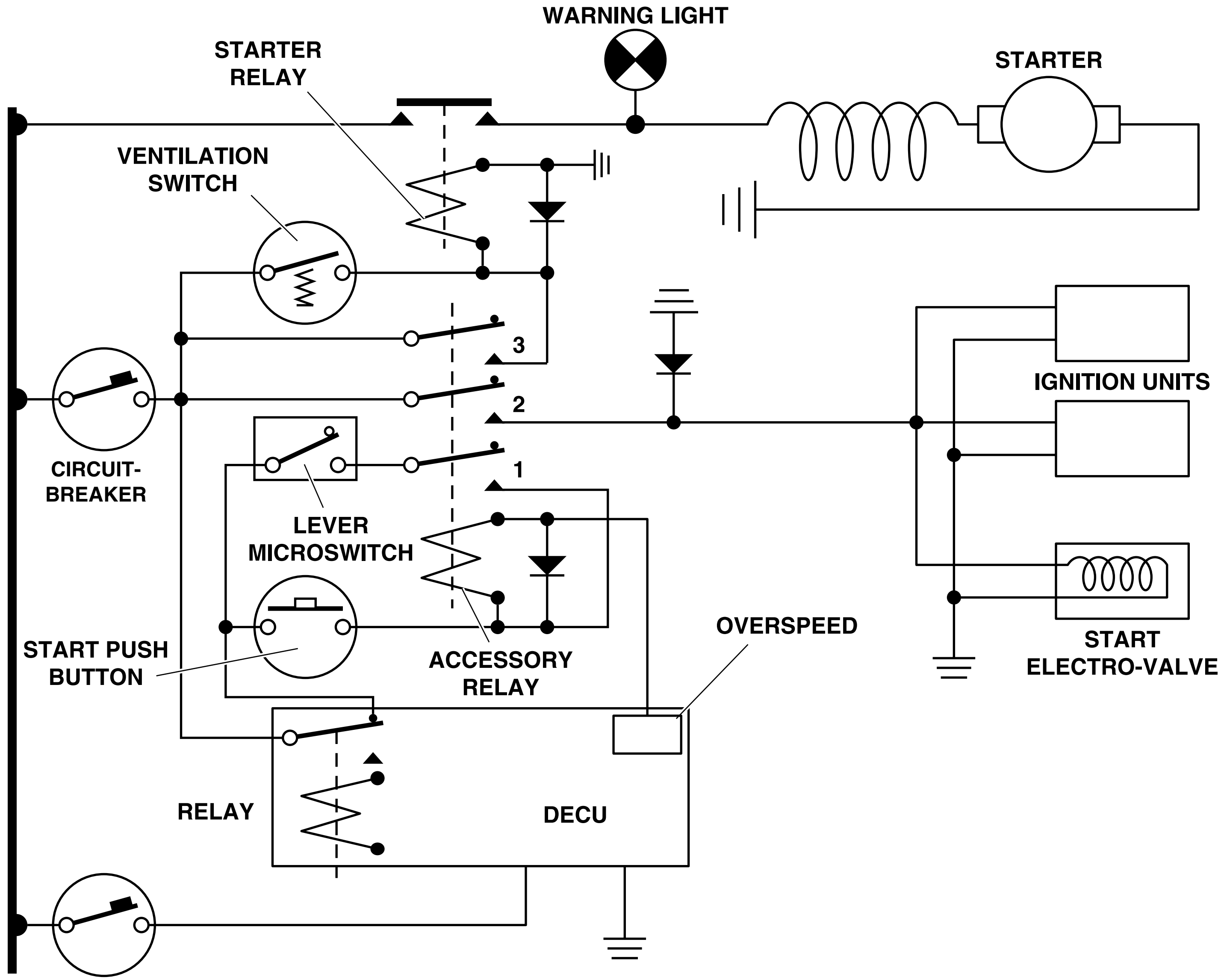
The starting system is cut off when the self-sustaining speed is reached, either manually by releasing the push-button or automatically by the relay in the DECU.

Remember that in this case, there is no governed idle, and that the fuel flow is manually metered by the throttle lever (the start servo-valve being isolated by closing the shut-off valve on the device).

Ventilation

The ventilation switch directly supplies the starter relay.

The ventilation time is determined manually : ventilation stops when the push-button is released. But the ventilation phase must not exceed 15 seconds.



STARTING SYSTEM - OPERATION (2)

STARTER - GENERAL

Function

The starter motor cranks the gas generator during starting and ventilation.

Position

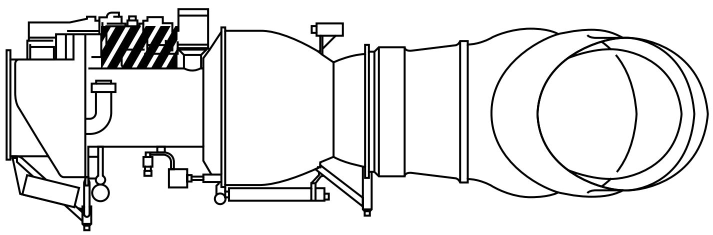
- On a flange at the rear part of the accessory gearbox on the upper part of the air intake.

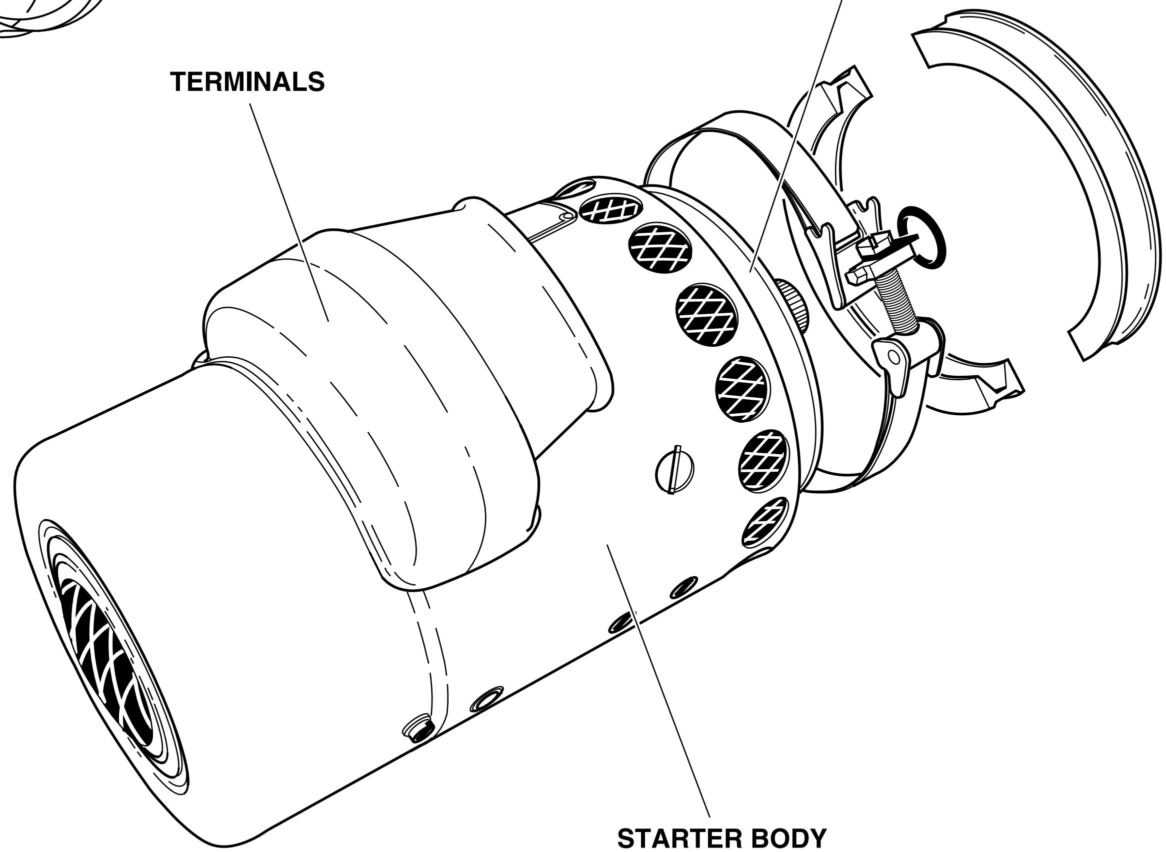
Main characteristics

- Type : electrical starter
- Supply : direct current on high intensity line
- Insulation :
  - $\geq$ 2 MΩ (new starter)
  - $\geq$ 50 kΩ (minimum for a used starter).

Main components

- Starter
- Mounting flange
- Terminals.





Type
Direct Current
electrical engine

Supply
Direct Current on
high intensity line

STARTER - GENERAL

STARTER - DESCRIPTION - OPERATION

Description

The starter comprises the following components :

- Connection terminals
- Rotor
- Stator
- Brushes
- Cooling fan
- Drive shaft

The starter is mounted on a support which includes the free wheel.

Operation

Engine cranking

When "START" is selected the starter contactor closes and connects the aircraft DC bus bar to the starter.

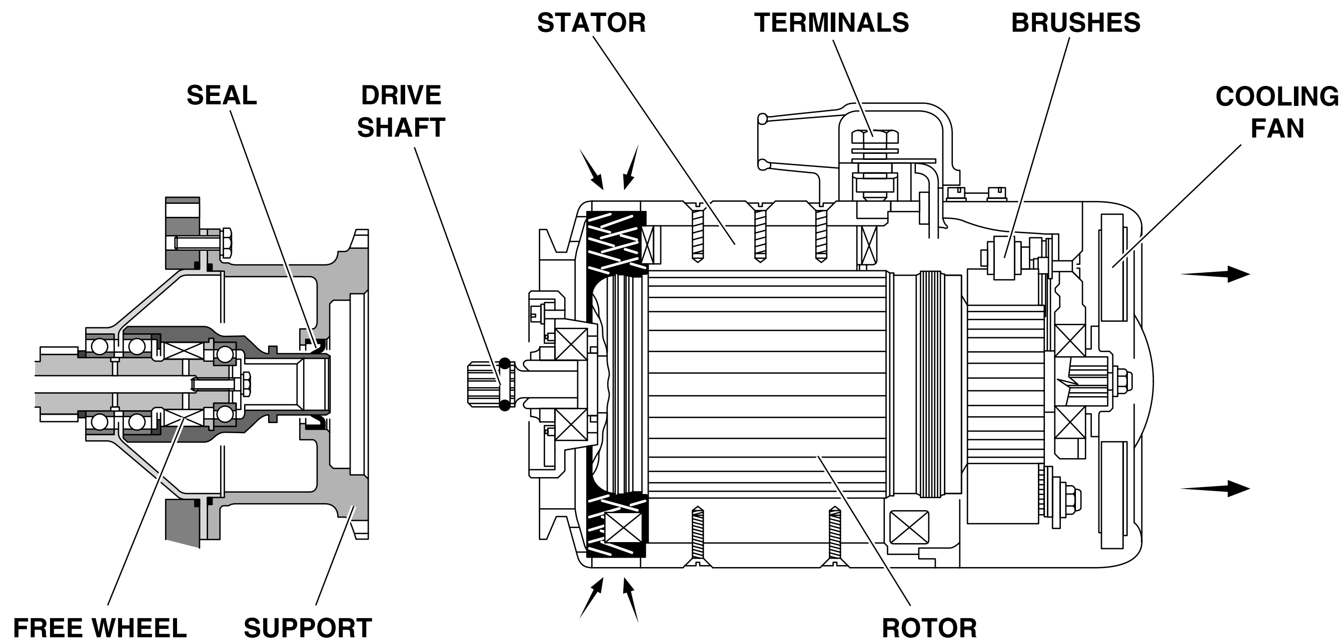
The starter then cranks the gas generator rotating assembly through the accessory drive train.

The torque on the starter shaft is inversely proportional to the gas generator speed and will be higher when the atmospheric temperature is low.

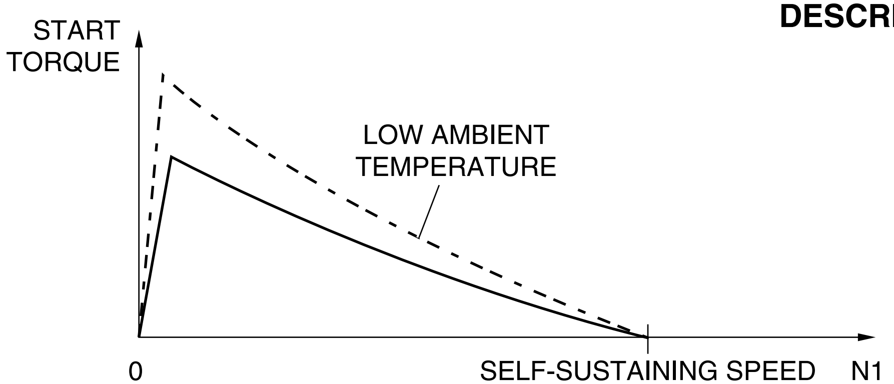
The gas generator rotation speed N1 increases up to self sustaining speed (45 % N1) at which point the torque becomes negative and the starter is no longer supplied (starter contactor opening).

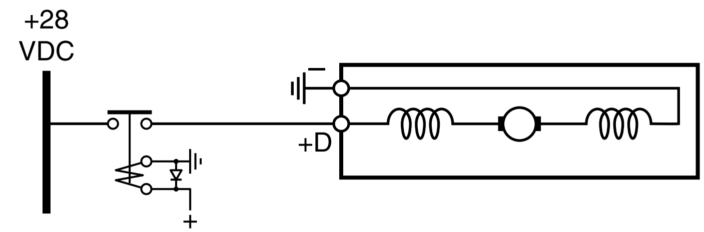
After starting

At the end of starting, the starter is disconnected from the accessory drive gear by the free wheel.



DESCRIPTION





STARTER SUPPLY

OPERATION

STARTER - DESCRIPTION - OPERATION

IGNITION SYSTEM

Function

This system ensures the ignition of the fuel sprayed by the start injectors into the combustion chamber.

Position

All the components of the system are fitted on the engine.

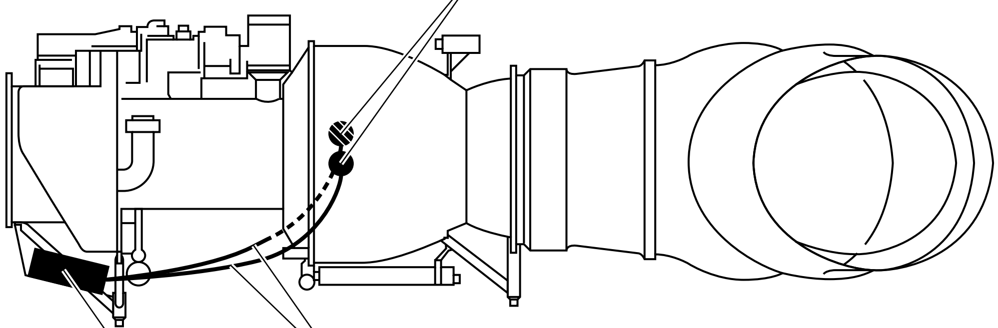
Main characteristics

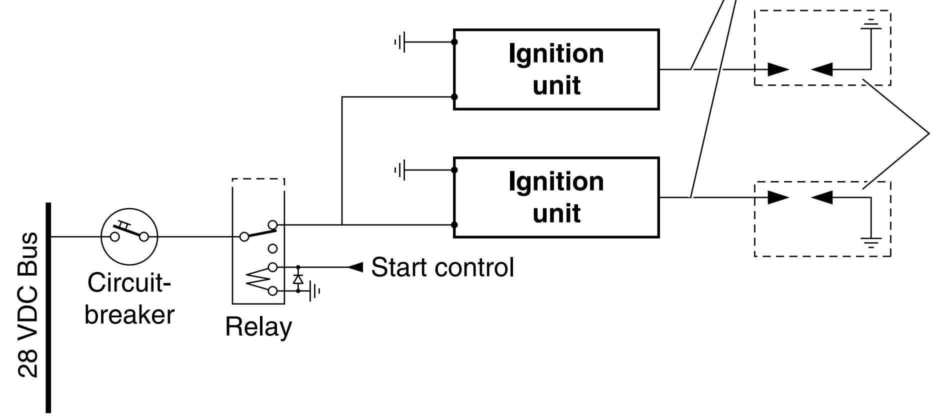
- Type : High Energy
- Supply voltage : 10 to 32 VDC
- Dual system : 2 ignition units, 2 igniter plugs.

Main components

- Ignition units
- Ignition cables
- Igniter plugs.

Note : *Refer to following pages for the description and operation of the components.*





Type
High Energy

Supply voltage
10 to 32 VDC

Dual system
2 ignition units,
2 igniter plugs

IGNITION SYSTEM

IGNITION UNITS - GENERAL

Function

The ignition unit transforms the input voltage into a high energy output.

Position

- Mounted on a bracket on the lower part of the air intake casing.

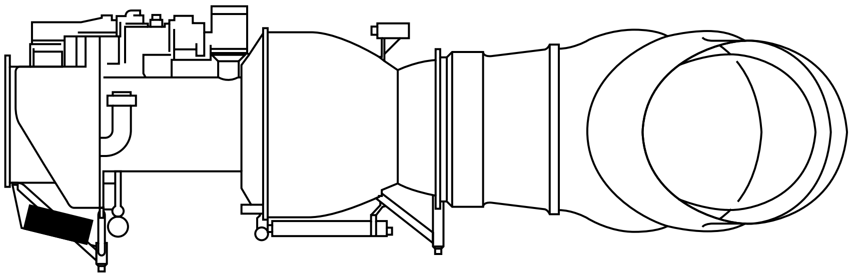
Main characteristics

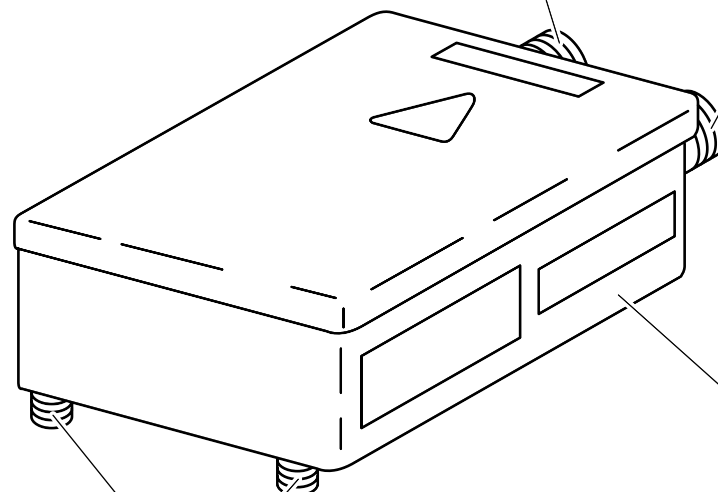
- Type : High Energy
- Supply voltage: 10 to 32 VDC
- Energy : 0.5 joule per spark, 3 kVolts
- Frequency : 120 ± 30 discharges/minute.

Note *: There are 2 identical ignition units. Each one supplies an igniter plug.*

Main components

- Ignition unit
- Input connector
- Output connector
- Mounting screws.





Type
High Energy

Supply voltage
10 to 32 VDC

Energy
0.5 joule / spark, 3 kVolts

Frequency
120 ± 30 discharges / minute

IGNITION UNITS - GENERAL

IGNITION UNITS - DESCRIPTION - OPERATION

Description

The ignition unit includes the following components :

- Converter
- Transformer
- Rectifier
- Capacitor
- Discharge tube.

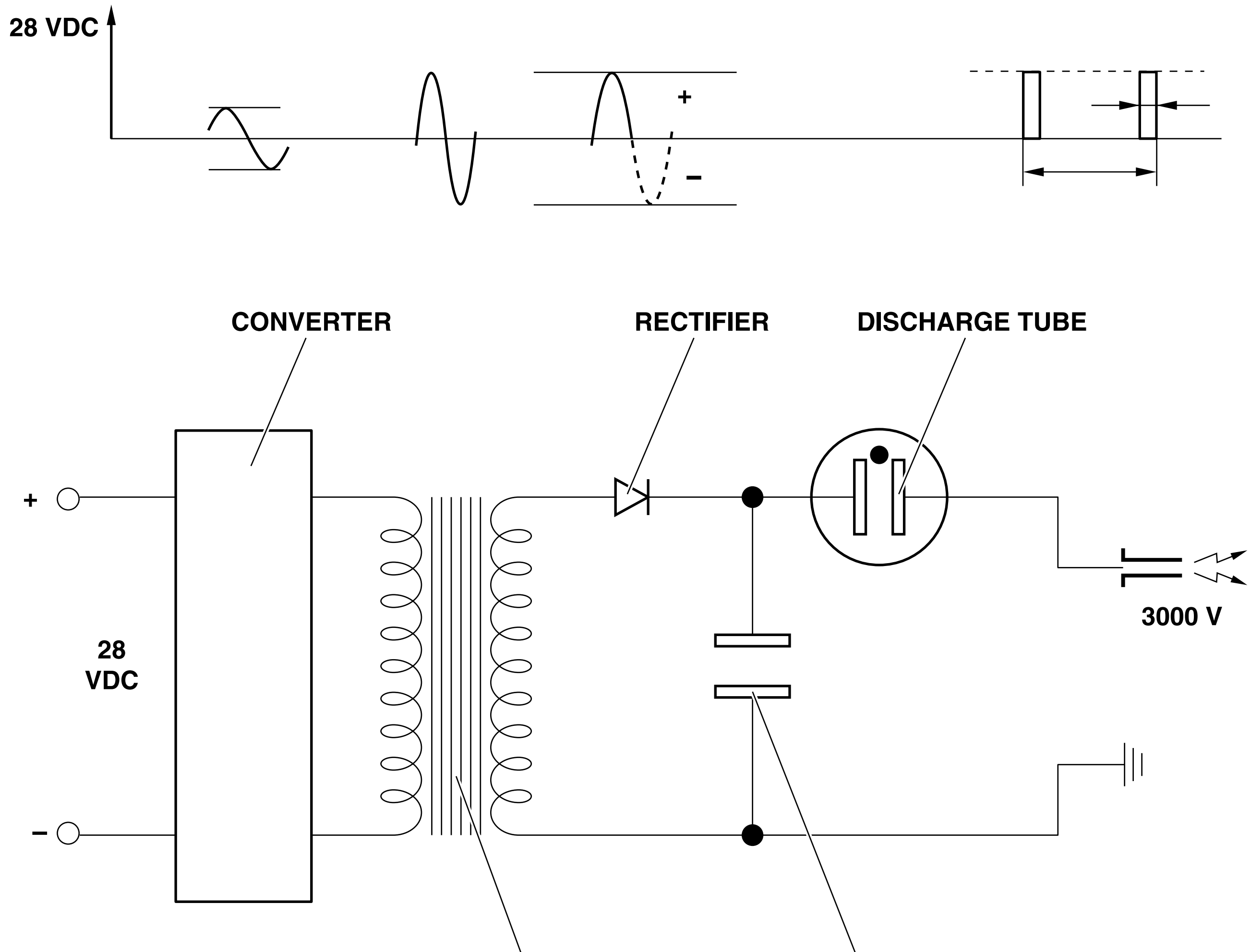
Operation

The converter transforms the DC voltage (28 VDC) into alternating voltage

The transformer amplifies the alternating voltage and supplies the rectifier.

The rectifier selects the positive phases and loads the capacitor. The capacitor accumulates the electrical loads (positive phases) and discharges at regular intervals into the discharge tube.

The discharge tube controls the load/unload periods. High energy voltage is delivered to the igniter plug through the ignition cable (voltage of 3000 Volts).



IGNITION UNITS - DESCRIPTION - OPERATION

IGNITER PLUGS - GENERAL

Function

The igniter plugs produce sparks to ignite the fuel sprayed by the start injectors.

Position

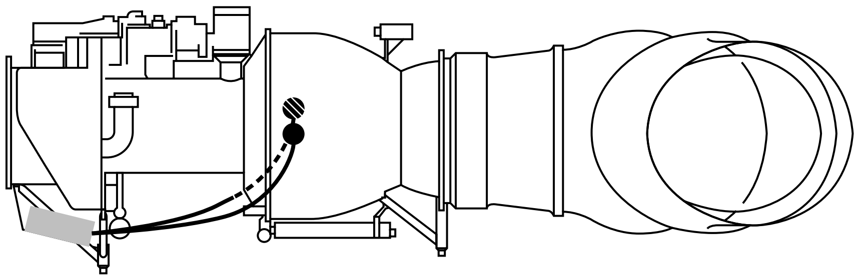
- Mounted beside the start injectors on either side of the turbine casing.

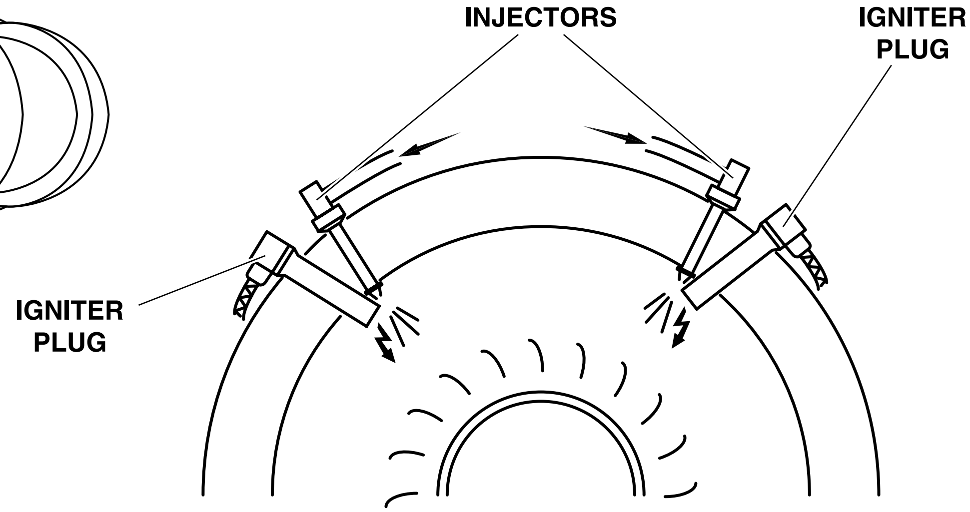
Main characteristics

- Quantity : 2
- Igniter plug type : high energy, surface discharge
- Ignition cable type : multi-core nickel-plated copper wire, shielded (max operating voltage : 5 kVolts).

Main components

- Igniter plug
- Mounting flange
- Ignition cable.

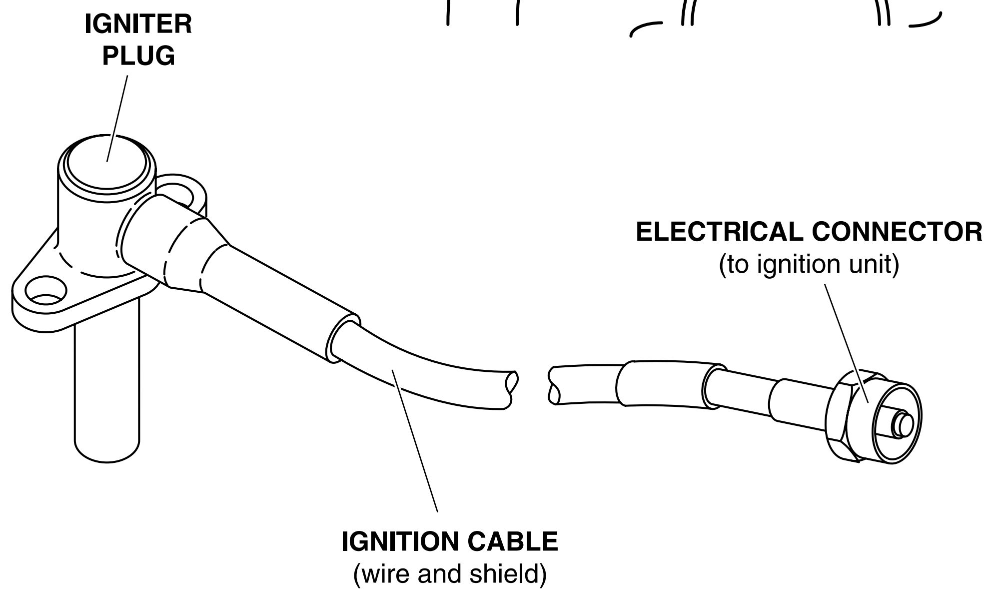




Igniter plug type
High Energy
Surface discharge

Ignition cable type
Multicore nickel-plated
copper wire

Quantity
2



IGNITER PLUGS - GENERAL

IGNITER PLUGS - DESCRIPTION - OPERATION

Description

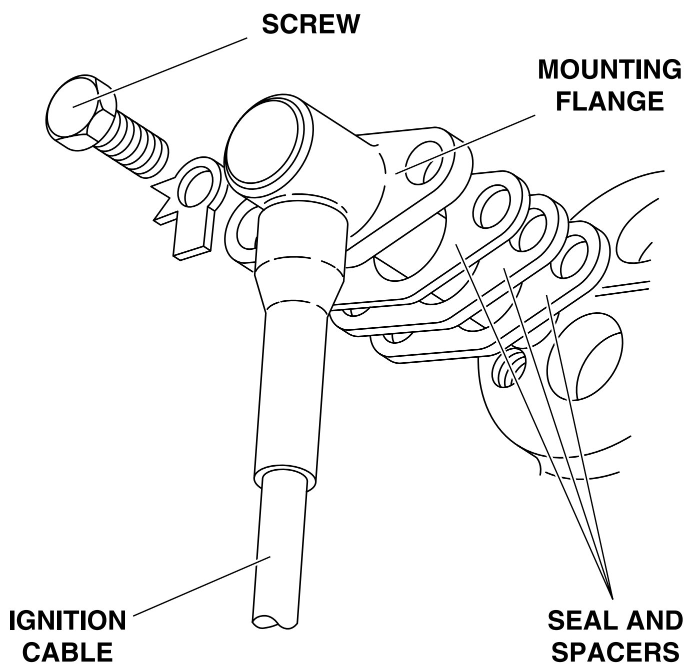
An igniter plug comprises :

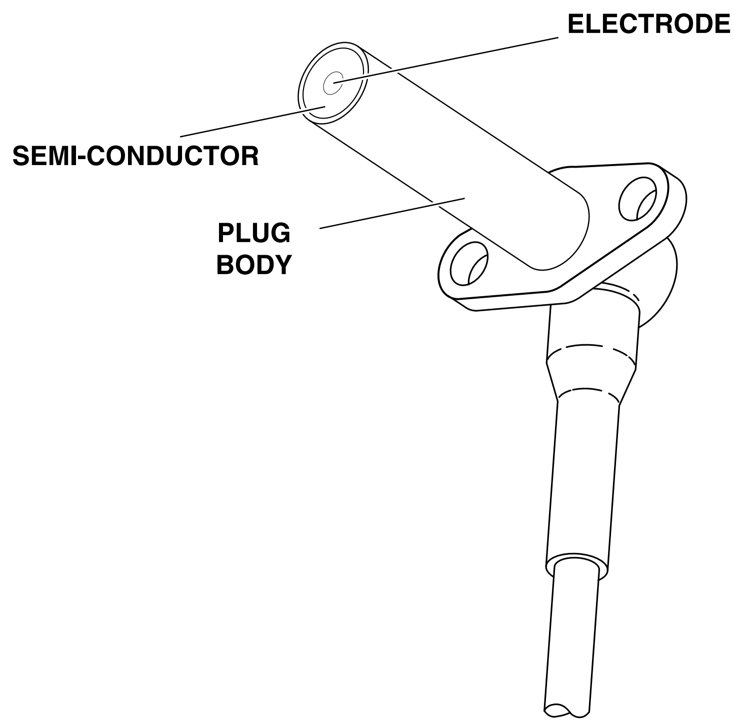
- An external body connected to the electrical negative
- A semi-conductor
- A central electrode connected to the electrical positive
- A mounting flange (mounting by means of 2 screws on combustion chamber casing bosses)
- An ignition cable which connects the igniter plug to the ignition unit
- Seal and spacers.

Operation

The high energy current produced by the ignition unit is supplied to the central electrode of the igniter plug. It discharges, across the semi-conductor to the plug body causing a powerful spark.

This spark ignites the fuel/air mixture being sprayed by the start injectors.





IGNITER PLUGS - DESCRIPTION - OPERATION

10 - ELECTRICAL SYSTEM

ELECTRICAL SYSTEM

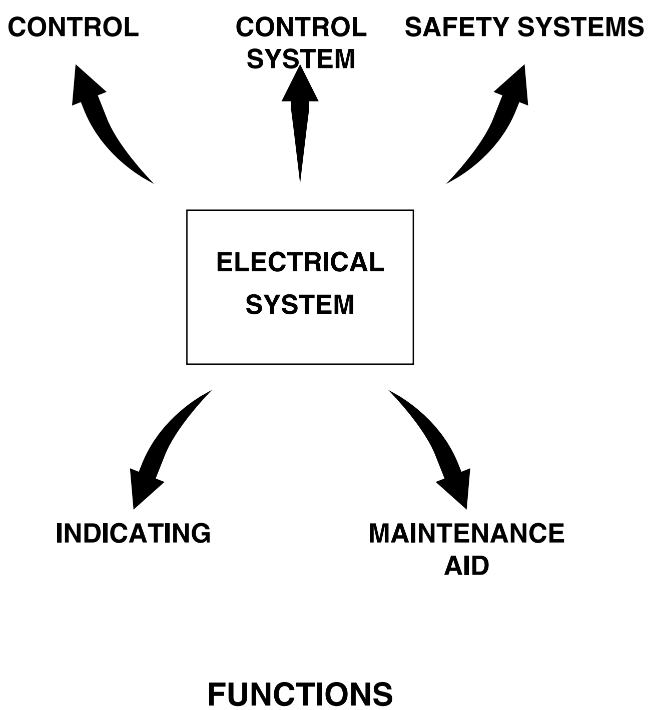
Function

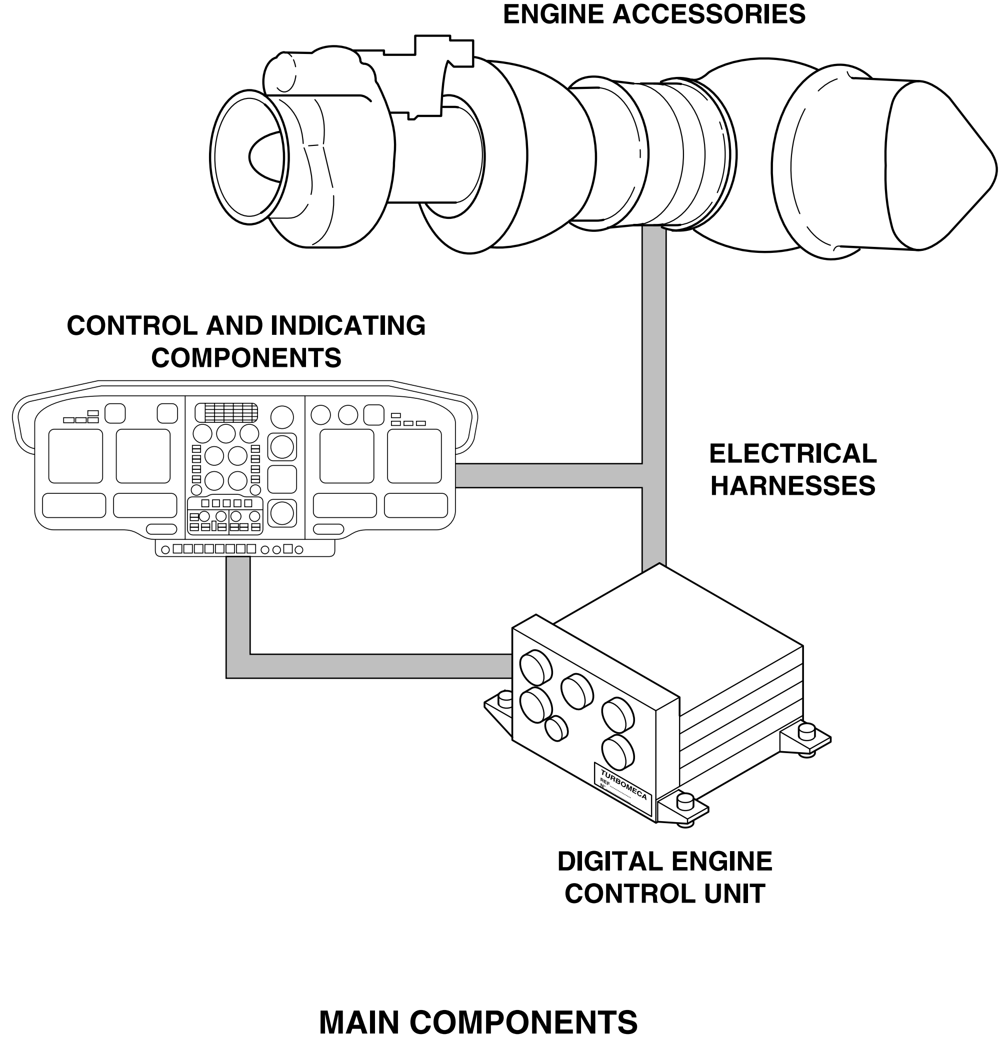
The system contributes to the various indicating and control functions of the engine :

- Control
- Control system
- Safety systems
- Operating indication
- Maintenance aid.

Main components

- Engine electrical components (control components and sensors)
- Control and indicating components
- Digital Engine Control Unit (installed in the airframe)
- Electrical harnesses.





ELECTRICAL SYSTEM

ELECTRICAL ACCESSORIES - GENERAL

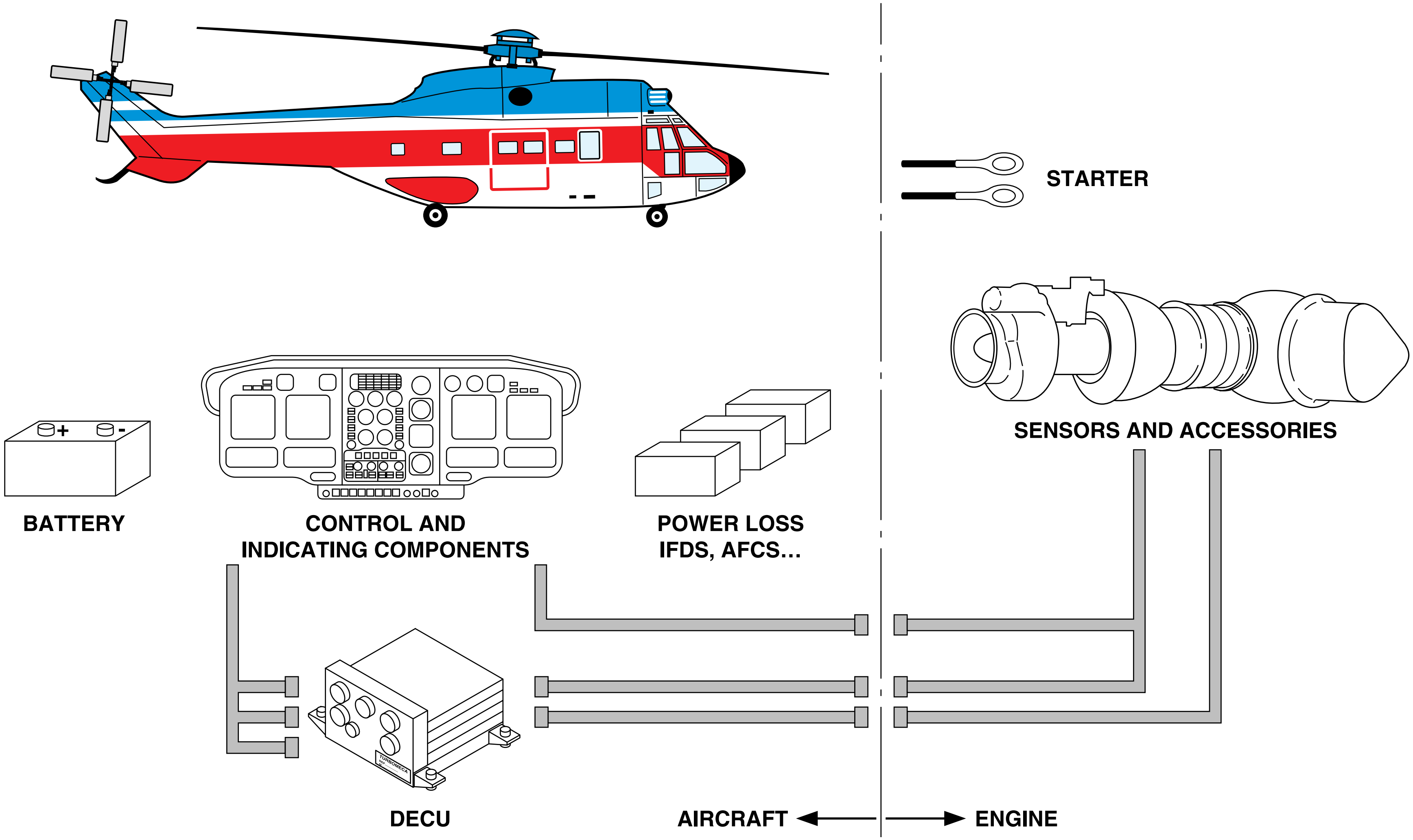
Function

The electrical accessories are involved in various engine functions. This chapter summarises the various accessories. For the detail of each one, refer to the appropriate chapter.

Accessory classification

The accessories can be classified as :

- Control components (push buttons, selectors…)
- Indicating components (warning lights, indicators…)
- Starting and control accessories (sensors, electrical accessories…).



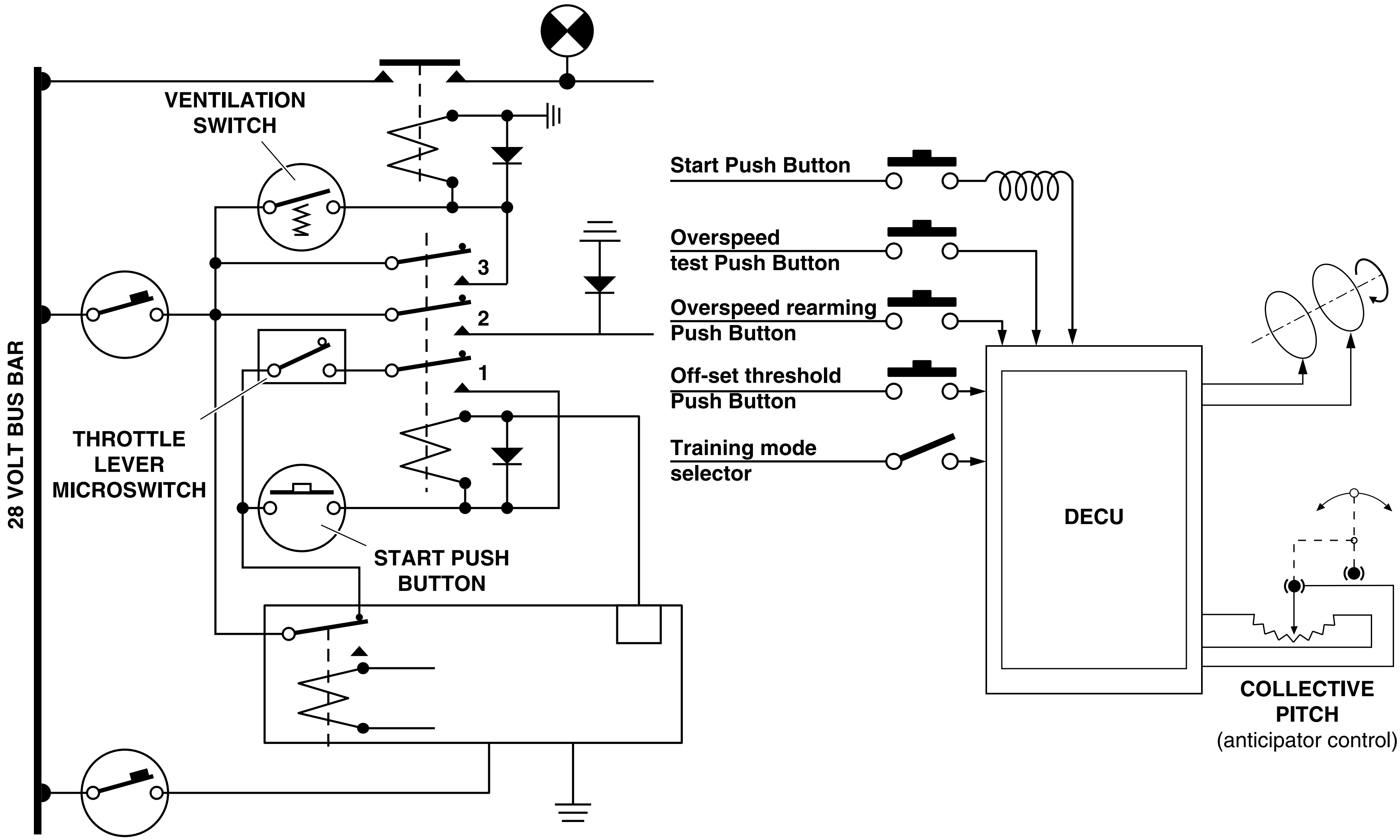
ELECTRICAL ACCESSORIES - GENERAL

ELECTRICAL ACCESSORIES - DESCRIPTION (1)

This page lists the various engine controls.

Control components

- 28 Volt bus bar
- Start push button
- Ventilation switch
- Throttle lever microswitch
- Bleed valve off-set threshold push button
- Collective pitch (anticipator control)
- Overspeed rearming push button
- Overspeed test push button
- "Training mode" selector.



CONTROL COMPONENTS

ELECTRICAL ACCESSORIES - DESCRIPTION (1)

ELECTRICAL ACCESSORIES - DESCRIPTION (2)

This page lists the indicating components.

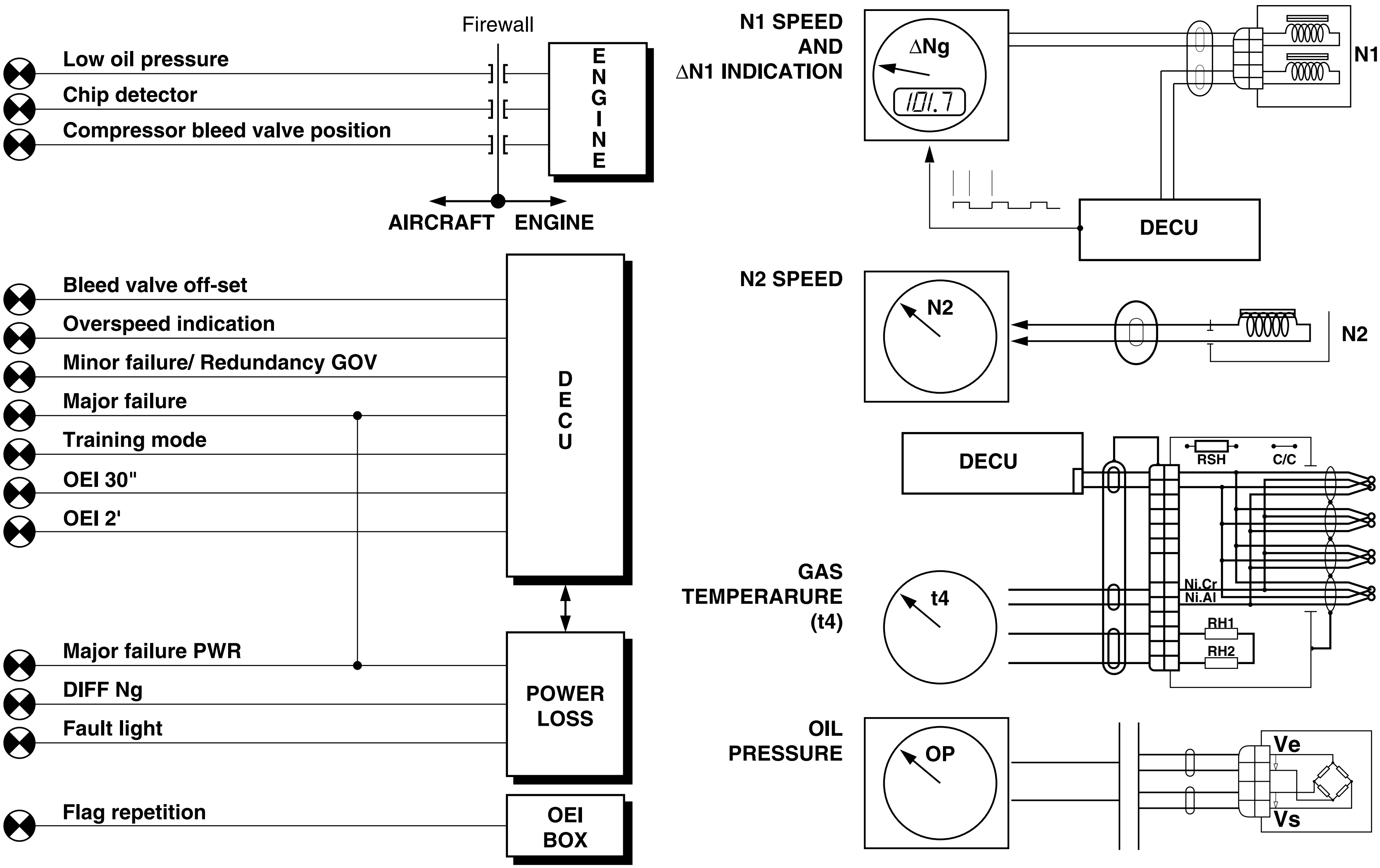
Warning lights

- Low oil pressure
- Chip detector
- Bleed valve position
- Bleed valve off-set
- Overspeed indication
- Control redundancy and minor failure (GOV)
- Control major failure (PWR)
- Training mode
- OEI 30 sec. stop
- OEI 2 min stop
- DIFF Ng
- Fault light during "Power Loss" test
- OEI box flag repetition.

Note : *Ng = N1*

Indicators

- N1 speed and ΔN1
- N2 speed
- Torque (aircraft system)
- Gas temperature (t4)
- Oil pressure
- Oil temperature.



INDICATING COMPONENTS

ELECTRICAL ACCESSORIES - DESCRIPTION (2)

ELECTRICAL ACCESSORIES - DESCRIPTION (3)

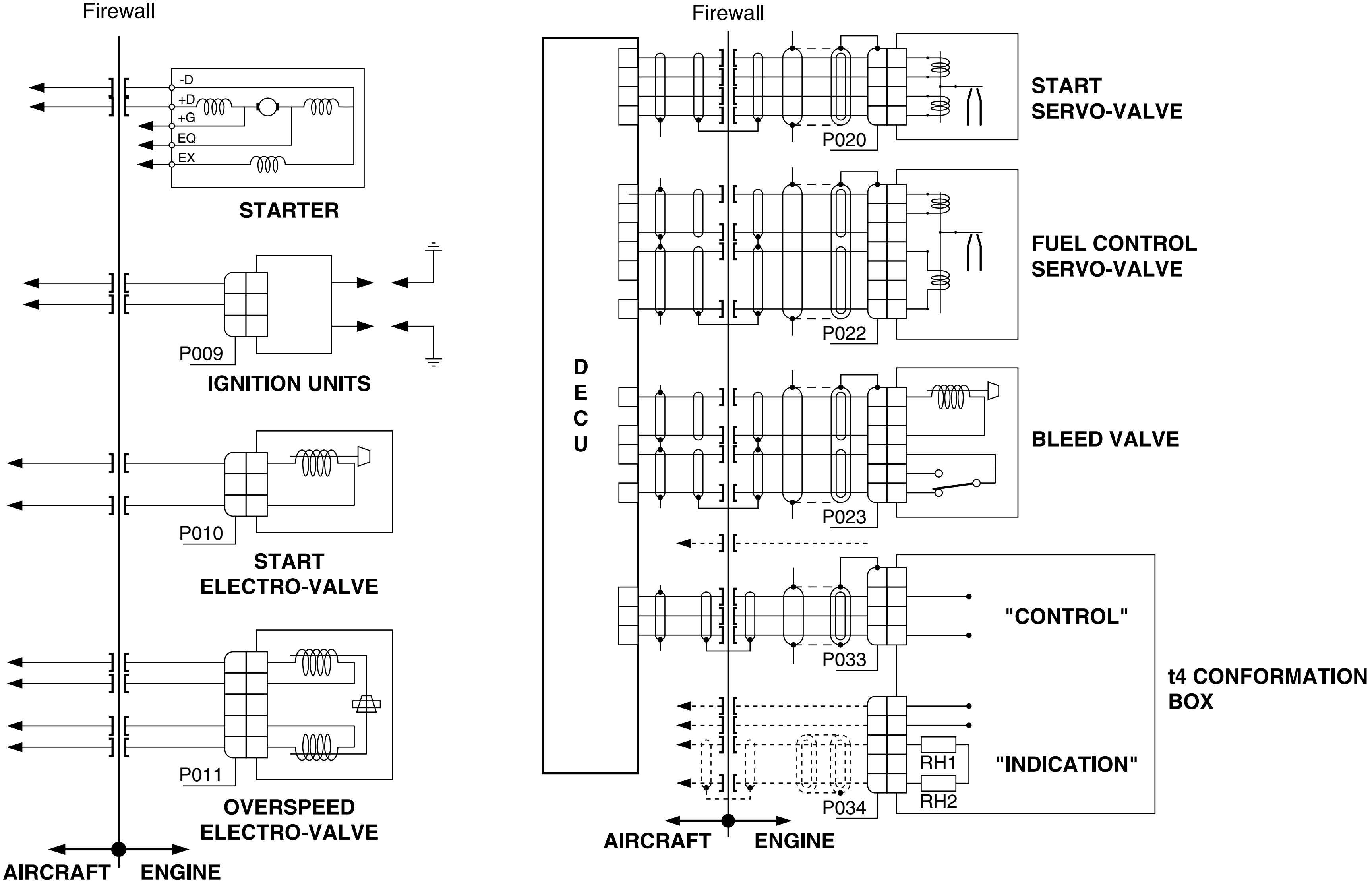
This page lists the various controlled accessories of the engine.

Start accessories

- Starter
- Ignition unit (x2)
- Start injector electro-valve
- Overspeed electro-valve.

Engine control accessories

- Start servo-valve
- Fuel Control servo-valve
- Bleed valve (off-set threshold)
- t4 conformation box.



CONTROL AND STARTING ACCESSORIES

ELECTRICAL ACCESSORIES - DESCRIPTION (3)

ELECTRICAL HARNESSES

Function

The harnesses connect the engine electrical components to the DECU and the aircraft circuit.

Description

The control and monitoring harness is composed of elementary harnesses terminated by connectors to be connected to the engine accessories.

These elementary harnesses are grouped into 2 harnesses terminated by connectors for connection with the aircraft systems.

Each elementary harness is shielded and identified with a sleeve bearing a group of letters corresponding to the accessory connected.

The DECU 1 and 2 are connected to each other (mutual monitoring of the overspeed). They also provide signals to the "Power Loss" system.

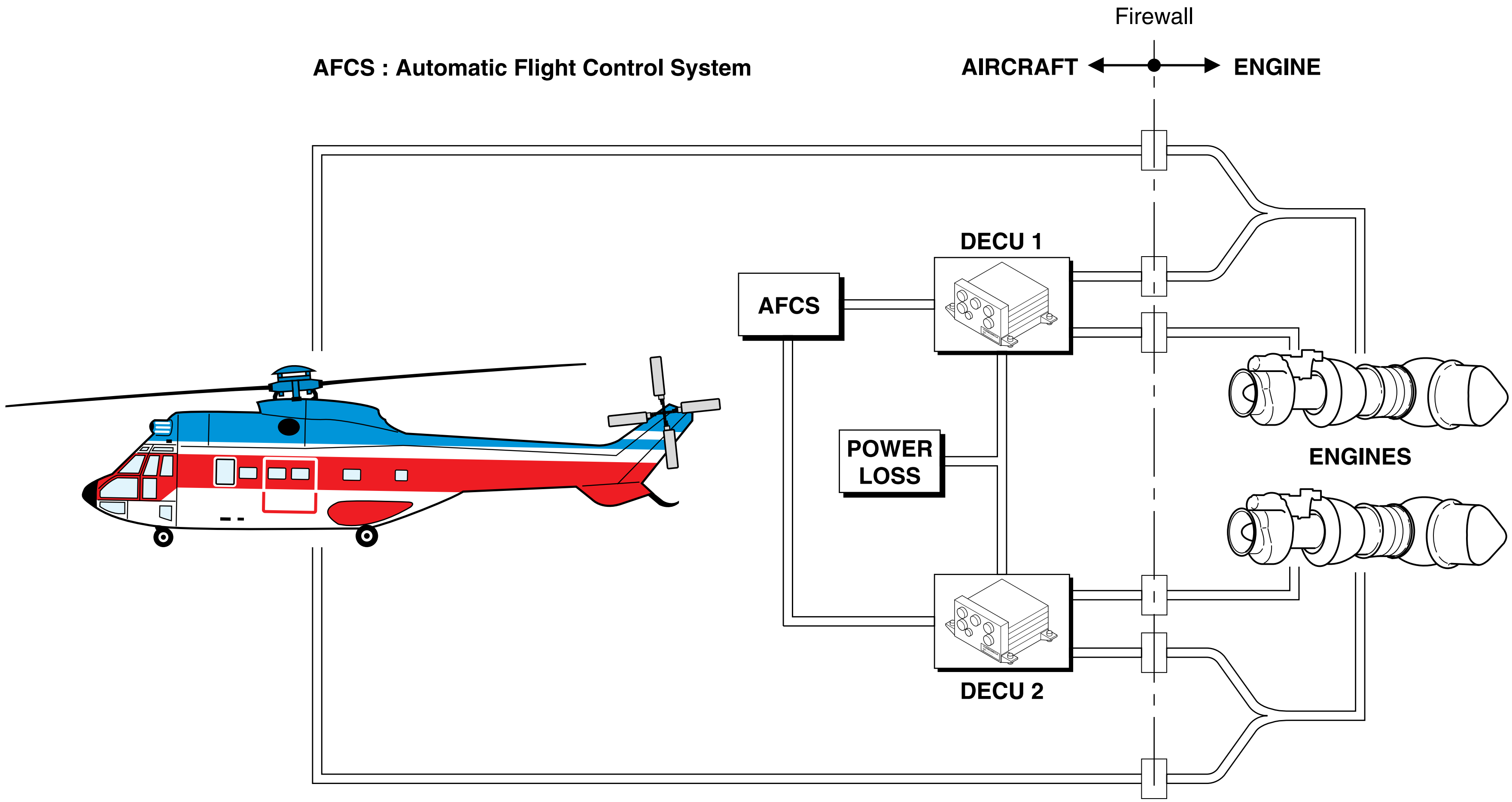
Each DECU is also connected to the AFCS (Automatic Flight Control System).

Harnesses

- DECU - engine harness
- Aircraft - engine harness
- Aircraft - DECU harness.

Identification

Harness	Identification on Sleeves
High Energy ignition unit	B.A.H.E.
"OEI" unit	B.O.E.I.
t4 unit	T4
Chip detector	B. MAGNETIQUE
Ng piston position sensor (FCU)	POSITION N1
H.P. gas generator speed sensor	N1
Overspeed and draining valve	E.C.SURV.N2
Fire detection	D. INCENDIE
Fire detector :	
• on FCU	
• on draining valve	
Threshold change electro-valve	E.C.SEUIL V.D.
Start electro-valve	E.C. DEM.
Low oil pressure switch	M.B.P.HUILE
Start servo-valve	S.V.D.
Fuel control servo-valve (FCU)	S.V.R.
Bleed valve indication	M.V.D.
Oil temperature probe	T.HUILE
Oil pressure transmitter	P.HUILE
Connection to aircraft	
Earth	



ELECTRICAL HARNESSES

11 - ENGINE INSTALLATION

ENGINE COMPARTMENT

Function

The engine compartment accommodates the engines.

Position

- In front of the helicopter main gearbox.

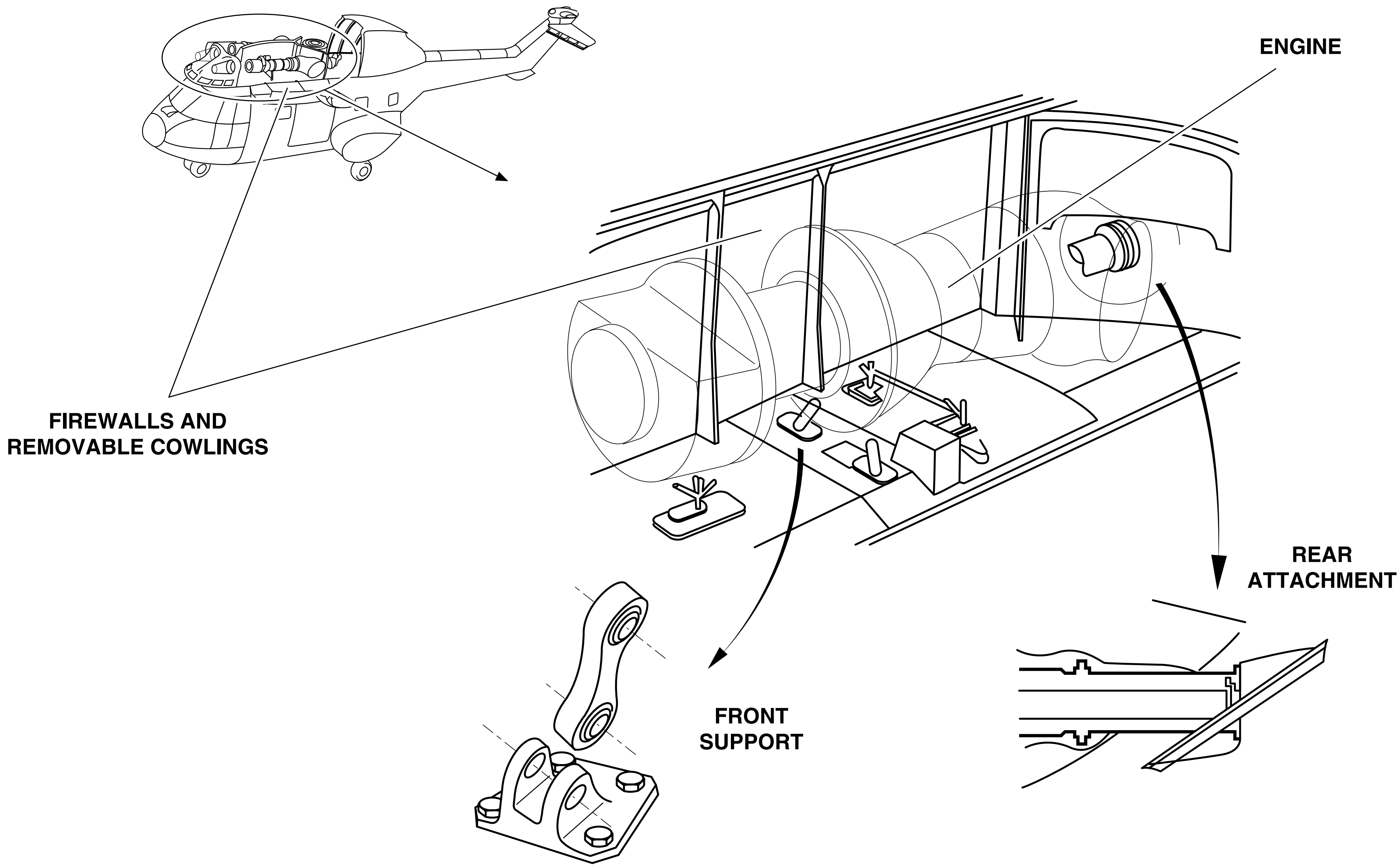
Main components

- Firewalls
- Removable cowlings.

Description

The compartment is separated by firewalls, which form 2 fireproof enclosures and removable cowlings which enable easy access to the engine. The engine is ventilated by atmospheric air, in order to keep the temperature within acceptable limits in the different zones.

Note *: Refer to aircraft manual for more details.*



ENGINE COMPARTMENT

ENGINE MOUNTING

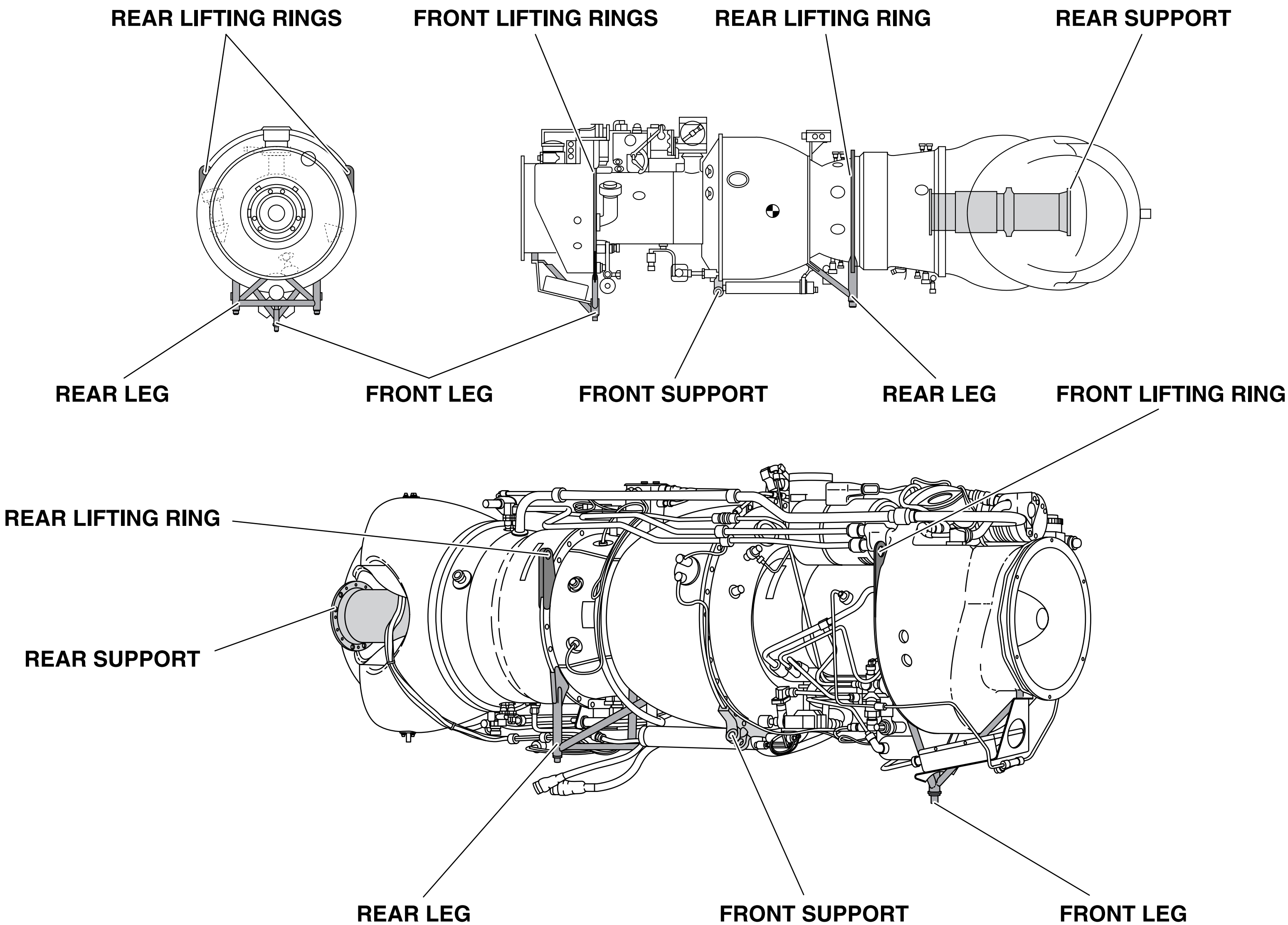
Function

The engine mountings attach the engine to the airframe.
The lifting rings allow the engine to be lifted.

Position

- Supports :
  - Front (two brackets on the counter-casing)
  - Rear (linking tube)
  - Three legs (one at the front, two at the rear)

- Lifting rings :
  - Front (integral with the rear cover of the tank)
  - Rear (bolted to the flange of the power turbine casing).



ENGINE MOUNTING

POWER DRIVE

Function

The power drive transmits the engine power to the helicopter transmission system.

Position

- Inside the linking tube, at the rear of the engine.

Main characteristics

- Mounting flange on power turbine shaft
- "Bendix" transmission shaft (supplied by the aircraft manufacturer)
- Linking tube with cardan joint.

Main components

- Power drive
- Transmission shaft
- Linking tube (with cardan joint).

Description

The power drive includes a mounting flange fitted onto the power turbine shaft.

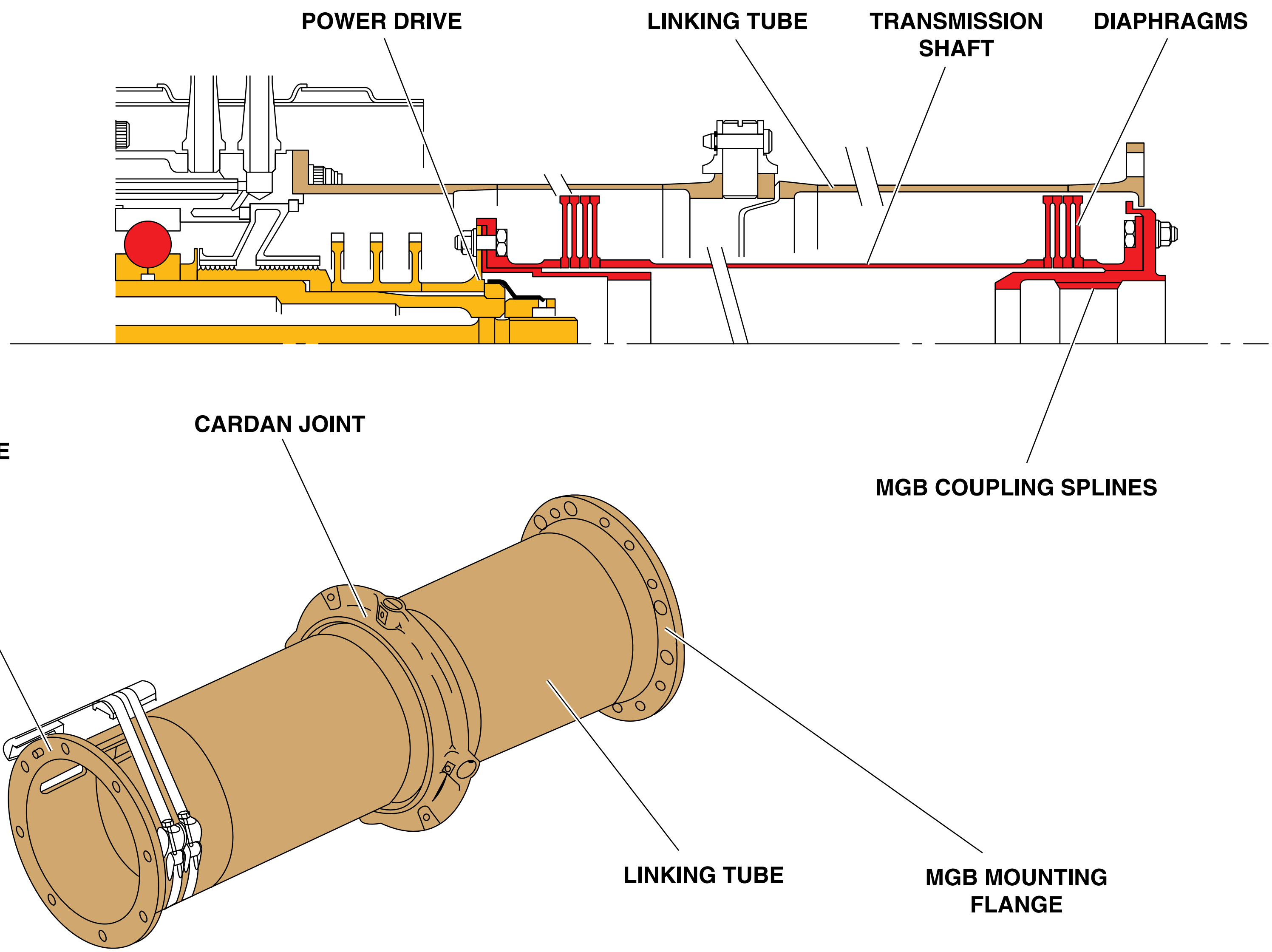
The transmission shaft is a "Bendix" flexible shaft.

It transmits the engine power. It absorbs :

- The misalignment between engine and the MGB
- The shear load and torque stresses
- The deformations due to expansion.

It includes steel diaphragms assembled by electron beam welding.

The linking tube includes a mounting flange for the mounting onto the engine, a central cardan joint and a mounting flange for mounting onto the main gearbox.


POWER DRIVE
LINKING TUBE
TRANSMISSION SHAFT
DIAPHRAGMS
MGB COUPLING SPLINES
ENGINE MOUNTING FLANGE
CARDAN JOINT
LINKING TUBE
MGB MOUNTING FLANGE

POWER DRIVE

AIR INTAKE

Function

The air intake directs the air into the engine air intake.

Position

- In front of the engine.

Main characteristics

- Supplied by the aircraft manufacturer
- Air flow: 5.5 kg/s (12.1 lbs/sec.).

Main components

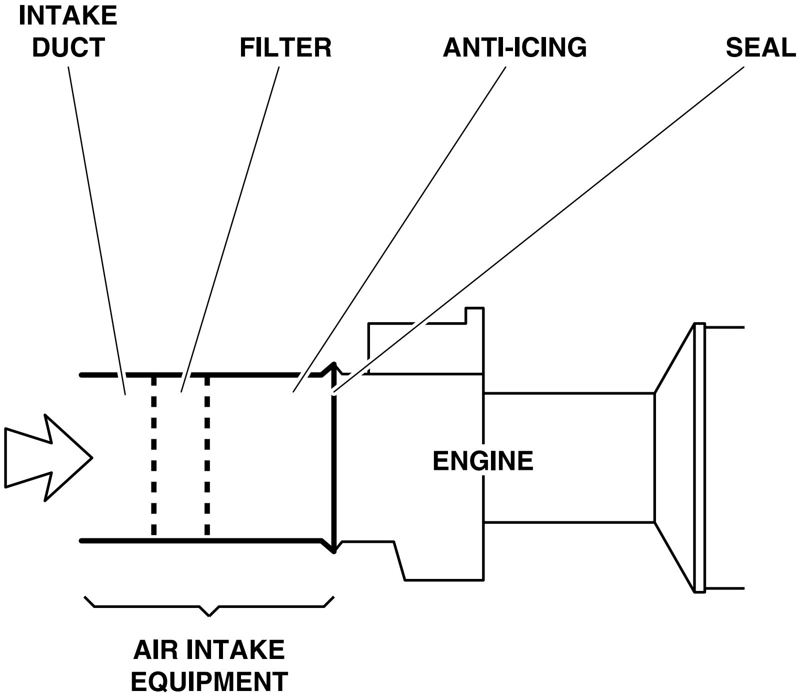
- Intake duct
- Filter
- Seal
- Anti-icing system.

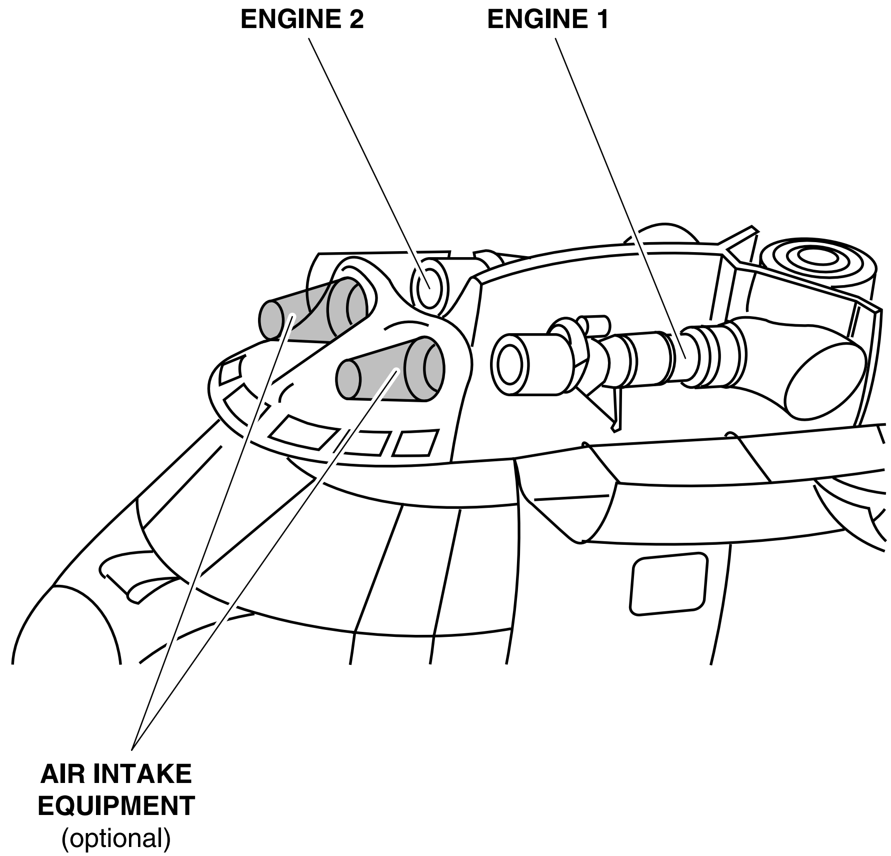
Description

A clamp connects the engine air intake casing to the aircraft intake duct.

Air is taken in through a dynamic intake, and through a set of protection devices (filter, anti-icing system…).

An inflatable seal pressurised with P2 air, is installed between the engine air intake casing and the aircraft intake duct, to ensure the sealing.


INTAKE DUCT
FILTER
ANTI-ICING
SEAL
ENGINE
AIR INTAKE EQUIPMENT


ENGINE 2
ENGINE 1
AIR INTAKE EQUIPMENT (optional)

AIR INTAKE

EXHAUST SYSTEM

Function

The exhaust system discharges the exhaust gas overboard.

Position

- At the rear of the engine.

Main characteristics

- Rotatable to the left or to the right
- Gas temperature : ≈ 570 °C (1058 °F).

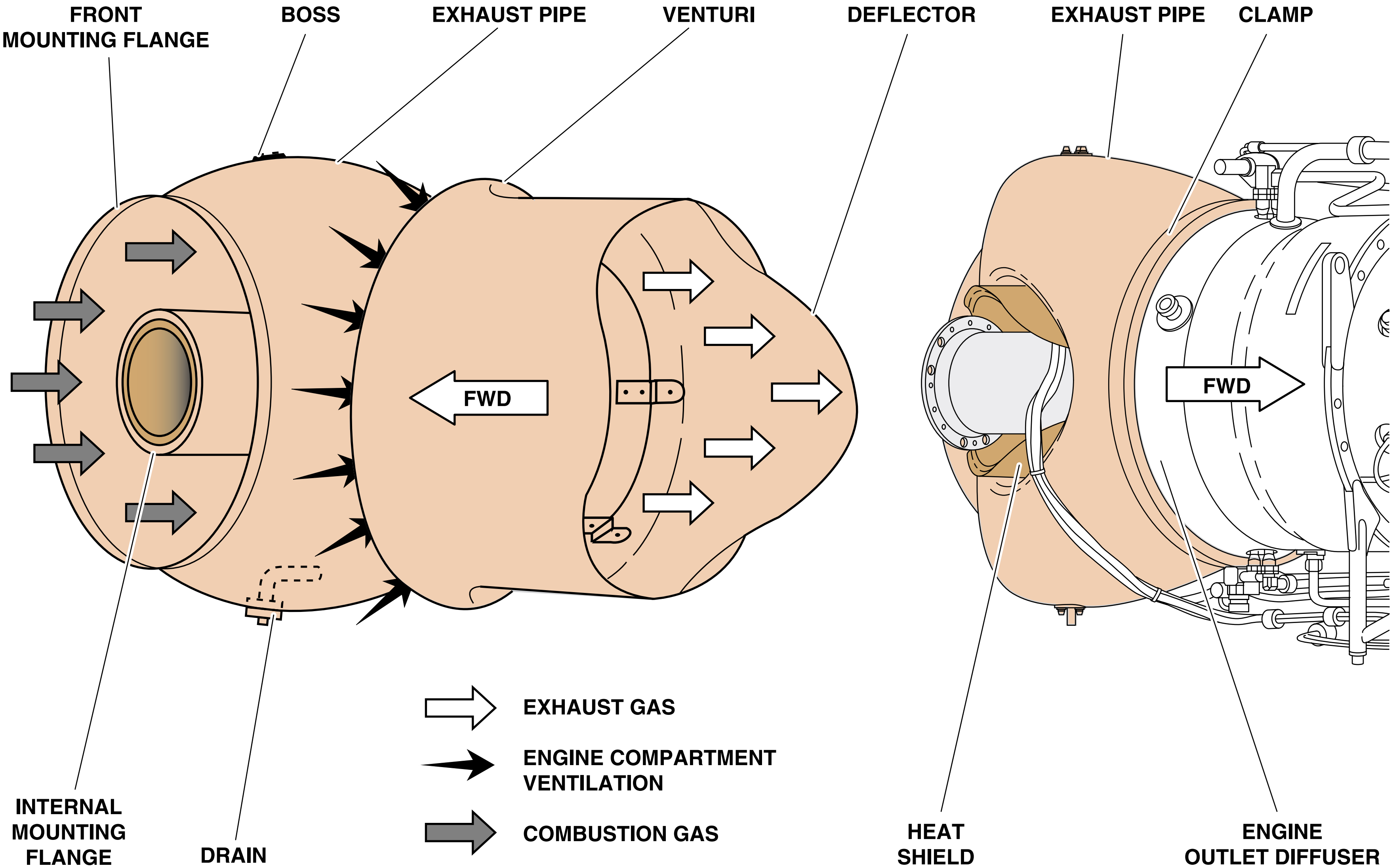
Main components

- Exhaust pipe
- Venturi extension
- Heat shield.

Description

The exhaust system is a sheet metal component which includes :

- A front mounting flange
- An exhaust pipe which includes two bosses for the draining system
- A venturi extension, to cool the engine compartment. It is fitted with a deflector
- A heat shield which protects the power drive and the sensors against heat diffusion.



EXHAUST SYSTEM

SYSTEM INTERFACES (1)

Function

This part deals with engine-aircraft interfaces : air, oil, fuel, electrical, mechanical.

Air system

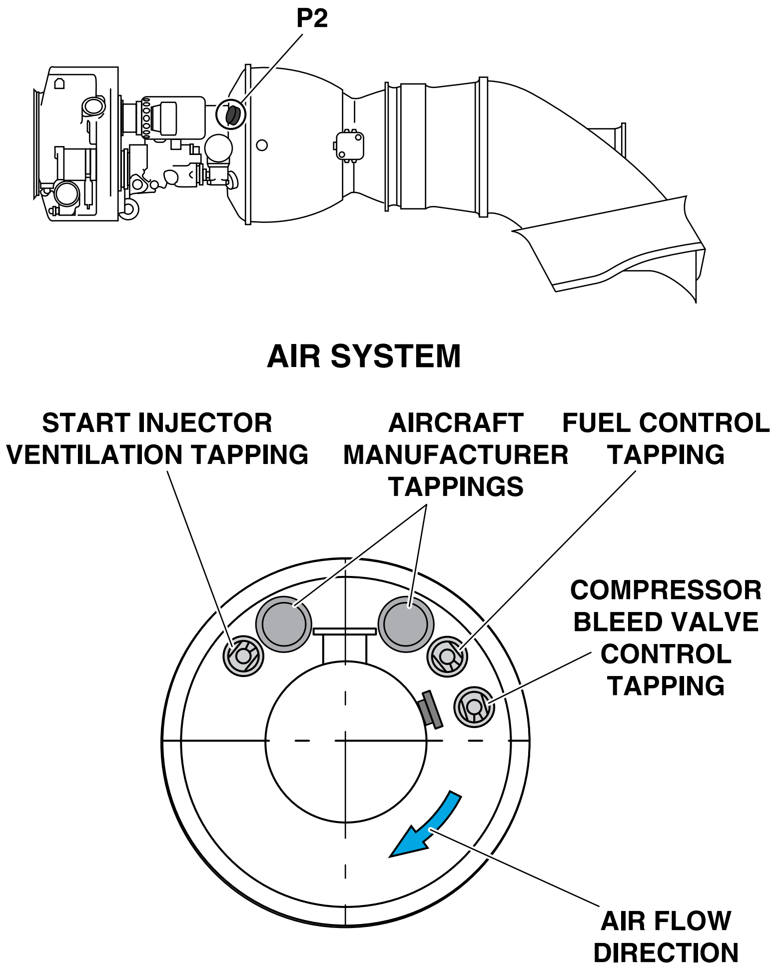
In addition to the tappings used by the engine for its own operation, air tappings are available for use by the aircraft manufacturer.

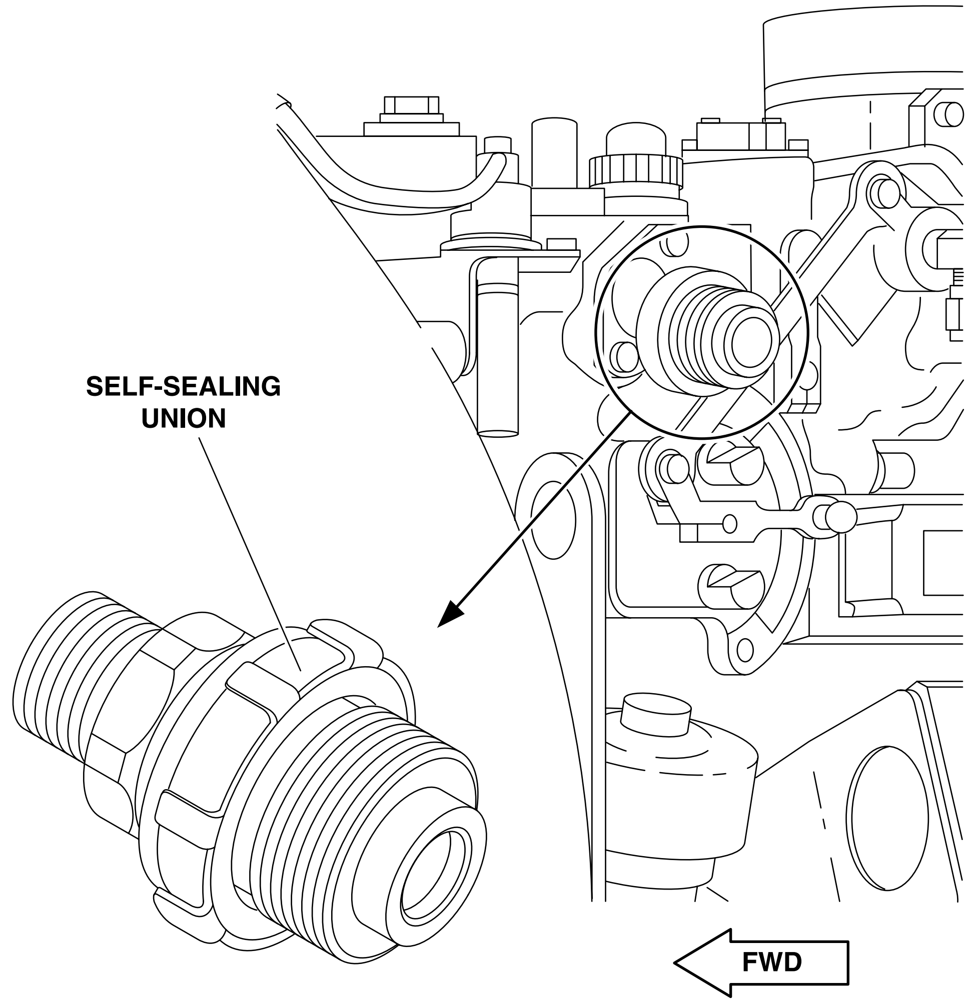
They are located on either side of the compressor casing, and they supply air at compressor pressure. The flow is limited (180 g/s (0.396 lb/sec.)). Let us remember that any tapping affects the engine performance.

Fuel system

The fuel control unit is fitted with a self sealing union, to which the fuel supply pipe of the aircraft system is connected.

The aircraft fuel system supplied the engine system under determined conditions of filtering, flow and pressure.





FUEL SYSTEM

SYSTEM INTERFACES (1)

SYSTEM INTERFACES (2)

Electrical system

The aircraft-engine connection is ensured by three electrical connectors.

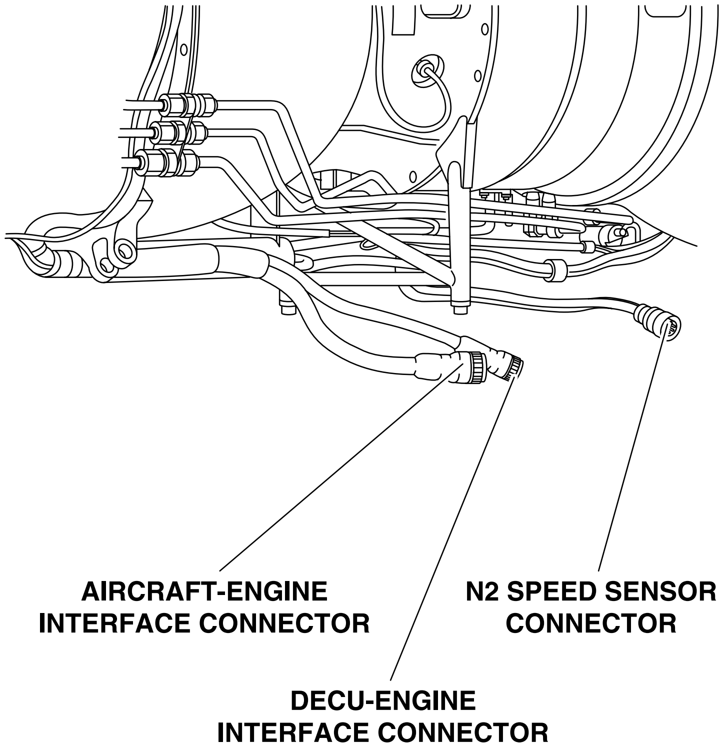
- A connector for the N2 sensors
- A DECU-engine connector
- An aircraft-engine connector which includes the fire detection.

The starter wiring is ensured by two heavy duty cables which are independent of the engine accessory harness.

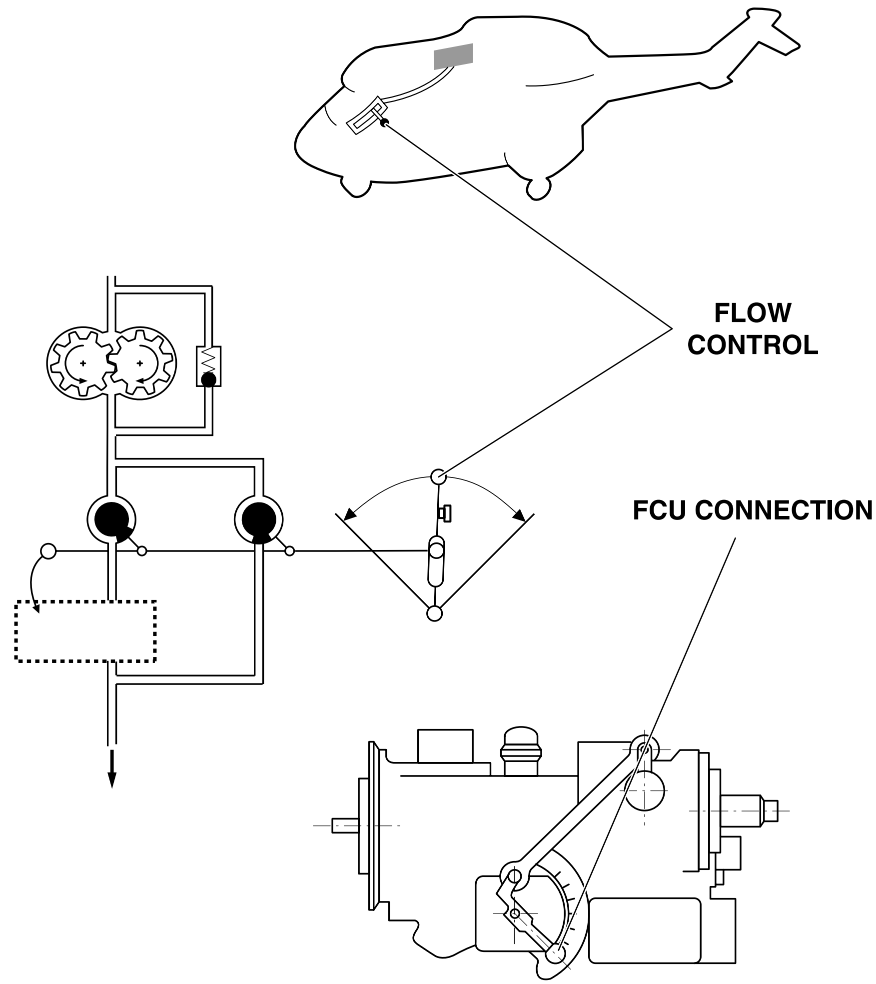
Mechanical control

This is the mechanical control operating the fuel control unit.

It includes the control lever located on the upper panel of the cockpit, the linking cable and the ball joint for the connection onto the throttle lever of the FCU.



ELECTRICAL SYSTEM



MECHANICAL CONTROL

SYSTEM INTERFACES (2)

DRAIN SYSTEM

Function

The drain system evacuates the leaks and drains of certain components, via the exhaust pipe.

It also drains the exhaust pipe and the centrifugal breather discharge.

Position

- At the lower part of the engine
- Collector volume : 450 cm^3
- Possible combustion chamber drain leak : ≈ 50 cm^3
- Purge leak during engine shut-down : 50 to 60 cm^3.

Main characteristics

- Anti-pollution drain system.

Main components

- Turbine casing drain valve
- Drain collector
- Pipes
- Exhaust pipe drain
- Collector discharge pipe, on outlet diffuser.

Functional description

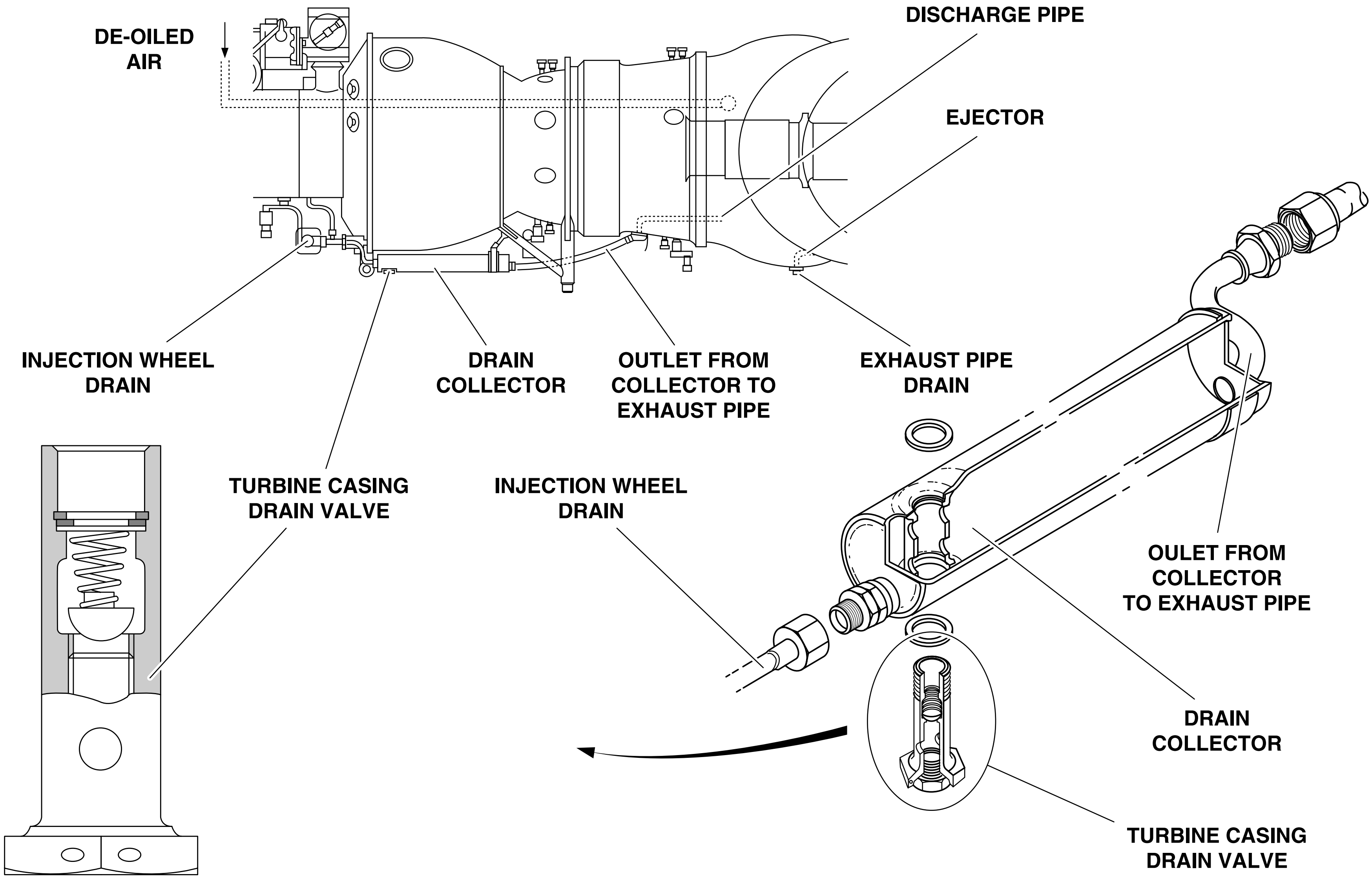
The drain valve is screwed into the lower part of the turbine casing with the collector.

The drain collector collects the injection wheel drain (purge) and turbine casing drain.

The fuel accumulated in the drain collector is sucked out by the gas flow, evacuated into the exhaust pipe and dispersed into the exhaust gases.

The de-oiled air from the centrifugal breather is conducted to the exhaust pipe.

The exhaust pipe drain is connected to the aircraft drain system and is fitted with an ejector to prevent heat transmission to the aircraft.



DRAIN SYSTEM

FIRE PROTECTION

Function

The fire protection system detects overtemperature in the engine compartment and gives a cockpit indication. An extinguishing system is installed in the aircraft

Main characteristics

- "Cold" zone :
  - Detector setting : 300 °C (572 °F) < T < 340 °C (644 °F), nominal value : 300 °C (572 °F)
  - Quantity : 2

- "Hot" zone :
  - Detector setting : 400 °C (752 °F) < T < 450 °C (842 °F), nominal value : 400 °C (752 °F)
  - Quantity : 4.

Main components

- Engine :
  - Detectors
  - Electrical wiring

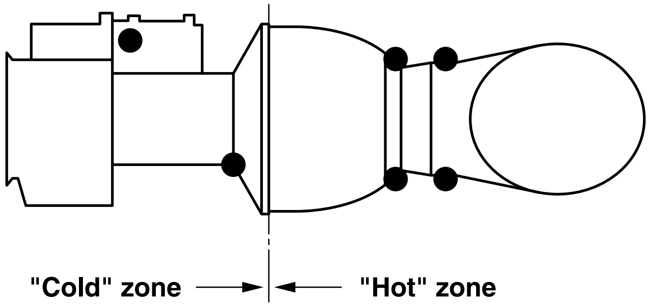
- Aircraft :
  - Indicating lights
  - Fire detection unit
  - Test selector
  - Extinguishing system.

Fire detectors

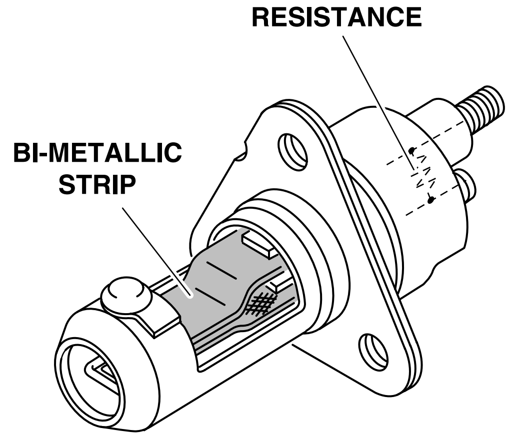
Each fire detector includes a bi-metallic strip which opens the electrical circuit in case of overheat. It is fitted with a resistance in parallel which enables the system to differentiate between the normal opening of a detector and a wiring defect.

Note 1 : *Post TU 134, each fire detector is fitted with a sealed capsule which houses the bi-metallic strip.*

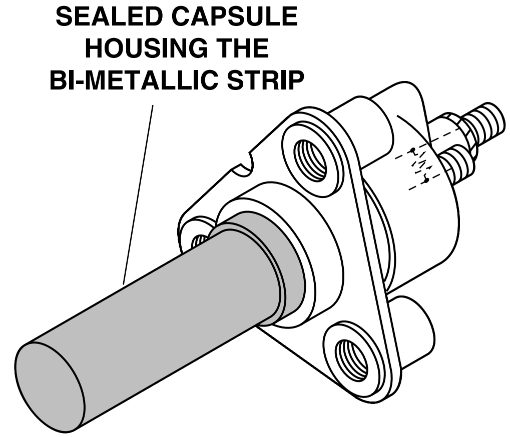
Note 2 : *Refer to the aircraft manual for more information on the extinguishing system.*



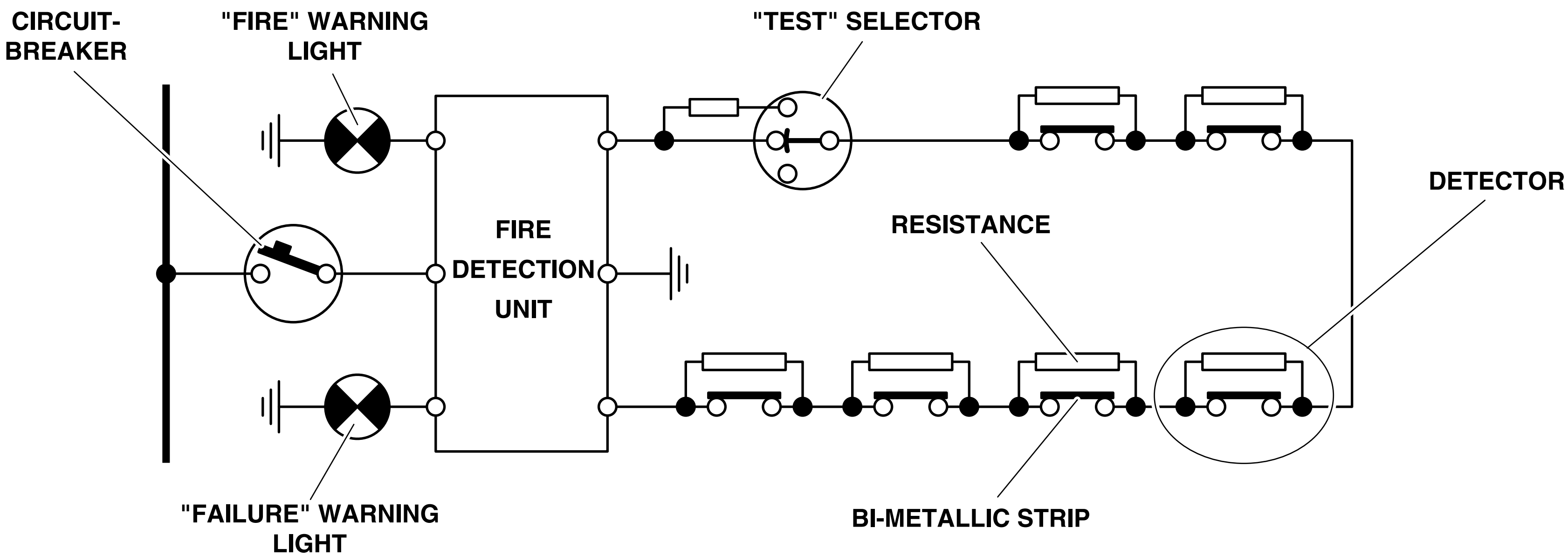
LOCATION OF THE DETECTORS



FIRE DETECTOR PRE TU 134



FIRE DETECTOR POST TU 134



FIRE PROTECTION

12 - OPERATING LIMITATIONS AND PROCEDURES

OPERATING LIMITATIONS

This part gives the different operating limitations for training purposes. Refer to the official manuals for the operating limits.

Operating envelope

The engine is designed to operate within a clearly defined climatic range (temperature t0/pressure altitude Zp diagram) (example of limits : Zp = -500 m, +7620 m (-1640 ft, +24994 ft) ; t0 = -50 °C, +50 °C (-58 °F, +122 °F)).

The starting envelope also has given limits (e.g. : Zp = -500 m, +7620 m (-1640 ft, +24994 ft) ; t0 depending on the fuel, oil and conditions.

Gas generator rotation speed (N1)

The N1 speed is an operating parameter. The limits are given for different ratings (e.g. : min N1 ≈ 65 %, N1 take-off ≈ 100 %, N1 OEI 30 sec. ≈ 104.5 %).

Acceleration of N1 : from 70 % to 95 % (in less than 4.5 seconds).

Power turbine rotation speed (N2)

The nominal N2 speed is given for a certain power setting (refer to NR speed and static droop). E.g. : nominal N2 ≈ 100% ; max transient N2 ≈ 117,9% (limit of 20 sec.) ; overspeed N2 shut-down ≈ 121,5 %.

t4 gas temperature

The t4 temperature is a monitoring parameter especially during start (e.g. : max start temperature : from 800 °C to 850 °C (1472 °F, 1562 °F), according to Zp ; t4 at different ratings from 770 °C to 870 °C (1418 °F, 1598 °F)).

Torque

The torque limit is imposed by the aircraft transmission. The max torque limits are given for steady power settings and for transitory overtorque in AEO and OEI modes.

Oil

There are various limits (pressure, temperature, consumption) associated with the oil system (e.g. : max consumption = 0,15 l/h (0.33 lb/hr) ; normal pressure comprised between 170 kPa and 600 kPa (24.65 PSI, 87 PSI) ; min pressure = 170 kPa (24.65 PSI) ; max temperature = 120 °C (248 °F)).

Starting

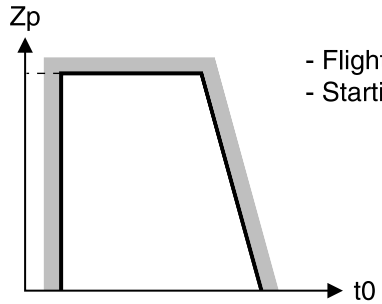
There are many limits associated with engine starting :

- Min voltage before start (≥ 25 V)
- Min voltage during start (> 15 V)
- Start duration (≈ 30 sec.)
- Ventilation duration (≤ 15 sec.)
- Number of consecutive starts : 3
- Time before subsequent attempts (20 min)
- Stabilisation time before shut-down (1 to 2 min according to t0)
- Run-down time at shut-down (> 1 min 55 sec. between 50 % and 0 %).

Other limits

Max air tapping, electrical consumption, load factors, vibration…

OPERATING ENVELOPE



- Flight
- Starting

GAS GENERATOR ROTATION SPEED

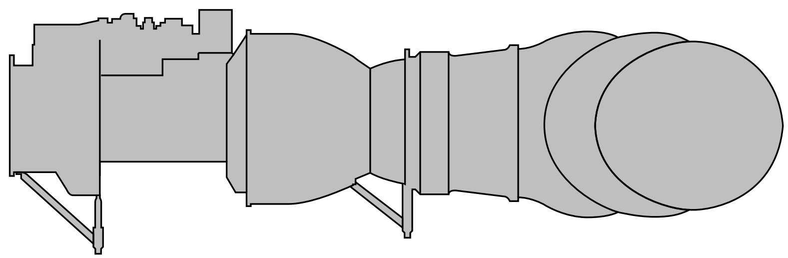
- Min N1
- AEO N1 } normal,
- OEI N1 } training

POWER TURBINE ROTATION SPEED

- Nominal N2
- Max transient N2
- Overspeed N2 (shut-down)

TORQUE

- Max stabilised C
- Max transient C



GAS TEMPERATURE

- Max start temperature
- Max temperature t4 at max rating…

OIL

- Max consumption
- Max pressure
- Min pressure
- Max temperature

STARTING

- Electrical voltage
- Number of consecutive starts
- Waiting, stabilisation, run-down and ventilation time

OTHER LIMITS

- Air tapping
- Electrical consumption
- Load factors
- Vibration

OPERATING LIMITATIONS

OPERATING PROCEDURES

Operating procedures are listed for training purposes. Refer to aircraft manuals.

Pre-start checks

Inspections, checks…

Starting

- Power on, booster pump and start selection
- Verify indicators and engine parameters (N1, N2, t4, oil…).

In flight engine control

- The control is entirely automatic (the engine adapts to the flight conditions). Trim if necessary and OEI mode selection
- Check of parameters.

Engine shut-down

- Stabilisation and stop selection
- Verification of parameters and run-down time if necessary.

Ventilation (dry ventilation)

- Select ventilation (max 15 sec.)
- Verify N1.

Re-start

- Identical to ordinary start (wait for N1 < 10 %).

Training procedures

- Training selection for engine failure training
- Training/normal selector : on training.

Manual control procedure

- Manual fuel control (after control system failure). Throttle lever in "plus" or "minus" range. Monitoring of the parameters
- Start manual control (throttle lever in acceleration range).

Particular procedures

- Flame out, fire, defects… (refer to flight manual).

STARTING

- Check
- Starting

IN FLIGNT ENGINE CONTROL

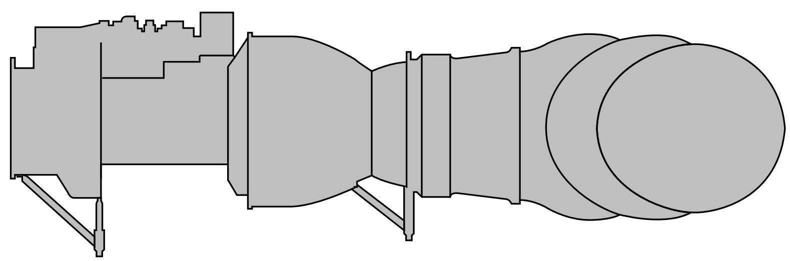
- Automatic
- Check of parameters

ENGINE SHUT-DOWN

- Stabilisation
- Selection
- Check (run-down…)

PARTICULAR PROCEDURES

- Operation with power turbine locked
- Flame-out
- Fire
- Failures…



VENTILATION

- Selection
- Limitations

MANUAL CONTROL PROCEDURE

- Engine control in manual mode
- Manual starting

TRAINING PROCEDURE

- Selection
- Failure training

RE-START IN FLIGHT

- Wait for N1 threshold
- Procedure identical to ordinary start

OPERATING PROCEDURES

13 - VARIOUS ASPECTS OF MAINTENANCE

MAINTENANCE CONCEPT

Introduction

The engine is designed to have a high availability rate with reduced maintenance.

The main aspects of the maintenance concept are the following :

- Effective modularity
- Good accessibility
- Reduced removal and installation times
- On-condition facility
- Quick repair.

Maintenance levels

Four maintenance levels can be considered :

First line maintenance (O level) : engine installed in the aircraft.

- Scheduled and preventive maintenance
    - Checks and inspections
    - Life limit or completed TBO removal
- Corrective maintenance
    - Fault detection
    - Component replacement (LRU)
    - Check.

Second line maintenance (I level) : engine maintenance in shop.

- Corrective maintenance : module removal and installation.

Third line maintenance (H level) : heavy maintenance which involves module repairs.

- Corrective maintenance : component replacement.

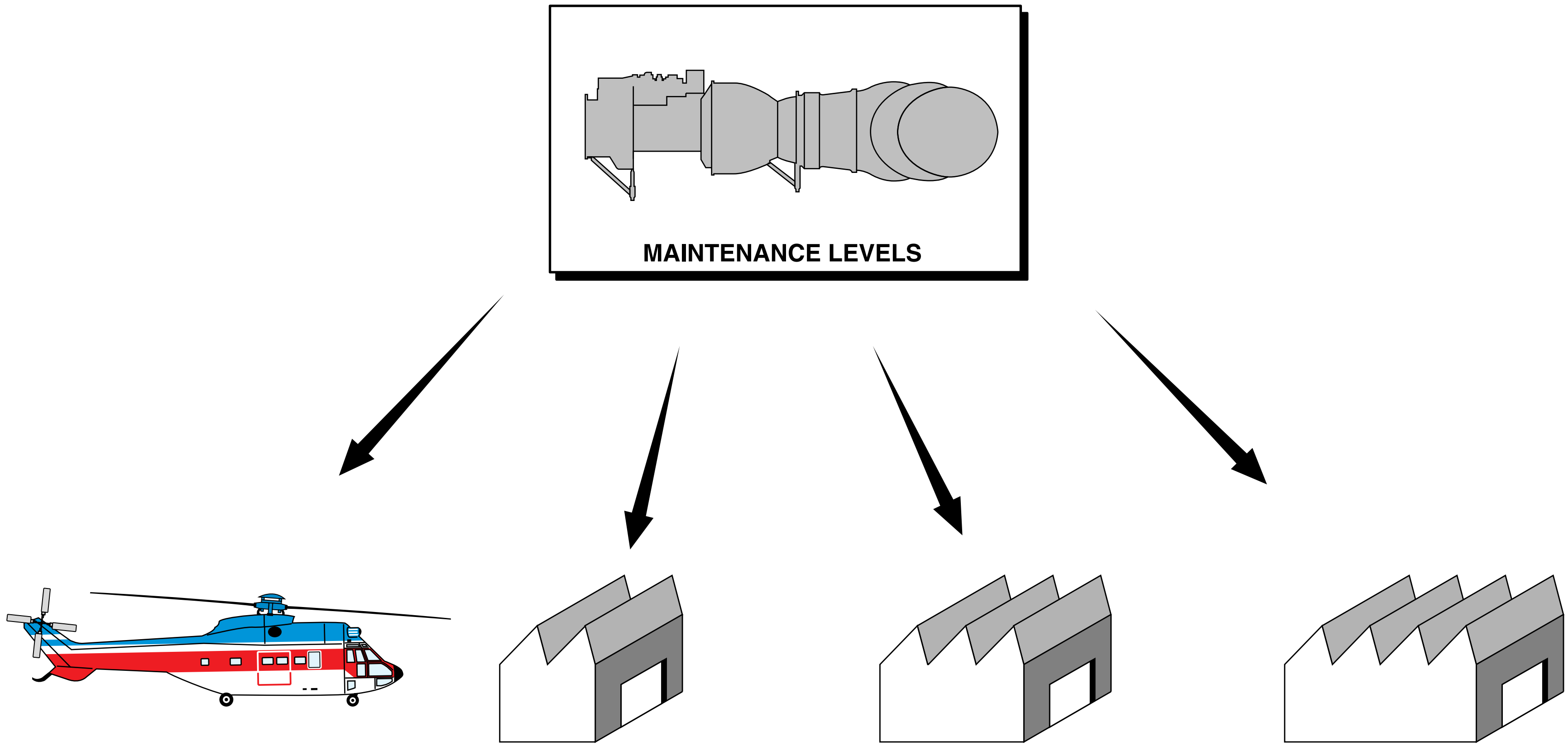
Fourth line maintenance (D level) : overhaul and repair in specific shop.

- Maintenance scheduled when the TBO is completed or when the life limits of some components are reached
- Corrective maintenance.

Other aspects of the maintenance

Refer to the following pages.

Note *: LRU - Line Replaceable Unit*
SRU - Shop Replaceable Unit.



1st LINE MAINTENANCE
(O level)
(engine installed on aircraft)
- Scheduled or preventive maitenance
- Corrective maintenance

2nd LINE MAINTENANCE
(I level)
(engine removed)
- Corrective maintenance (modules…)

3rd LINE MAINTENANCE
(H level)
(engine removed)
- Heavy maintenance

4th LINE MAINTENANCE
(D level)
(engine removed in specific shop)
- Scheduled maintenance (overhaul, repair)
- Corrective maintenance

MAINTENANCE CONCEPT

TBOs AND LIFE LIMITS

Engine, module and accessory TBOs

TBOs (operating Time Between Overhauls) are defined for the engine, the modules and the accessories. These TBOs, determined by tests and experience, are subject to an extension programme.

Component life limits

Certain components (mainly rotating parts) also have a life limit which requires the part to be scrapped when the limit is reached.

Counting of hours and cycles

A cycle is a clearly defined operating sequence. Cycle counting is effected either manually or by an automatic counter which gives a display of cycles done. The method of counting cycles is described in Chapter 5 of the maintenance manual.

A counting check (comparison between automatic counting and manual counting) is a procedure planned in the periodic maintenance.

Example of TBOs

Engine and modules in hours

Accessories : Fuel Control Unit : engine TBO or 10 years. All the other accessories according to condition. They are considered as consumable or repairable.

Examples of life limits

Mainly rotating parts :

- Axial compressor rotor : 13000 cycles
- Centrifugal compressor rotor : 10000 cycles
- Turbine wheels : 6000 cycles.

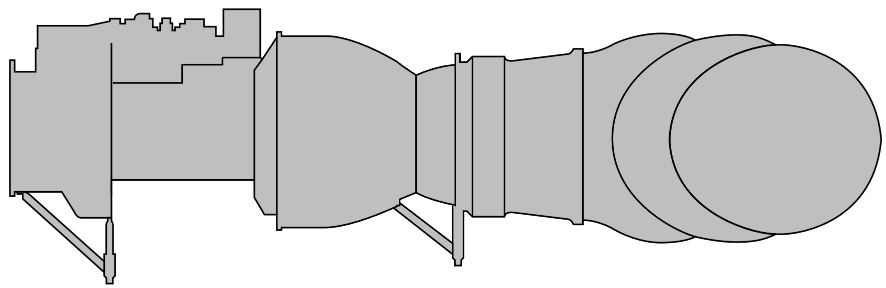
Note *: TBO : Time Between Overhaul.*

TBO

- Engine
- Modules
- Accessories

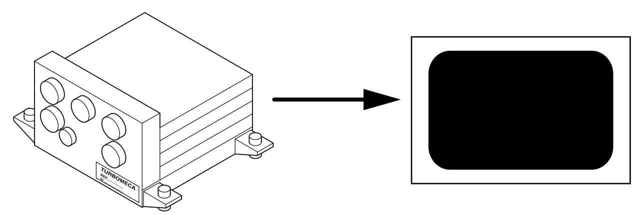
COUNTING

- Manual counting
- Automatic counting
- Counting verification



LIFE LIMITS

Cycles for :
- Axial compressor rotor
- Centrifugal compressor rotor
- Turbine wheels



AUTOMATIC COUNTING

TBOs AND LIFE LIMITS

PREVENTIVE MAINTENANCE

Preventive maintenance includes the procedures which must be systematically carried out.

Servicing inspections

- Inspection before the first flight of the day
- Inspection after the last flight of the day
- Inspection "before flight" and "after flight".

(Refer to maintenance manual 5.10.01 page 1)

Periodic inspections

- Procedures "blocked" (at fixed intervals for all the procedures) or staggered (each procedure is distributed over a period of time to reduce the turnaround time while still respecting the intervals)
- 50 hour, 500 hour or calendar inspections (18 months)
- Special inspections
  - Particular inspections
  - Inspections according to airworthiness.

Main inspection points of preventive maintenance

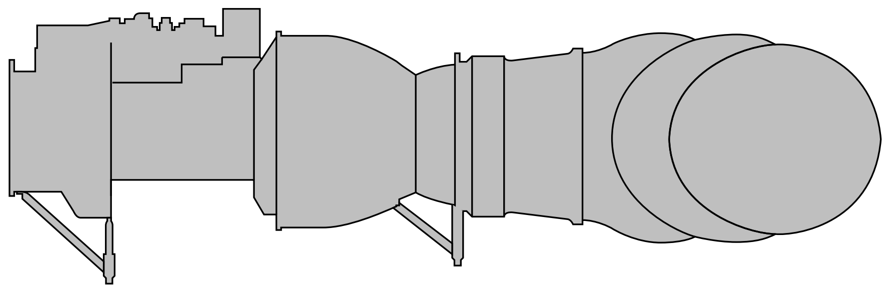
- Visual inspections
- Magnetic plug and filter inspection
- Oil sampling for analysis
- Level checks
- Compressor cleaning (according to operating conditions)
- Ground run test
- DECU data operation :
  - Hour counting check
  - Cycle counting check
  - Mode check
- Static droop check.

SERVICING INSPECTIONS

- **Inspection** "after the last flight of the day"
- **Inspection** "before the first flight of the day"
- **Inspection** before flight
- **Inspection** after flight

PERIODIC INSPECTIONS

- Procedure "blocked" or "staggered"
- 50 hour inspection
- 500 hour or calendar inspection (18 months)
- Special inspections



MAIN INSPECTION POINTS

- **Visual checks** : air intake, compressor, exhaust, turbine, casings, attachments, pipes, wiring, controls
- **Run-down check**
- **Inspection of filters** : oil filter, fuel filter, air filter, air tapping unions and jets
- **Inspection of magnetic plugs**
- **Oil sampling** (for analysis)
- **Oil level** (and replenishment if required)
- **Compressor cleaning** (depending on operating conditions)
- **Ground run test**
- **DECU data operation**

PREVENTIVE MAINTENANCE

ON-CONDITION MONITORING

When applying on-condition maintenance, the maintenance procedures are carried out according to the condition of engine components. It requires monitoring which includes appropriate procedures studied during the engine design.

Objectives of on-condition monitoring

The objective is to increase safety and to reduce maintenance costs (e.g. filter pre-blockage detection, ...).

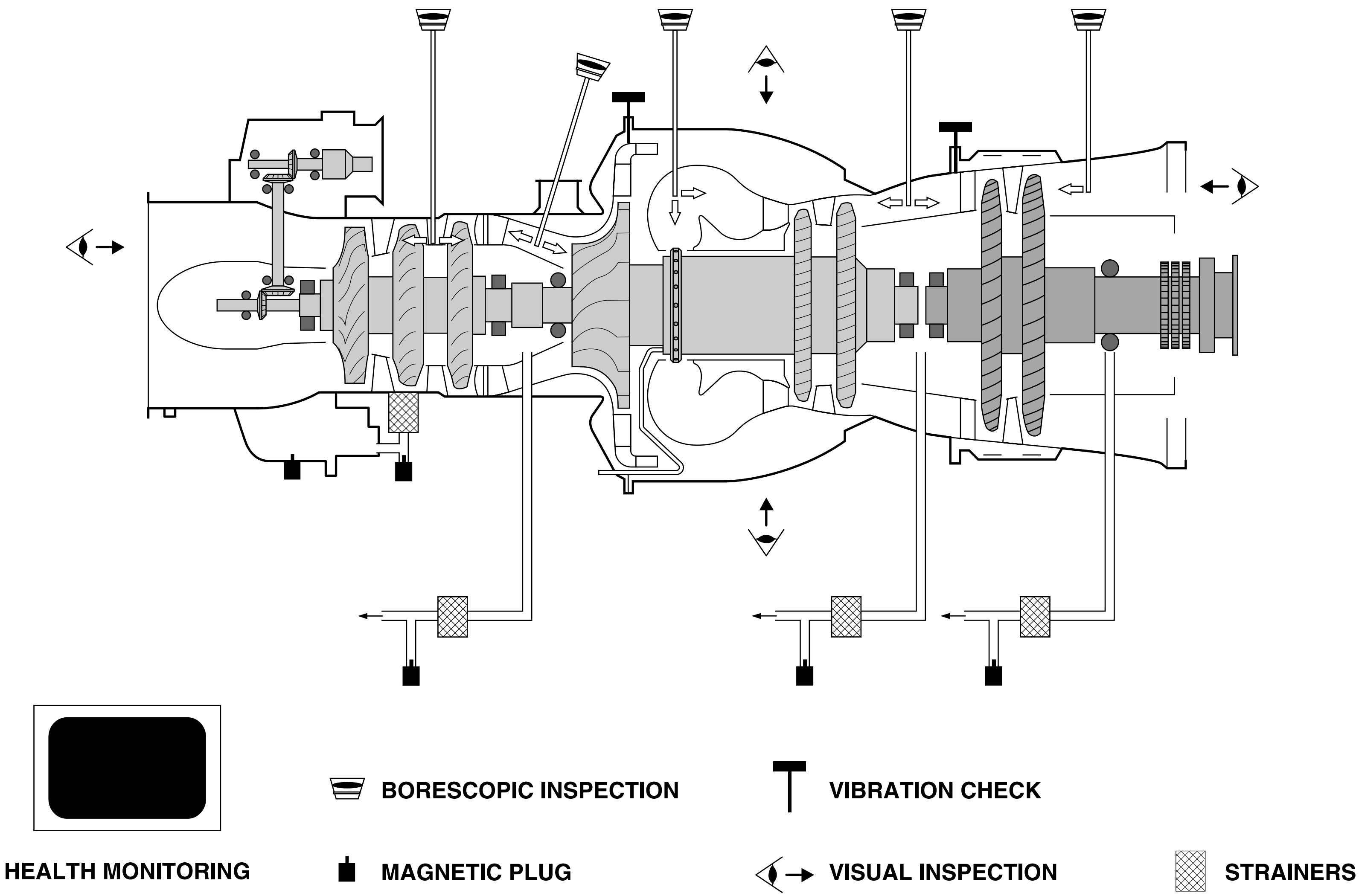
This is obtained as the monitoring ensures an early diagnosis of defects which could have serious consequences ; on the other hand, monitoring avoids unnecessary maintenance tasks (e.g. scheduled replacement of the filter, ...).

On-condition monitoring resources

On-condition monitoring implies an appropriate design of the engine which allows the use of monitoring tools.

The following procedures are considered :

- **Borescopic inspection** : this permits inspection of internal parts which are not accessible without disassembly : compressor, combustion chamber and turbine. A special tool is used to allow direct visual inspection of the parts
- **Lubricating oil check** : various methods are used to check for the contamination of the oil (magnetic plugs, strainers, sampling). Samples of oil are taken at regular intervals and the samples are analysed to measure the contamination and anticipate incipient failures (analysis by magnetoscopy, ferrography, spectrometric oil analysis)
- **Vibration level check** : the vibration level of the rotating assemblies gives an indication of the engine condition. Sensors installed at given points are used to measure the vibration level. This type of check is carried out during periodic inspections or according to engine condition
- **Health monitoring** : can be ensured by a special instrument and the Digital Control Unit (refer to chapter "CONTROL SYSTEM")
- **Visual inspection** : conventional visual inspections are also considered for on-condition monitoring (inspection of : air intake, power turbine, free rotation of rotating assemblies, miscellaneous supports, engine mounting, exhaust pipe and engine general).



ON-CONDITION MONITORING

CORRECTIVE MAINTENANCE

The objective of corrective maintenance is to put the engine back into normal service as soon as possible. Corrective maintenance includes all procedures which must be carried out when required (failure, defect…). It implies general and particular activities.

Maintenance activities

Among the general maintenance activities, the following can be mentioned :

- **Standard practices** : these are the practices which are not specific to a product. When applied to a given engine, they are however described in the maintenance manual. They are actually practised during a training course
- **Special tools** : special tooling is described in a catalogue ; the use of tools is also described in the maintenance manual
- **Spare parts management** : Spare parts are described in a catalogue. Management of spares is the responsibility of the operator in liaison with the manufacturer
- **Technical documentation** : Adequate use of the proper documentation (refer to corresponding chapter).

Corrective maintenance main tasks

- **Removal and installation** : removal and installation of the complete power plant, of the accessories and of the modules and of some engine components as required.

Note *: Assembly and disassembly of the engine is dealt with in general overhaul and repair.*

- **Functional checks** : functional check of systems, and accessories…
- **Condition checks**
- **Adjustments**
- **Miscellaneous procedures** : cleaning, storage…
- **Repairing** (components may be repairable or consumable)
- **Fault finding** (refer to corresponding section of this chapter)
- **Particular instructions** : for example, procedures in the event of oil contamination, surge, heavy landing, handling accident, lightning…

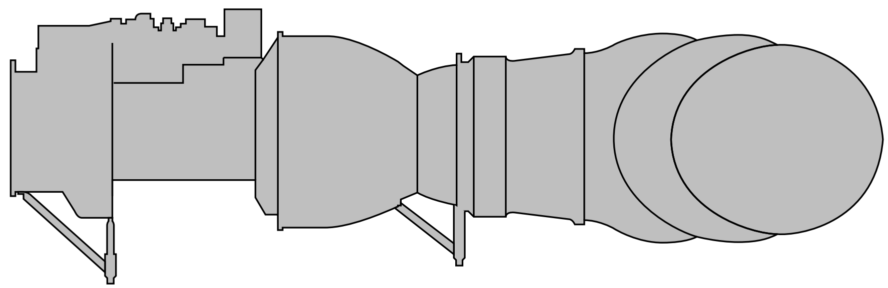
For training purposes only

CORRECTIVE MAINTENANCE

- To put the engine back into normal service as soon as possible

MAINTENANCE ACTIVITIES

- Standard practices
- Use of special tools
- Spare parts management
- Technical documentation



CORRECTIVE MAINTENANCE MAIN TASKS

- Removal and installation
- Functional and condition checks
- Adjustments
- Miscellaneous procedures (cleaning, storage…)
- Repairing (consumable or repairable components)
- Fault finding
- Particular instructions

CORRECTIVE MAINTENANCE

LUBRICANTS - FUELS - MATERIALS

This part deals with information on materials used : fuels, lubricants, greases, fluids.

Lubricants

The engine manufacturer recommends the use of synthetic oils which keep their lubricating properties over a wide temperature range and have a longer operating life.

Medium viscosity oils (5 cSt) are more particularly recommended but other types (fluids : 3 to 3.9 cSt) may be used as an alternative.

The maintenance manual (chapter 71.00.02) contains specification tables and precautions.

We shall remind you here that the mixture of oils of different types is not recommended. Therefore the system should be flushed when the oil specification is changed.

Fuels

The quality of the fuel is essential for the correct operation of the engine. It is particularly important to ensure a proper fuel supply : specification, water content, purity…

The maintenance manual (chapter 71.00.02) contains tables indicating the fuel types with the corresponding US, UK, NATO and French specifications.

Two types of fuel can be considered :

- The "normal fuels" which can be used without restriction in all the operating envelope
- The replacement fuels which may be used, but with particular restrictions and for a limited time in order not to affect the engine TBO.

Materials

Various products are used for engine maintenance.

For example graphite grease, molybdenum disulphide for the installation of parts, cleaning and inhibiting products.

The various products must be used carefully, for instance use of trichlorethylene on titanium alloy parts is forbidden.

LUBRICANTS
(maintenance manual, chapter 71)

- **Normal lubricants :** medium viscosity synthetic oils 5 cSt
- **Alternative lubricants :** medium and low viscosity oils 3 to 3.9 cSt
- No mixture of oils of different specifications
- Flushing of the system when the oil specification is changed

FUELS
(maintenance manual, chapter 71)

- **Normal fuels :** (without restriction)
- **Alternative fuels** (with particular restrictions : operating times, additives…)

MATERIALS

- **Part installation :** graphite grease, molybdenum disulphide…
- **Cleaning :** water, fuel, alcohol, detergent…
- **Storage :** waterproof product...

LUBRICANTS - FUELS - MATERIALS

TOOLING

This part deals with information on maintenance tools.

Tools

Maintenance requires certain tools, but in addition to the normal standard tools, a certain number of special tools and test equipment can be used.

During a training course, these tools are used to carry out practical work : current maintenance and modular maintenance tools.

The tools are described in an illustrated catalogue and also in the maintenance manual.

In the catalogue, tools can be identified either by their function, or by a picture or the reference number.

Tool classification

We can distinguish :

- Tools used for standard practices (e.g. : thread insert replacement)
- Blanking devices
- Handling equipment (e.g. : lifting device, engine support, transport trolley)
- Packing equipment (e.g. : wood or metal container)
- Tools used for removal and installation (e.g. : extractors, wrenches, supports for module removal and installation)
- Tools for miscellaneous procedures and checking equipment :
  - Oil drain
  - Compressor washing
  - Vibration check
  - Borescopic inspection
  - Pressure transmitter check (torquemeter, fuel, oil)
  - Check of the ignition system
  - Check of the electrical harness
  - Electrical measurement
  - Fuel injection system permeability.

Note : *The tools are to ISO standard.*

TOOLS

- Normal
- Specific

CATALOGUE

Identification by :
- Function
- Picture
- Reference

TOOLING CLASSIFICATION

- Standard practices
- Blanking devices
- Hanling equipment
- Packling equipment
- Removal and installation
- Inspection and miscellaneous procedures:
  - Oil drain
  - Compressor washing
  - Vibration
  - Borescopic inspection
  - Pressure transmitters
  - Ignition system - Harness
  - Electrical measurement
  - Fuel injection system permeability

TOOLING

TECHNICAL PUBLICATIONS - GENERAL

This part deals with the engine technical documentation.

Operation documents

The operation documents are :

- The control documents (e.g. : flight manual)

- The management documents (e.g. : engine log book (records and provides information on the engine status)).

Maintenance documents

- The current maintenance documents are the following :
  • Maintenance manual (describes the engine and its systems and all the maintenance procedures)
  • Service bulletins (approved by the authorities, and issued to inform the operators of a modification or an instruction which affects the operational aspects)
  • Service letters (letter sent to inform the operator of certain instructions related to the operation of the engine)
  • Modification index

- The general overhaul and repair documents :
  • Overhaul manual
  • Standard practices manual
  • Work specification

- The deep maintenance documents (specific manuals).

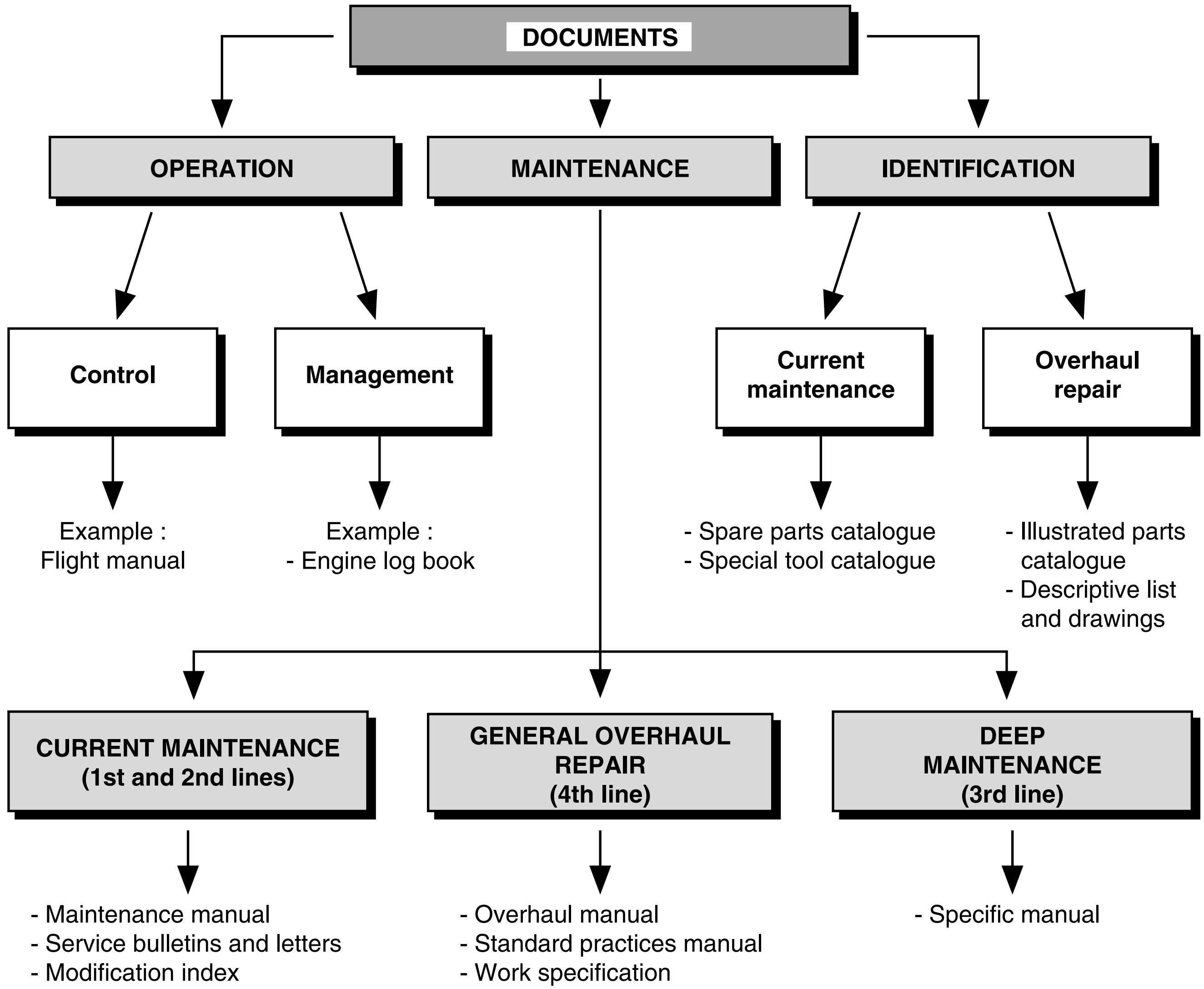
Identification documents

The identification documents are :

- The current maintenance documents :
  • Spare parts catalogue (list and reference of all the spare parts)
  • Special tool catalogue (tool designations and references).

- Overhaul and repair documents :
  • Illustrated parts catalogue (illustrates in detail all the engine and accessory parts ; only used for general overhaul)
  • Descriptive list and drawings.

Note *: Before all maintenance procedures :*
- Refer to official documentation
- Use the documentation "in a rational way"
- Make sure that documentation is up-to-date.



TECHNICAL PUBLICATIONS - GENERAL

TECHNICAL PUBLICATIONS - MAINTENANCE MANUAL

It describes the engine and its systems and all the maintenance procedures.

Layout

This document has been compiled according to the requirements in the American standard "A.T.A. 100" as follows :

CHAP	DESIGNATION
00	Introduction
05	Time limits / Maintenance checks
12	Servicing
26	Fire protection
70	Standard practices
71	Power plant
72	Engine
73	Fuel and control
74	Ignition system
75	Air system
77	Engine indicating
78	Exhaust system
79	Oil system
80	Starting

Page numbering (ATA 100, rev. 28)

Description and operation .... from 1 to 99
Trouble shooting .... from 101 to 199
Particular procedures .... from 201 to 299
Removal .... from 301 to 399
Installation .... from 401 to 499
Cleaning .... from 601 to 699
Replacement .... from 701 to 799
Inspection .... from 801 to 899
Servicing .... from 1101 to 1199
Storage .... from 1201 to 1299
Tests .... from 1301 to 1399

Layout of a chapter

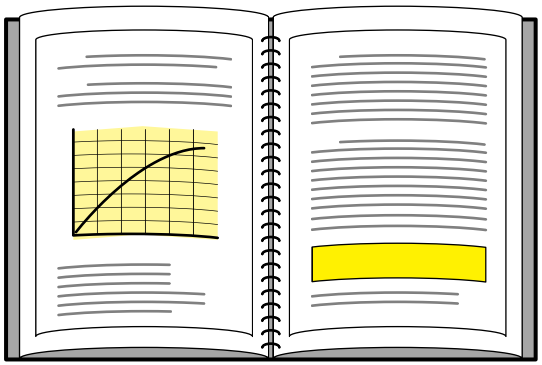
0. IntroductionCleaning
1. General TO
2. Purpose
3. Complementary documentation
4. Breakdown
   A. Chapters
   B. Page numbering
   C. Item numbering
   D. Illustration
5. Effectivity
6. Revisions
   A. Normal revisions
   B. Temporary revisions
7. Use of this manual
   A. Systematic maintenance operation
   B. Optional maintenance operations
   C. Replacement of modules
8. List of abbreviations

OBJECTIVE

- Description / operation of the engine and its systems
- Maintenance procedures

LAYOUT

- Chapters
- Sub-chapters
- Paragraphs



NUMBERING

- Gives the subject treated by the page

CONSULTATION

- Consultation method
- Up-dating

TECHNICAL PUBLICATIONS - MAINTENANCE MANUAL

TECHNICAL PUBLICATIONS - ENGINE LOG BOOK

Function

This log book is used for :

- Recording all information about the engine, the modules and the accessories, including the hours and cycles used and work carried out
- Recording the basic modification standard of the engine.

Contents

- Test bed results sheet
- Section A : test certificate and record of modifications embodied on non modular parts
- Section B : record of modules
- Section C : record of equipment
- Section D : availability state
- Section E : operation, maintenance and servicing
- Maintenance and accessory log cards.

Use of the log-book

- Test bed results sheet and section A : completed in the factory, may not be modified by the operator
- Section B : when a module is replaced, record the reference number, the serial number and the date on the right hand page
- Section C : accessory replacement : when an accessory is replaced, the details should be entered on the right hand page.
- Section D : TBO : the TBO of a replacement module should be recorded here
- Section E :
  - "Daily" column : record the daily hours and cycles
  - "Total since new" column : record the accumulated hours and cycles
  - "Total since start of life" column : record the accumulated hours and cycles since the last modular rebuild.

Note : *After changing a module the "total since start of life" column should be returned to zero.*

  - "Observations" column :

    Record :

    - The type of work carried out
    - The reference, serial N°, hours/cycles and reason for change of module or accessory replaced
    - The embodiment of a modification.
  - Module/Component log card : record fitting/removal details.

SECTION B

R	Désignation / *Identity*	Fabricant - Référence *Manufacturer - Reference*	N° Série *Serial No*	Date Signature	R	Désignation / *Identity*	Fabricant - Référence *Manufacturer - Reference*	N° Série *Serial No*	Date Signature

SECTION C

R	Désignation / *Identity*	Fabricant *Manufacturer*	Référence / *Reference*		N° Série *Serial No*	h équipt pose *Accy hrs when fitted*	Tot. h. moteur / *Total eng. hrs*		Date Signature
			Fabric. / *Manuf.*	Motorist. / *Eng. M.*			Pose / *Fitting*	Prévi. dépose *Forecast rmv.*	

SECTION D

1 - POTENTIEL / *T.B.O.*			
Moteur non modulaire ou modules / *Nonmodular engine or modules*	Total	Effectué *Consumed*	Disponible *Available*
	h	h	h
Boîte accessoires *Accessory gearbox*			
Compresseur axial *Axial compressor*			

2 - VIE LIMITE / *LIVE LIMIT*			
Pièces / *Parts*	Total	Effectué *Consumed*	Disponible *To be run*
	Cycles	Cycles	Cycles
Roue compresseur axial *Axial compressor wheel*			

SECTION E

Date	FONCTIONNEMENT / *TIME RUN*									Observations - Travaux effectués - Signature *Observations - Works carried out - Signature*
	Journalier *Daily*			Total depuis neuf *Total since new*			Total depuis état de disp. *Total since stat. of life*			
	H	Cycles		H	Cycles		H	Cycles		
		Gas Gen	T.L. P.T.		Gas Gen	T.L. P.T.		Gas Gen	T.L. P.T.	

TECHNICAL PUBLICATIONS - ENGINE LOG BOOK

PRODUCT SUPPORT

General

TURBOMECA provides the operator with the training and the assistance required to maintain the product in good operating condition.

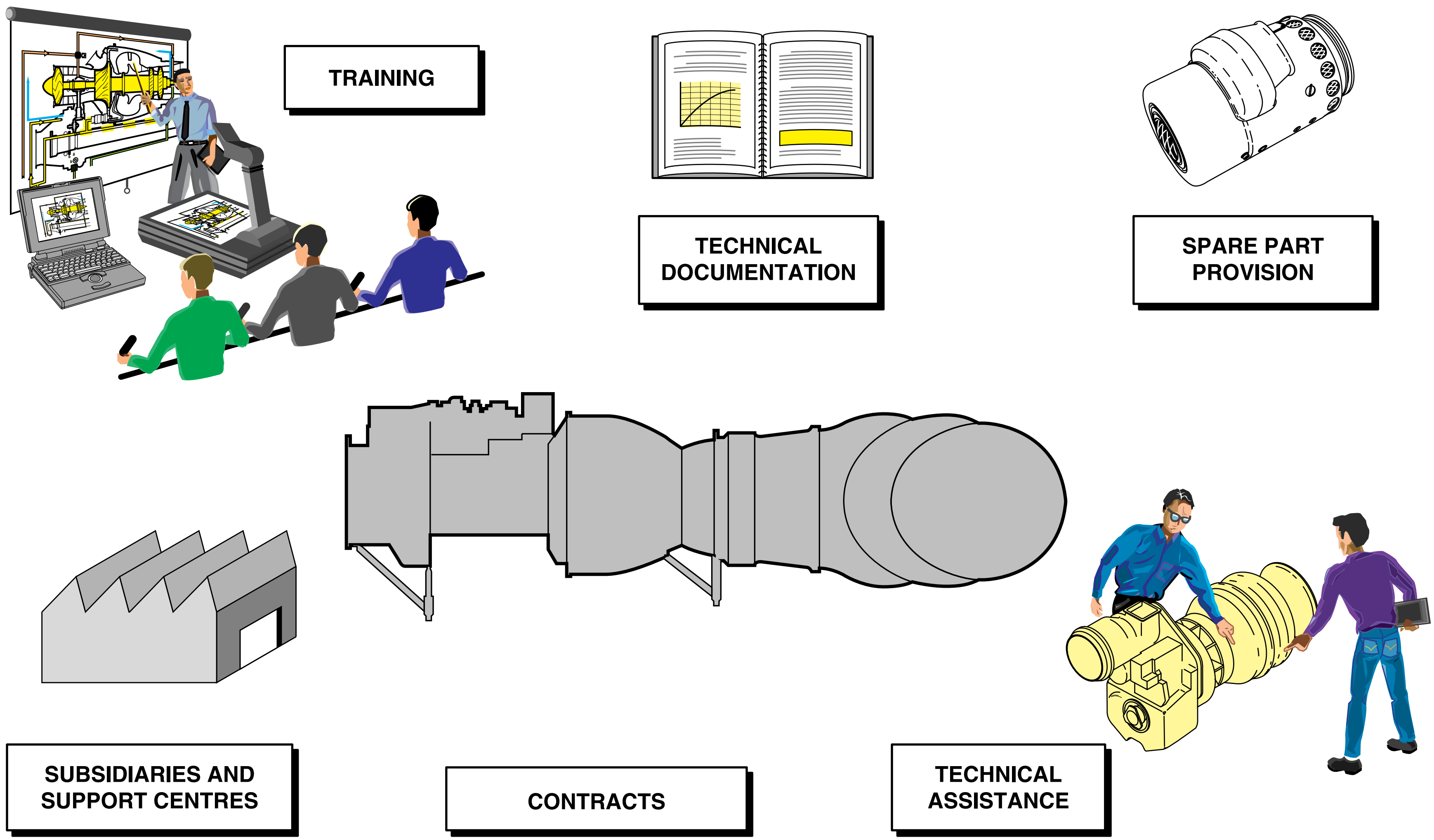
Main aspects of the support

The support covers the following fields :

- Training
- Technical documentation
- Spare part provision
- Technical assistance
- Engine overhaul and repair
- Contracts.

Subsidiaries and support centres

Subsidiaries and support centres have been set up to provide a world wide support.



PRODUCT SUPPORT

14 - MAINTENANCE PROCEDURES

MAINTENANCE PROCEDURES - GENERAL

This part is an introduction to the different maintenance procedures, which are described in the following pages for training purposes only.

These procedures are dealt with in discussion and practical work during a training course.

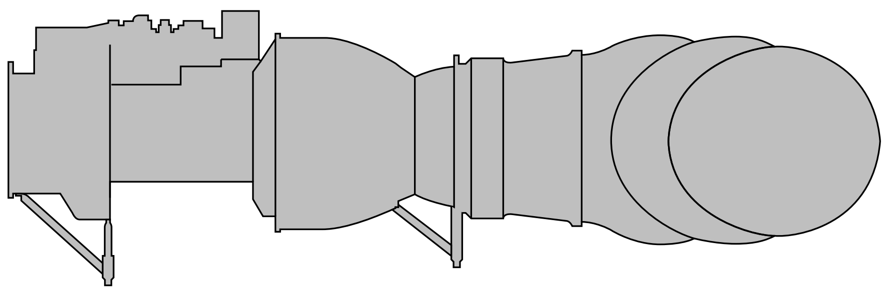
Procedures described

- Standard practices
- Cautions (Cautions, Warning)
- Storage
- Compressor washing
- Oil checks
- Miscellaneous checks
- Borescope inspection
- Axial compressor inspection
- Operating checks
- Vibration check
- Electrical harness check
- DECU check
- Permeability check
- Engine removal and installation
- Removal and installation of the accessories
- Module removal and installation
- Repair, general overhaul.

Note : *Refer to the maintenance manual and ensure that it is up to date before carrying out any maintenance procedure.*

PROCEDURES
- Definition - Instructions and operating modes

LIST OF PROCEDURES
- Standard practices - Cautions - Washing - Miscellaneous checks - Miscellaneous procedures - Removal, installation - Repair - Adjustments - …



Refer to maintenance manual before carrying out any maintenance procedure.

MAINTENANCE PROCEDURES - GENERAL

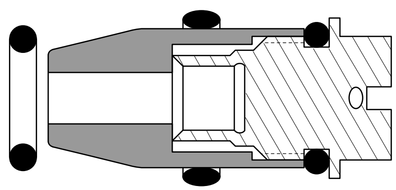
STANDARD PRACTICES

"Standard practices" means all procedures and practices, common to each engine and required for the maintenance and repair of gas turbine engines. These "standard practices" are dealt with in one chapter of the maintenance manual (chapter 70).

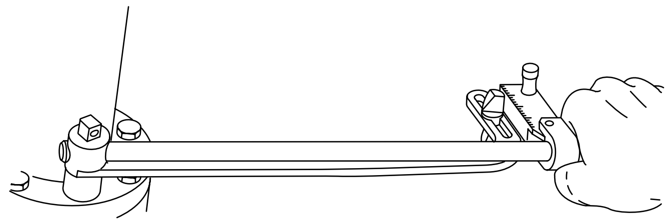
They are also dealt with in a specific document, called "standard practices glossary", mainly used by repairers.

Standard practices mainly deal with :

- Torque loading
- O'ring seal installation
- Locking of assemblies
- Pipe and union assembly
- Thread insert replacement
- Lip seal replacement.

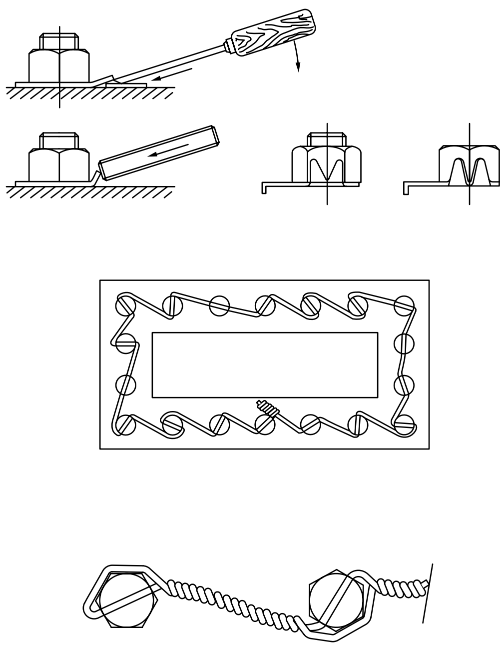


O'RING SEAL INSTALLATION

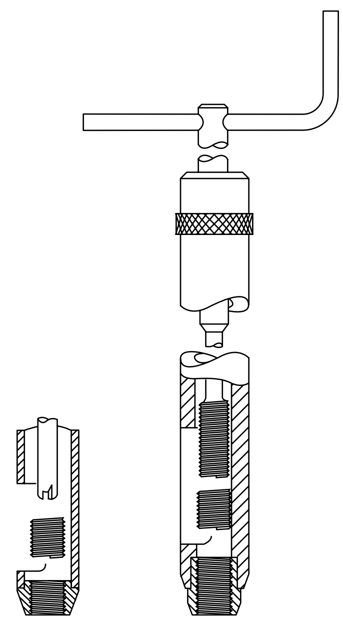


TORQUE LOADING
(torque wrench)

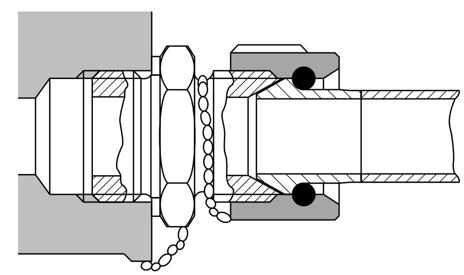
STANDARD PRACTICES
- Manual - Chapter 70 of the maintenance manual



LOCKING OF ASSEMBLIES



THREAD INSERT REPLACEMENT



PIPE AND UNION ASSEMBLY

STANDARD PRACTICES

PRECAUTIONS

Three types of advisory notice are used in the technical documentation :

- WARNING
- CAUTION
- NOTE.

Interpretation

WARNING : warns the reader of the possibility of physical harm (e.g. : wounding, intoxication, electrocution).

CAUTION : warns the reader of the possibility of damaging the engine or tooling.

NOTE : gives the reader advice on how best to carry out a task.

Examples

WARNING : do not breath the oil fumes. Do not leave oil in contact with the skin.

CAUTION : if the flush is being carried out because of metal particles in the oil system, change the filter and thoroughly clean the tank.

NOTE : take the oil sample before carrying out any replenishment.

List of the main notices

WARNING :

- Toxicity of engine oil, cleaning products and extinguishing products
- Eye protection
- Fire risk
- Electrical discharge from ignition units.

CAUTION :

- Use of the correct tool
- Use of certain products
- Weak points of the engine or tools
- Tightening torques.

NOTE :

- Oil analysis
- Cycle counting
- Engine storage
- Parameter measuring.

WARNING
(physical harm)

- Toxicity of engine oil and vapours
- Toxicity of cleaning products
- Toxicity of extinguishing products
- Eye protection
- Fire risk
- Electrical discharge from ignition units :
  - electrocution
  - risks with use in an inflammable atmosphere
- ……

CAUTION
(possibility of damage)

- Lug failure
- Titanium part cleaning
- Scrapping of O'ring seals
- Throttle lever use
- Use of the correct cleaning products
- Engine cooling
- Engine cleaning after use of extinguishing product
- Air intake mounting flange brittleness during engine lifting
- Engine balancing in vertical position
- Orifice protection during removal
- Borescope fragility
- Tightening torque
- No air bubbles during fuel injection system permeability check
- ……

NOTE
(advice)

- Oil analysis
- Cycle counting
- Installation of O'ring seals
- Engine storage
- Insulation measurements
- Recall of some torque values
- Procedural change with modification
- Inhibition of indicating lights
- ……

PRECAUTIONS

STORAGE

General

When an engine is not used for a long time, it must be protected against corrosive agents.

The most efficient protection consists of washing and protecting the air path by spraying a specific product, and housing the engine in a waterproof metal container with silicagel.

If a container is not available, the engine can be housed in a water and vapour proof bag with desiccant bags.

Type of storage

- **"Long term" storage** : procedure which protects the engine for a duration more than 3 months if the engine is not installed on the helicopter. The engine is then inhibited in the package (in non sealed case or in metal container)

- **"Short term" storage** : procedure which protects the engine for a duration less than 3 months if the engine is not installed on the helicopter.

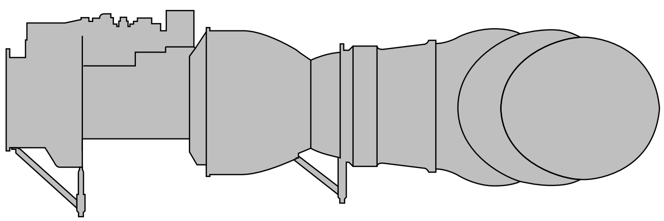
  If the engine is installed on the helicopter :
  - When the engine is not used for less than 7 days, install the air intake and exhaust blanking devices and close the cowlings
  - When the engine is not used between 7 days and 6 months, drain and replace the oil, do a 5 min. ground run check every 7 days
  - When the engine is not used for more than 6 months, remove the engine and do the "long term" storage procedure.

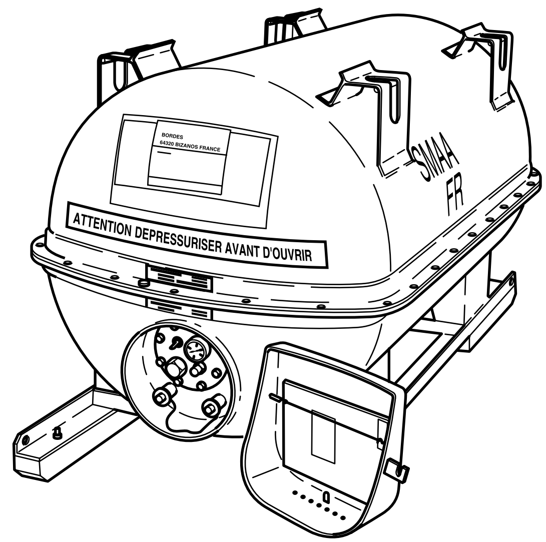
GENERAL

- Protection against corrosive agents
- Cleaning, internal and external protection

TYPE OF STORAGE

- **"Long term" :** duration more than 3 months (storage in a container)
- **"Short term" :** duration less than 3 months (protection cover)





PROCEDURES

- Engine installed on aircraft (less than 7 days or between 7 days and 6 months)
- For engines not installed on aircraft (3 months and more than 3 months)
- Internal and external protection
- System protection
- Waterproofing products
- Blanking devices

PACKAGE

- In non sealed case
- In metal container : procedure, storage and periodic inspections

  Note : *Package of engine, modules and accessories*

STORAGE

COMPRESSOR WASH

General

Compressor washing avoids fouling and corrosion of the air path and particularly of the compressor.

Types of treatment

- Washing : removal of corrosive deposits (particularly salt deposits)
- Cleaning : removal of deposits on the internal parts
- Protection : protection of surfaces against corrosion.

Frequencies

- Washing : frequently in salt laden atmosphere
- Cleaning : during periodic inspection and before storage, if necessary
- Protection : before storage in case of long term down time.

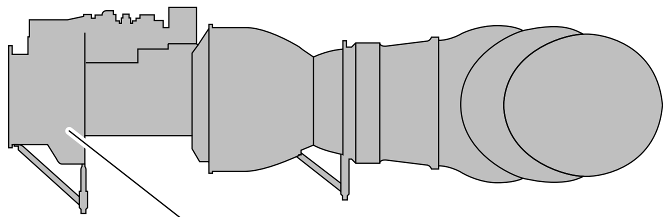
Note *: Frequencies depend on operating conditions.*

Procedures

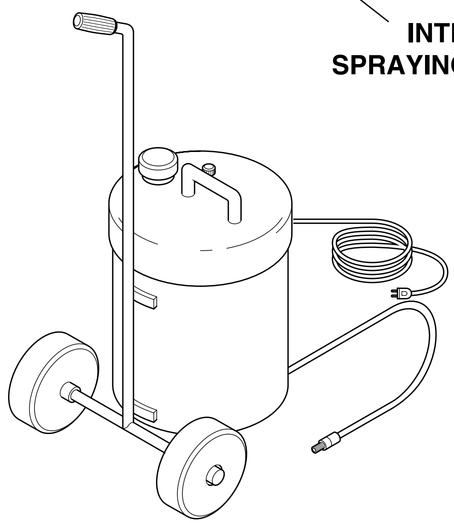
Compressor washing mainly consists of spraying a suitable product in the air intake during one or several ventilation sequences (water, cleaning fluid…).

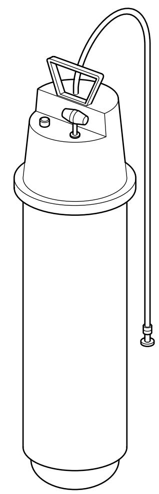
Note *: Let us remember that the engine is fitted with a spraying manifold. Washing and cleaning during a ventilation is considered the most efficient.*

GENERAL
- To clean and prevent corrosion of the air path and particularly the compressor - Preventive operation



TYPES OF TREATMENT
- **Washing :** removal of corrosive deposits (particularly salt deposits) - **Cleaning :** removal of deposits likely to harm the internal parts - **Protection :** protection of surfaces against corrosion





PROCEDURES
- Spraying a suitable product in the air intake during one or several ventilations - Washing rig - Products (water, cleaning fluid)

FREQUENCIES
- **Washing :** frequently in salt laden atmosphere - **Cleaning :** at periodic inspection ; before storage or when necessary - **Protection :** before storage in case of long grounding

COMPRESSOR WASH

OIL SYSTEM SERVICING

This part summarizes the maintenance procedures for the oil system.

Particular instructions

Maintenance manual instructions must be followed in the following cases :

- Oil specification change
- Mixing with a product which is not in conformity with oil specification
- Oil life limitation
- Oil filter blockage
- Dilution.

Particle sampling

- Particle sampling procedure with magnetic plugs
- Particle interpretation
- Particle analysis.

Spectrometric oil analysis

- Purpose of the spectrometric analysis
- Sampling frequency
- Sampling procedure
- Word definition (ppm, concentration, contamination rate, thresholds…)
- Result interpretation (warning threshold and immediate stop table).

Oil change

- Drain conditions (blockage, particles, before removal)
- Drain procedure : through tank drain plug.

Oil filling

- Through tank filler cap
- Max and min level indicators on tank.

Oil system flushing

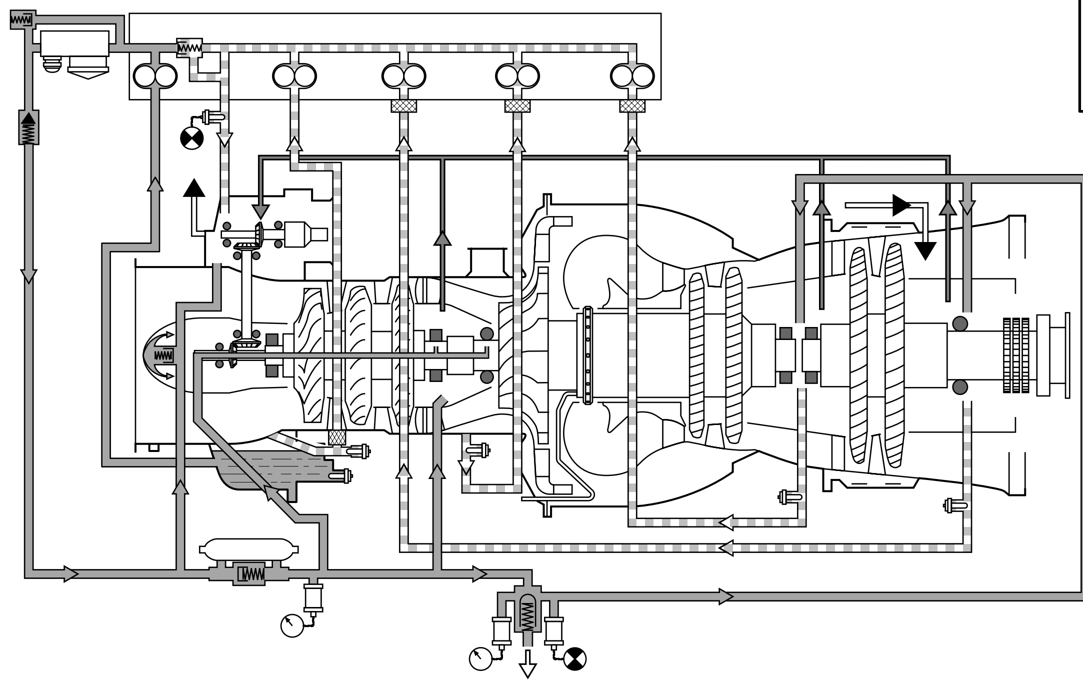
- Conditions (oil specification change, contamination, life limitation…)
- Procedure (draining, filling, ground run, draining, filter inspection, final filling).

FLUSHING

- Conditions
- Procedure

SPECTROMETRIC OIL ANALYSIS

- Purpose
- Frequency
- Procedure
- Definition
- Interpretation



DRAINING

- Conditions
- Procedure

PARTICLE SAMPLING

- Procedure
- Interpretation
- Analysis

FILLING

- Tank filler cap
- Max and min level indicators

PARTICULAR INSTRUCTIONS

- Oil specification change
- Mixing
- Life limitation
- Filter blockage
- Dilution

OIL SYSTEM SERVICING

MISCELLANEOUS PROCEDURES

This part only mentions some procedures which are part of the maintenance activity.

Introduction into service

The introduction into service includes :

- The preparation of an engine delivered in a wooden case
- The preparation of an engine delivered in a metal container
- Installation in the aircraft
- A ground run check.

Adjustments

The engine is designed not to require current maintenance adjustments.

Refer to pages 22 and 23 and to maintenance manual for more details.

Particular instructions

- **Fuel** : follow particular instructions in case of use of an alternative fuel and additives and in case of filter blockage
- **Foreign Object Damage (FOD)** : procedure according to the nature of the body ingested (direct visual inspection, borescope inspection, vibration check)
- **Exceeding of limits** : particular instructions in case of temperature, torque and speed exceedance, and in case of engine flame out, compressor surge
- **Heavy landing**
- **Damage during transport**.

Treatment after use of extinguishers

The treatment required after use of a fire extinguisher or an accidental operation of the extinguishing system, minimises corrosion by extinguishing products.

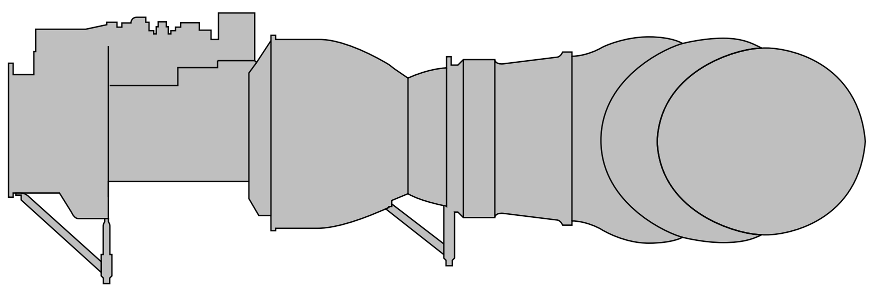
The treatment is different according to the conditions of the extinguisher use and to the extinguishing products (CO_2, foam, powder, halon…).

INTRODUCTION INTO SERVICE

- **Preparation** of an engine delivered in a wooden case
- **Preparation** of an engine delivered in a container
- **Installation** in the aircraft
- **Ground run** check

ADJUSTMENTS

- **The engine** is designed not to require current maintenance adjustments (refer to maintenance manual)



PARTICULAR INSTRUCTIONS

- **Fuel**
- **Foreign Object Damage**
- **Exceeding of limits**
- **Heavy landing**
- **Damage during transport**

TREATMENT AFTER USE OF EXTINGUISHERS

- **Normal or accidental use**
- **Treatment** to reduce corrosion by extinguishing products
- **Treatment** according to circumstances (fire or accidental use) and to the extinguishing product (CO_2, foam, powder, halon…)

MISCELLANEOUS PROCEDURES

BORESCOPIC INSPECTION

General

Borescopic inspection allows the inspection of the internal parts which are not accessible without disassembly. This type of inspection uses a special tool which allows a direct visual inspection of the parts.

Borescopic inspection can be carried out with the engine in or out of the helicopter, and on removed modules.

Special tools allow easier access to the engine parts for the borescopic inspection.

- A guide aids the checking of the centrifugal compressor
- A guide allows the checking of the 1st and 2nd stage nozzle guide vanes of the gas generator turbine.

Axial compressor borescopic inspection

This inspection is done by entering the borescopic guide on the right side, through the compressor washing pipe union and on the left side through the orifice below the start servo-valve.

Centrifugal compressor borescopic inspection

This inspection is done by entering the borescope guide through the orifice of the bleed valve boss.

The compressor blade check is done by slowly rotating the gas generator.

Borescopic inspection of the 2nd stage stator of the centrifugal compressor

This inspection is done by entering the borescope guide through the orifices of the igniter plugs.

Combustion chamber borescopic inspection

To do this inspection, it is necessary to remove the igniter plugs and the start injectors.

The combustion chamber inspection is done by entering the borescope through the igniter plug orifices.

Turbine 1st stage borescopic inspection

To do this inspection, it is necessary to remove the right hand igniter plug and to fit the turbine borescope guide.

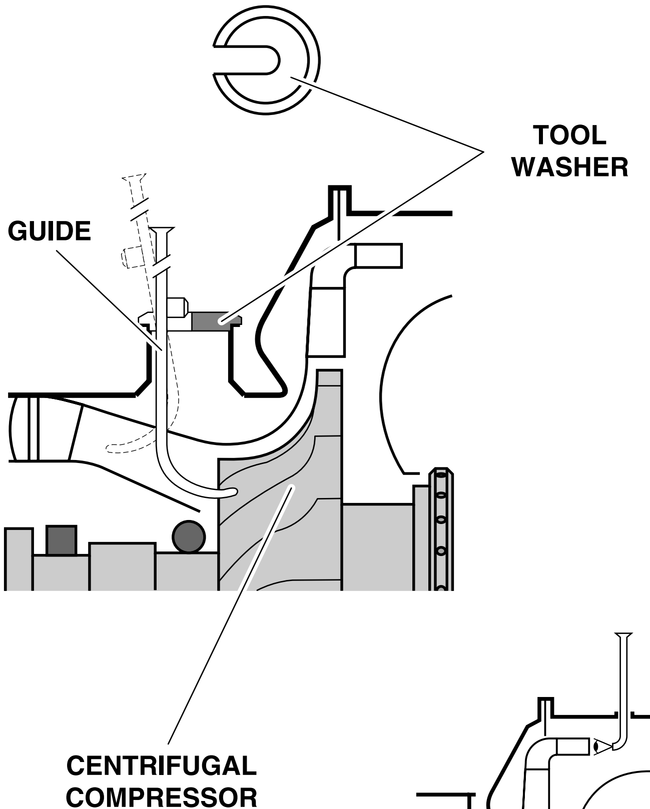
The turbine blade inspection is done by rotating the gas generator by hand.

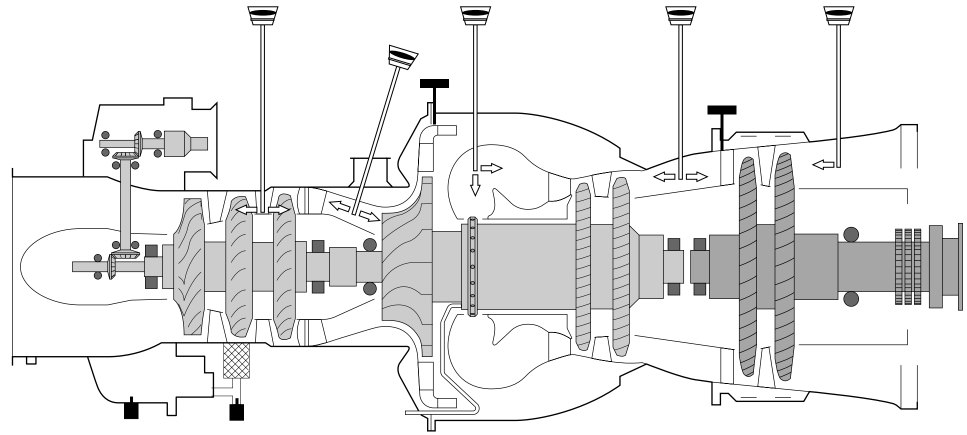
Turbine 2nd stage borescopic inspection

To do this inspection, it is necessary to remove the plug located on the diffuser casing.

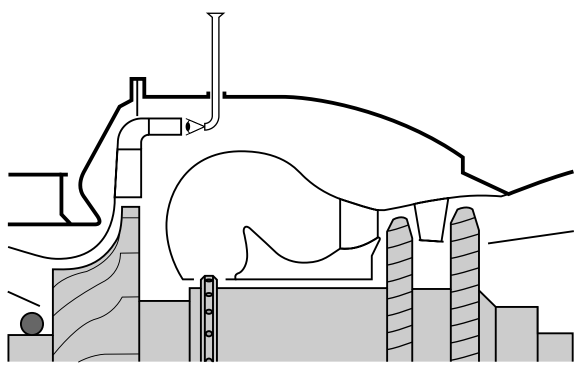
Power turbine borescopic inspection

To do this inspection, it is necessary to remove the four plugs (on the right and left of the engine) located on the diffuser casing and the power turbine casing.

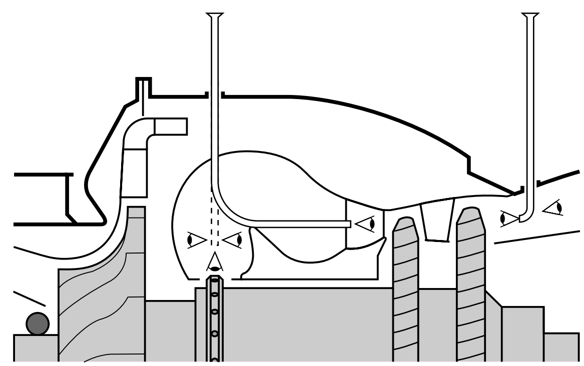




INSPECTION POINTS



2nd STAGE CENTRIFUGAL COMPRESSOR STATOR



COMBUSTION CHAMBER, TURBINES

BORESCOPIC INSPECTION

AXIAL COMPRESSOR INSPECTION

Function

This check permits the detection of dents, cracks and erosion.

Condition

This check can be carried out with the engine fitted or removed from the helicopter, and on a removed module.

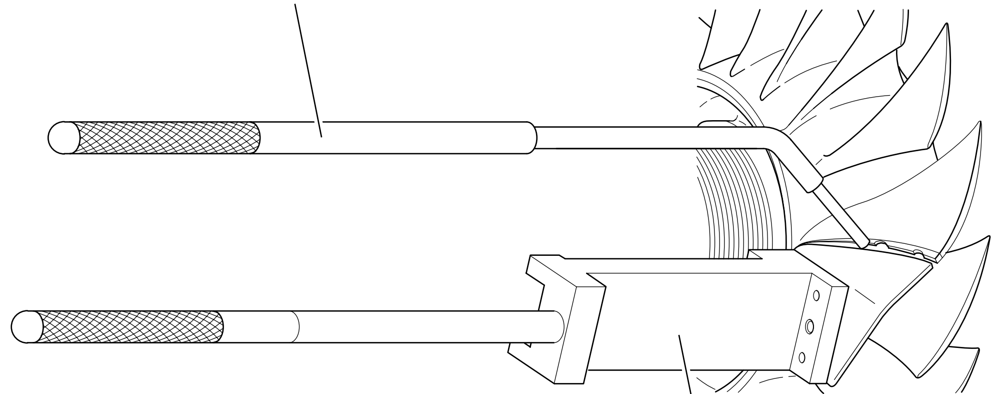
Procedures

- Visual inspection of the 1st stage
- Borescopic inspection of the 2nd and 3rd stages
- Erosion inspection using a gauge.

Criteria

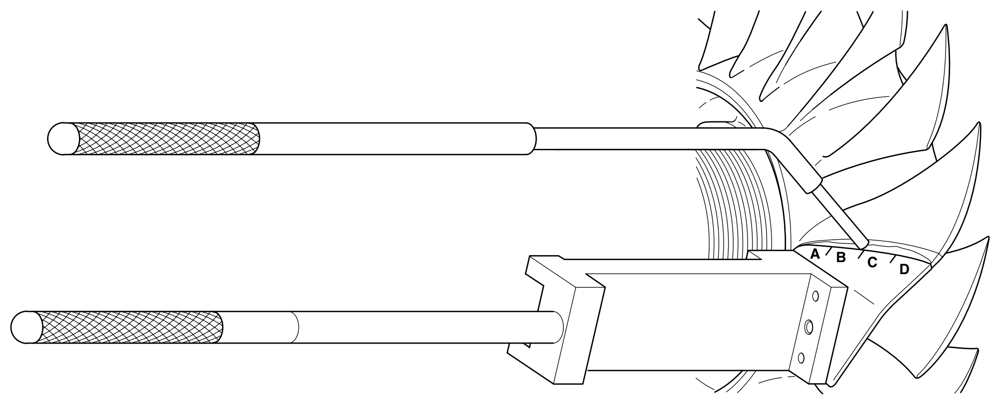
The maintenance manual details the procedure to be followed, the number of dents permitted, their max depth and the max permitted erosion value. No cracks permitted.

Refer also to the maintenance manual for the rework procedure of the axial compressor 1st stage blades.



DENT INSPECTION

CONDITION INSPECTION
- Visual inspection of the 1st stage - Borescopic inspection of the 2nd and 3rd stages - 1st stage dents and erosion using a gauge - Rework-blending



EROSION INSPECTION

AXIAL COMPRESSOR INSPECTION

OPERATING CHECKS - COMPRESSOR BLEED VALVE

Function

Threshold check of the compressor bleed valve.

Condition

This check is carried out with the engine in the aircraft.

Procedure

The closing and opening check is simply carried out by observing the N1 speed indicator and the bleed valve indicating light.

Criteria

The maintenance manual gives the minimum and maximum opening and closing values in standard conditions, and a calculation for the changing of the threshold with atmospheric temperature and altitude.

The average values of the thresholds in standard conditions are :

- Min opening : 27000 RPM
- Max opening : 28100 RPM
- Min closing = opening threshold +200 RPM.

Influence of t0 :

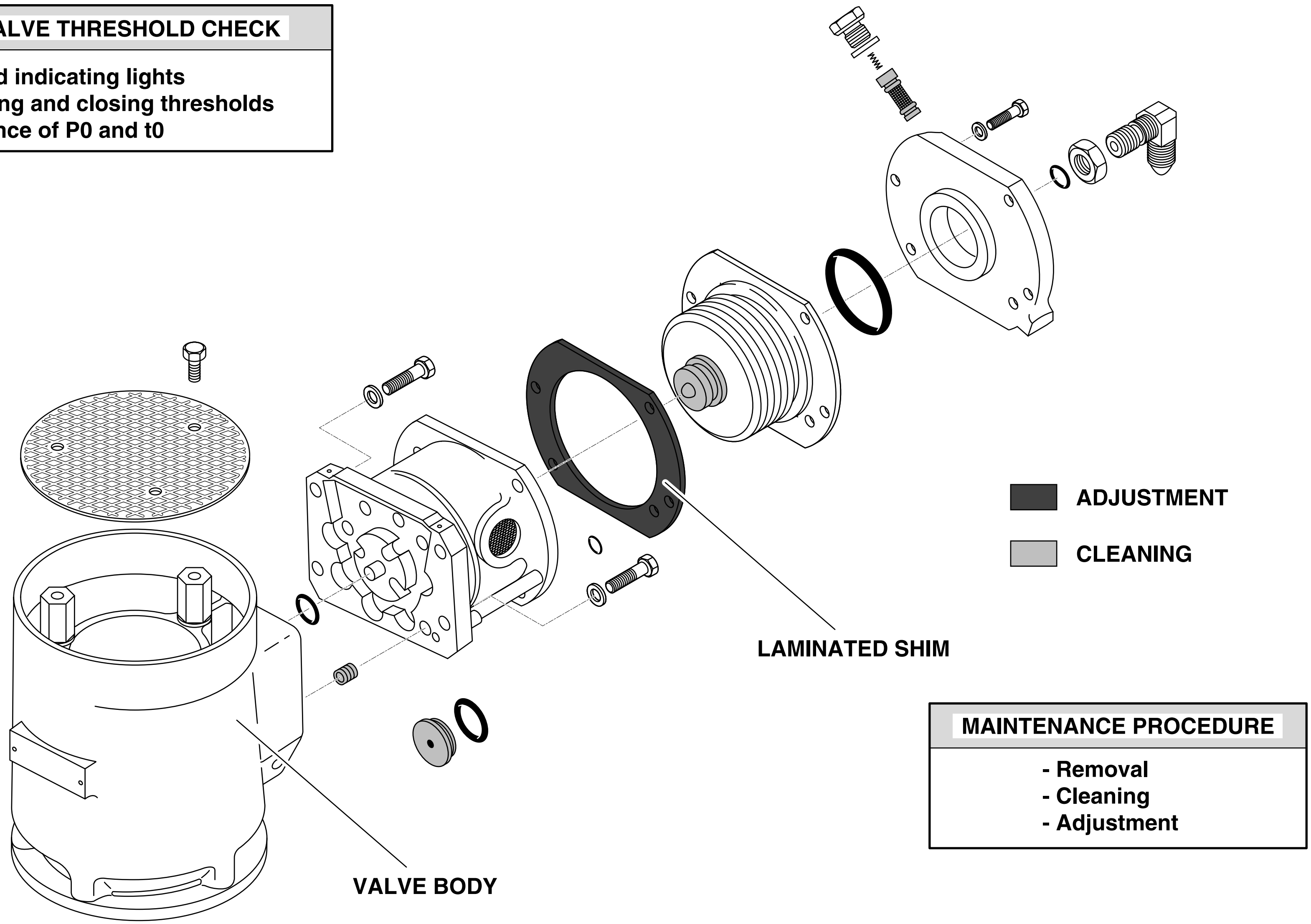
- Threshold increase of 470 RPM for 10 °C (50 °F) of t0 increase.

Influence of P0 :

- Threshold increase of 270 RPM for 1000 m (3280 ft) of altitude increase.

Note : *In case of operation out of tolerances, it is possible to clean and adjust the valve (refer to maintenance manual chapter 75.31.00).*

BLEED VALVE THRESHOLD CHECK
- N1 and indicating lights - Opening and closing thresholds - Influence of P0 and t0



MAINTENANCE PROCEDURE
- Removal - Cleaning - Adjustment

OPERATING CHECKS - COMPRESSOR BLEED VALVE

OPERATING CHECKS - STATIC DROOP AND CONTROL SYSTEM

Condition

This check is carried out in the event of a difference between the N1 speeds of the two gas generators in flight or if the N1 value of the "OEI 2 min" stop is not correct (ΔN max tolerable = 300 RPM or 1 %).

Procedure

This check is carried out in "Training" mode and according to the procedure defined in the flight manual.

The NR is read on a frequencymeter and the N1 on the cockpit digital indicator.

The NR and N1 could equally well be supplied by the helicopter monitoring system (ACMS/HUMS).

Read simultaneously the NR and the N1 at several defined points between flight idle and 90 % N1.

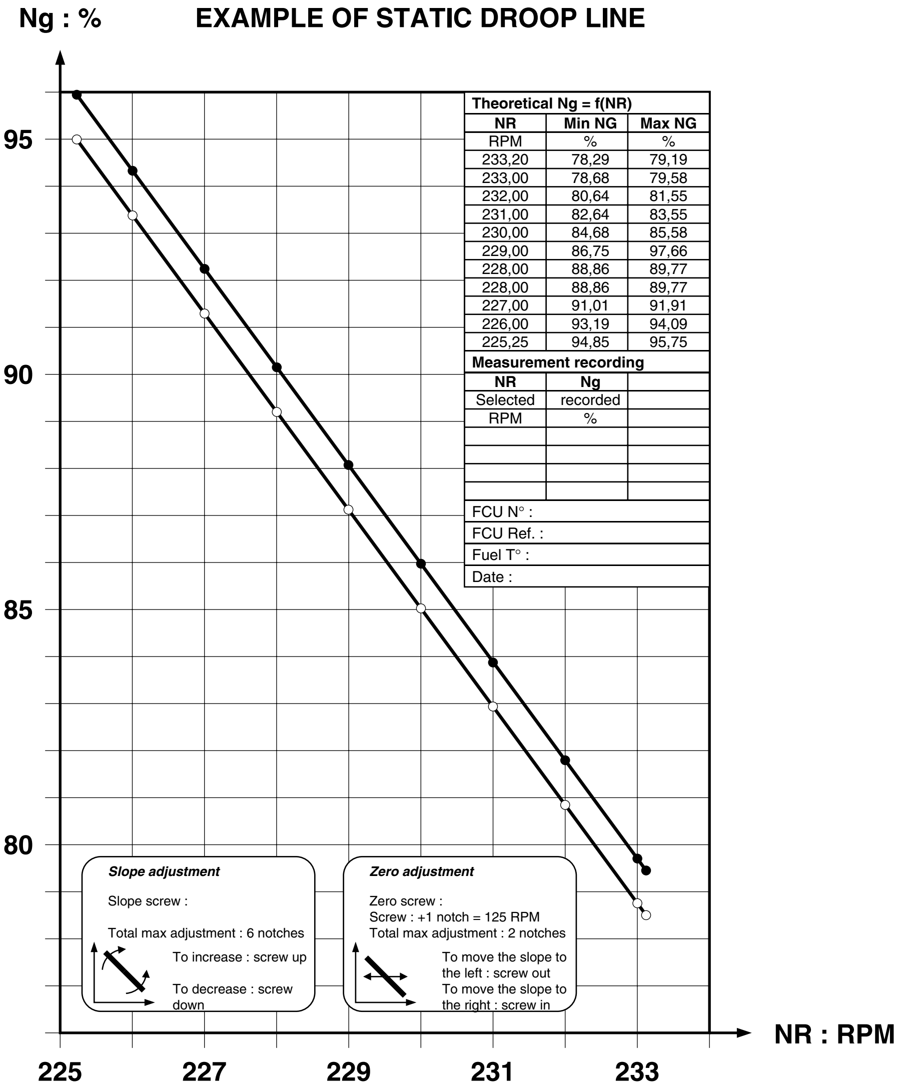
Plot these readings on the NG/NR graph. The line obtained must pass through the reference points (refer to chapter 73.21.00 in the maintenance manual).

It is possible to rectify the line obtained by adjusting the ZERO adjusting screw = parallel displacement ; SLOPE adjusting screw = line rotation.

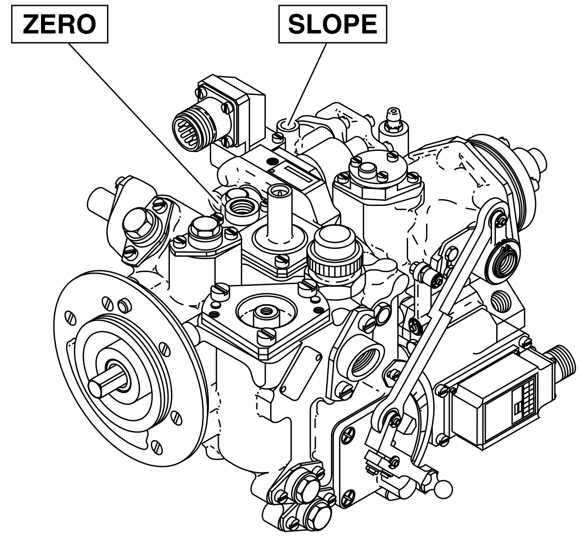
Check that the total number of notches IS NOT GREATER THAN THE NUMBER OF NOTCHES ALLOWED, in one or several adjustments.

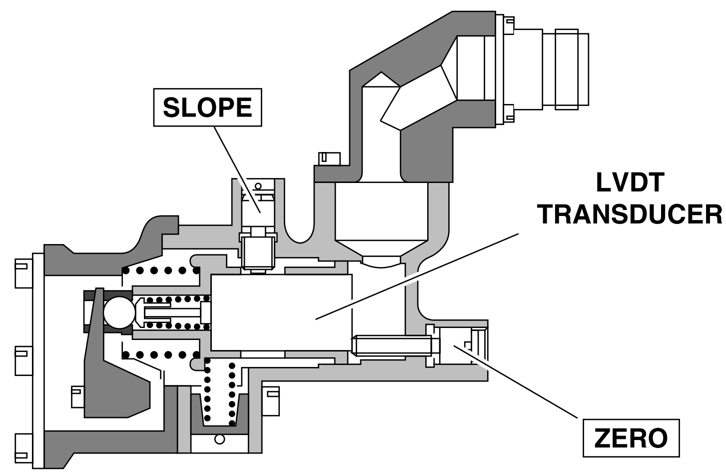
That is why the number of NOTCHES must be RECORDED for each adjustment.

After this(these) adjustment(s), a ground run test must be carried out to check the STATIC DROOP.



Theoretical Ng = f(NR)		
NR	Min NG	Max NG
RPM	%	%
233,20	78,29	79,19
233,00	78,68	79,58
232,00	80,64	81,55
231,00	82,64	83,55
230,00	84,68	85,58
229,00	86,75	97,66
228,00	88,86	89,77
228,00	88,86	89,77
227,00	91,01	91,91
226,00	93,19	94,09
225,25	94,85	95,75
Measurement recording		
NR	Ng	
Selected	recorded	
RPM	%	
FCU N° :		
FCU Ref. :		
Fuel T° :		
Date :		





ADJUSTMENT ON FCU

OPERATING CHECKS - STATIC DROOP AND CONTROL SYSTEM

VIBRATION CHECK

Conditions

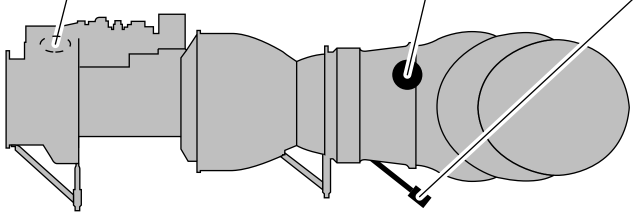
The vibration check is carried out in the following cases :

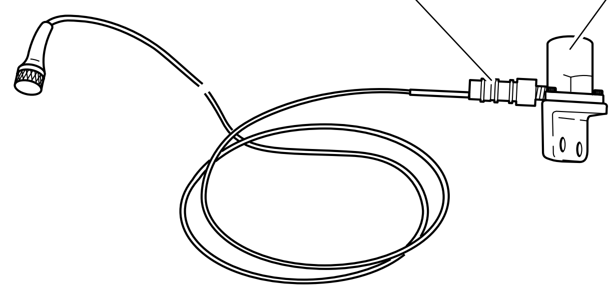
- After any failure due to an excessive vibration level
- In case of doubt about the engine vibration level
- After a modular maintenance operation.

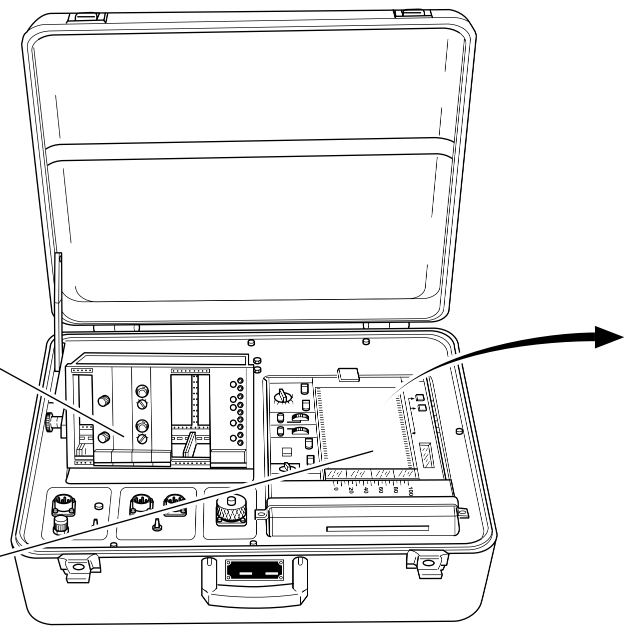
Procedure

This check is carried out with an accelerometer mounted on the engine. The accelerometer measures the vibration generated by the gas generator and the power turbine.

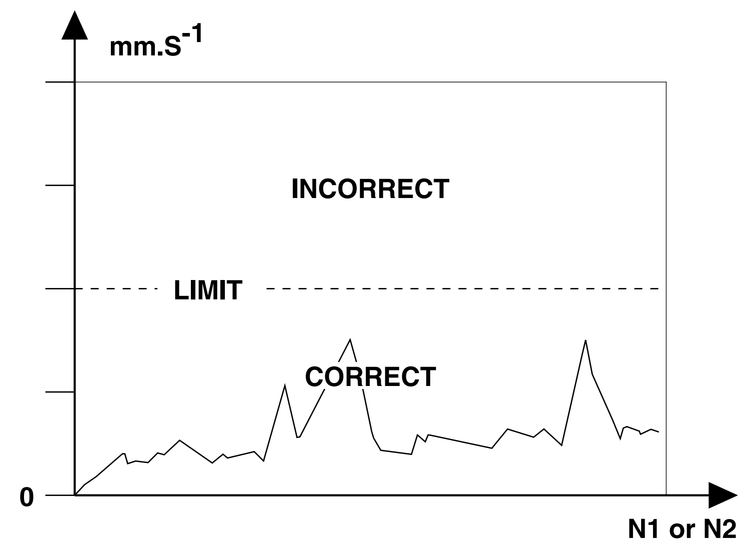
There are many vibration checking sets (refer to the maintenance manual).







TEST SET



EXAMPLE OF VIBRATORY LEVEL RECORDING

VIBRATION CHECK

ELECTRICAL HARNESS CHECK

Functions

The test set is used to check :

- The engine control and monitoring harness : continuity and insulation of the different harnesses to the DECU and the associated engine accessories
- The helicopter harness to the DECU by transmitting or receiving the signals from the instrument panel or from the DECU
- The voltage variations from the collective pitch potentiometer.

Conditions

This check is carried out after :

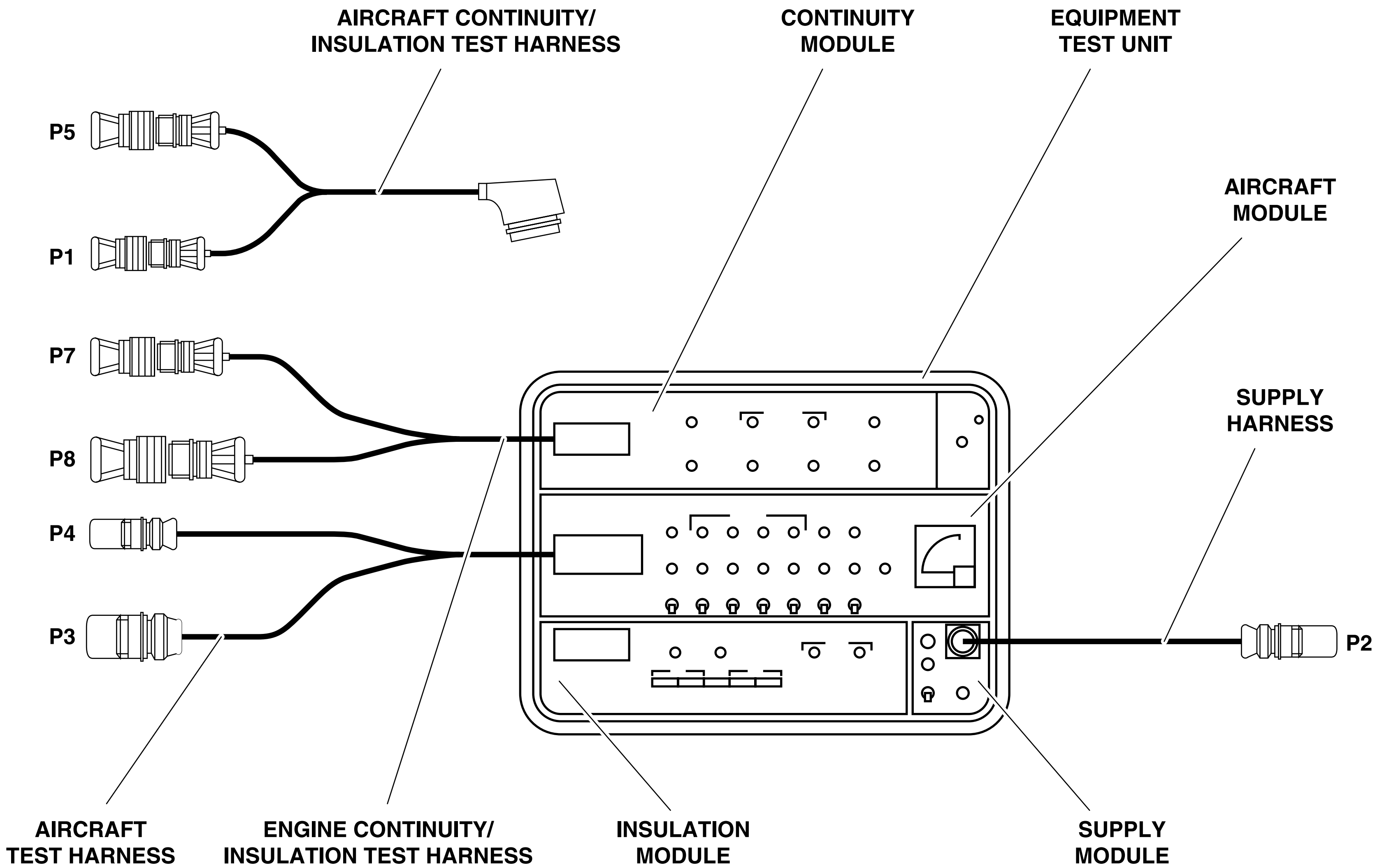
- A failure indicated by the DECU
- Replacement of the control and monitoring harness
- Replacement of the DECU and/or the engine.

Procedure

The check of each function is independent. It is recommended to install only the harness being checked to avoid overloading the power supplies.

The test set includes an autotest which ensures the conformity of the continuity of the test set and the corresponding harness.

The maintenance manual describes the procedure in chapter 71.51.00.



ELECTRICAL HARNESS CHECK

HEALTH MONITORING AND MAINTENANCE AID

Health monitoring

The Automatic Flight Control System (AFCS) compares the actual engine in operation with a "reference" engine under the same conditions (the "reference" engine is the "minimum" engine which would give the aircraft guaranteed performance).

The "reference" engine performance is stored in the memory of the AFCS. The actual engine data are transmitted by the DECU through the ARINC serial data link.

The pilot selects the engine to check, using the selector which connects the DECU to the helicopter health monitoring system (ARMS/HUMS).

The temperature difference Δt, or the power difference ΔW of the considered engine is then displayed on the display unit in the instrument panel.

Note *: It is also possible to carry out an engine power check by calculation, using the diagrams and procedure in the flight manual.*

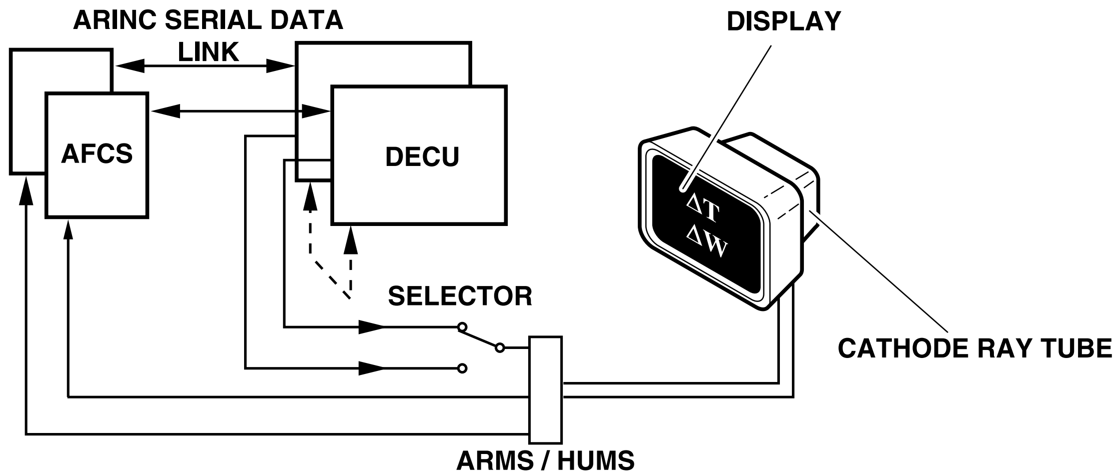
Maintenance aid

The DECU includes a built-in test system which provides a failure diagnosis.

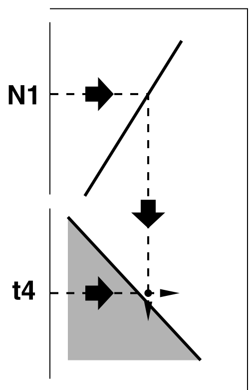
A serial data link (RS 232) transmits the diagnosis to the helicopter instrument panel.

This maintenance system identifies the faulty system and locates the defective component (sensor, servo-valve, DECU module…) using an alphanumeric coding (refer to maintenance manual and to the fault analysis at the end of this chapter).

The DECU ensures the counting of hours and cycles (gas generator and power turbine) and records the time spent at emergency ratings.



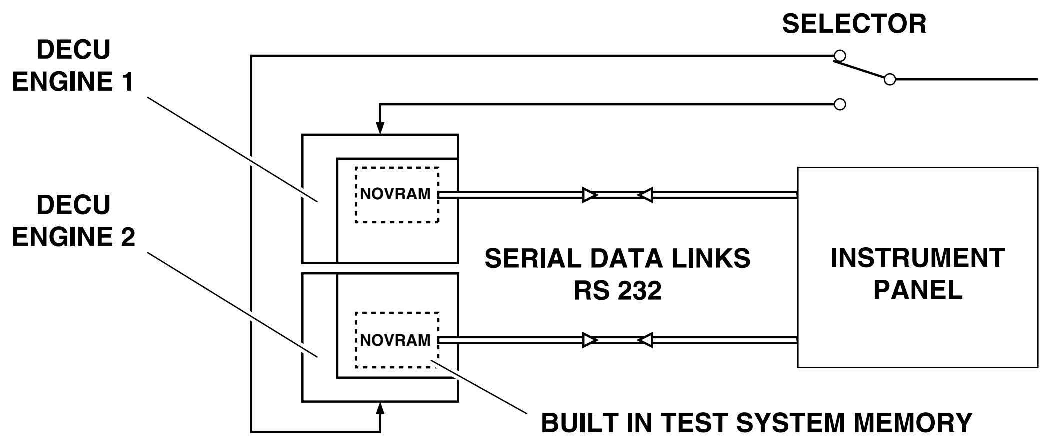
HEALTH MONITORING



ENGINE POWER CHECK GRAPH

INCORRECT

CORRECT



MAINTENANCE AID

HEALTH MONITORING AND MAINTENANCE AID

PERMEABILITY CHECK OF THE FUEL INJECTION SYSTEM

Objectives

- Preventive : mandatory check to ensure the N1 30 sec. OEI
- Corrective : repair in the event of N1 reduction (power loss…)
- In preventive or corrective procedure, the drain and overspeed valve sealing must be checked.

Conditions

- Preventive : this check is carried out every 500 operating hours during periodic inspections
- Corrective : this check is carried out before FCU replacement in the event of power loss.

The check is carried out with a special tool.

Procedure

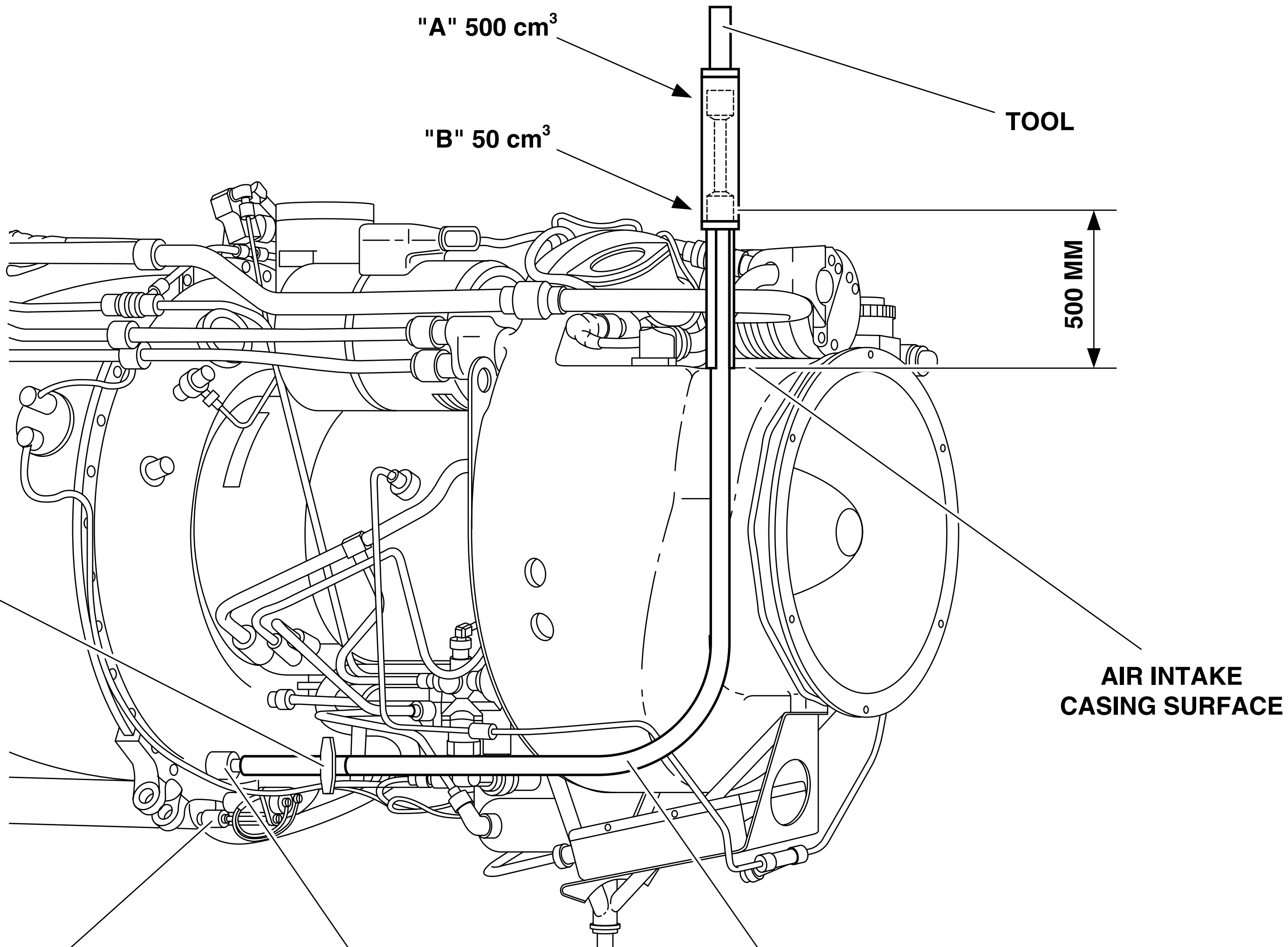
The check is carried out with the engine cold (max t4 : 50 °C (122 °F)) and is described in the maintenance manual (chapter 73.00.00).

It consists in measuring the flow through the fuel injection system (flow by gravity with time measurement).

This check ensures that the system is not clogged (injection manifold and centrifugal injection wheel).

In the event of a blockage, a fuel injection system cleaning procedure can be carried out.

CHECK
- Objective - Conditions - Procedure



PERMEABILITY CHECK OF THE FUEL INJECTION SYSTEM

MISCELLANEOUS CHECKS

This part summarizes the miscellaneous maintenance and check procedures. It only gives procedures which are dealt with in discussion and practical work during a training session.

Engine

- Measurement of the clearance of the linking tube
- Removal of the gas generator rear bearing
- Check of the combustion chamber cracks.

Oil system

- Check of leakproof unions
- Oil transmitter bench test
- Electrical check of the chip detector.

Fuel system

- Fuel system purge (on FCU)
- Check of check valve sealing
- Check of the drain and overspeed valve sealing
- Check of the engine fuel inlet union.

Electrical system

- Ignition system check (ignition units and igniter plugs)
- Check of thermocouple probes (continuity, insulation).

Power plant

- Engine acceleration check during starting and ground run
- OEI check in flight
- Check after OEI operation
- OEI availability check
  - Injection system permeability
  - Drain and overspeed valve sealing
  - Static droop and OEI stop.

ENGINE

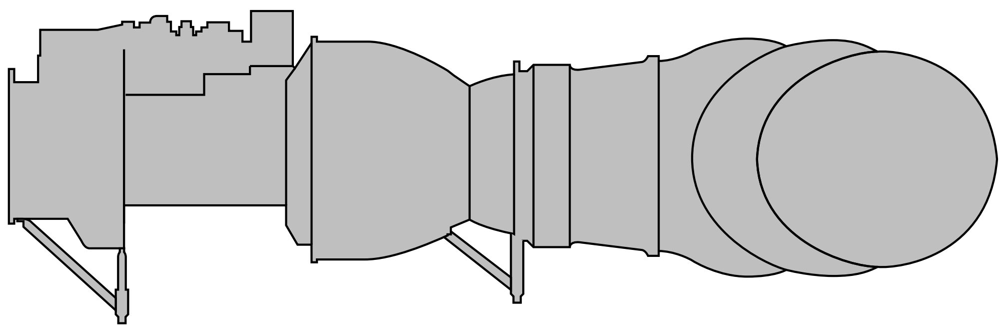
- Linking tube clearance
- Rear bearing removal
- Inspections
  e.g. : combustion chamber cracks

OIL SYSTEM

- Leakproof unions
- Oil pressure transmitter bench check
- Chip detector
  (electrical check)

FUEL SYSTEM

- System purge
- Sealing check :
  - check valve
  - drain and overspeed valve
- Engine fuel inlet union



POWER PLANT

- Acceleration check
- OEI check in flight
- Check after OEI operation
- OEI availability check

ELECTRICAL SYSTEM

- Ignition system check
- Insulation, continuity checks
  (e.g. : thermocouple probes)

MISCELLANEOUS CHECKS

REMOVAL AND INSTALLATION OF THE POWER PLANT

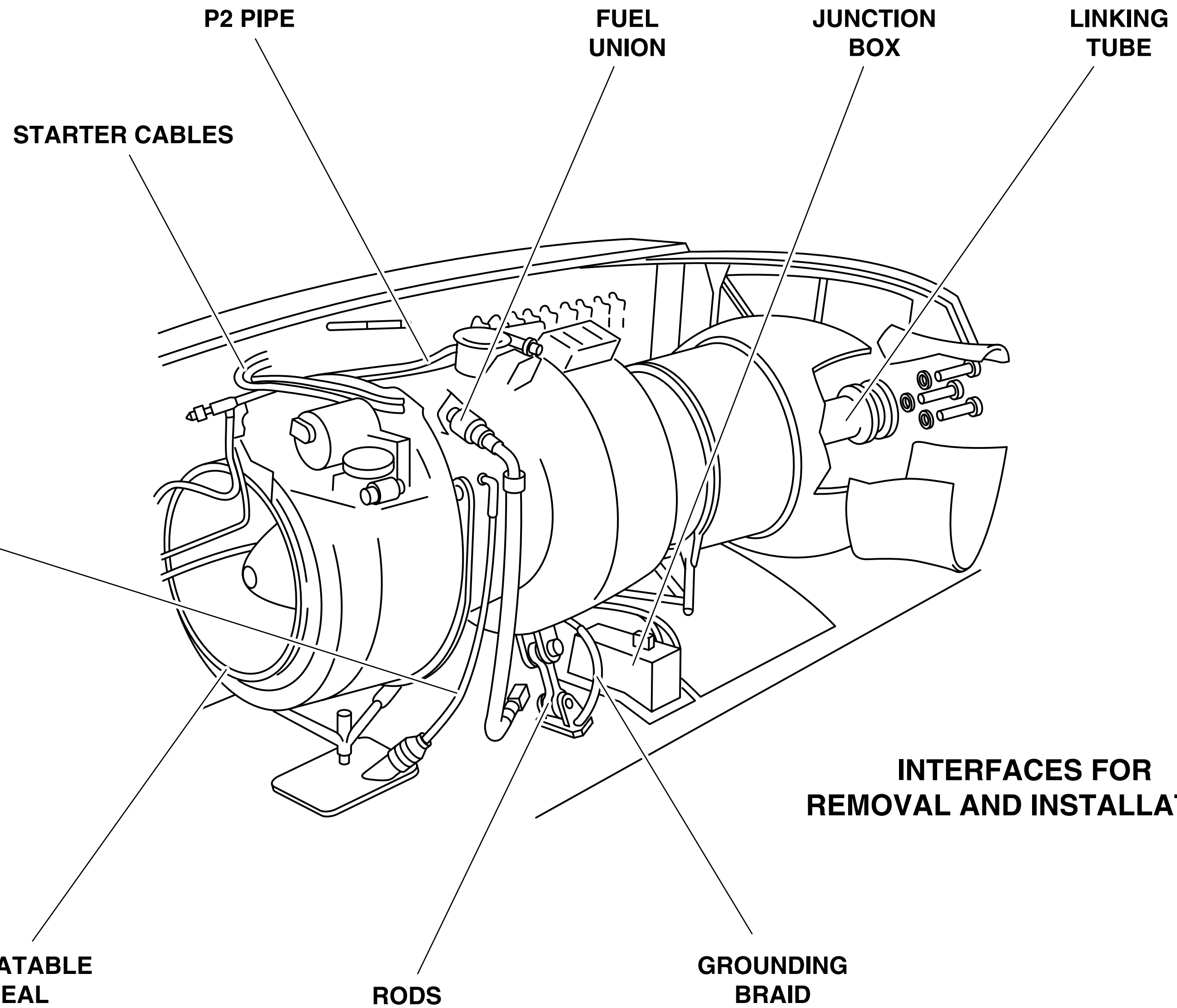
The engine installation in the airframe is the responsibility of the aircraft manufacturer. The removal and installation procedures are therefore described in the aircraft maintenance manual. Nevertheless, this section deals with these procedures generally for training purposes (the interface components, the engine equipment, the engine packaging are defined in the maintenance manual, chapter 71).

During installation, some points must be checked, such as :

- Before installation :
  - Check the engine general condition (casings, harnesses, pipes, accessories…)
  - Check the free rotation of the rotating assemblies
  - Check the condition and attachment of equipment
  - Remove the various blanks

- After installation :
  - Do a general check (attachments, levels, various connections…)
  - Do a ground run (starting, operation, stop, ventilation).

PROCEDURE
- Aircraft manufacturer responsibility - Check : - before installation - after installation



INTERFACES FOR REMOVAL AND INSTALLATION

REMOVAL AND INSTALLATION OF THE POWER PLANT

REMOVAL AND INSTALLATION OF THE ACCESSORIES

This part summarizes the accessories which can be replaced on the flight line (Line Replaceable Units).

List of the accessories

Refer to the following pages.

The table gives :

- The accessory identification
- The method of attachment
- Remarks.

Removal and installation procedure

Refer to maintenance manual. In a training course, procedures are dealt with during the course and practical sessions.

Caution - Warning - Note

Strictly follow the maintenance manual instructions : ignition unit, oil…

Refer to ADVISORY NOTICES in this chapter.

Consumable or repairable components

The accessories are considered as either consumable or repairable.

Some accessories which are considered as consumable : fire detectors, start injector, igniter plug, ignition unit, speed sensors, filters, strainers, magnetic plug…

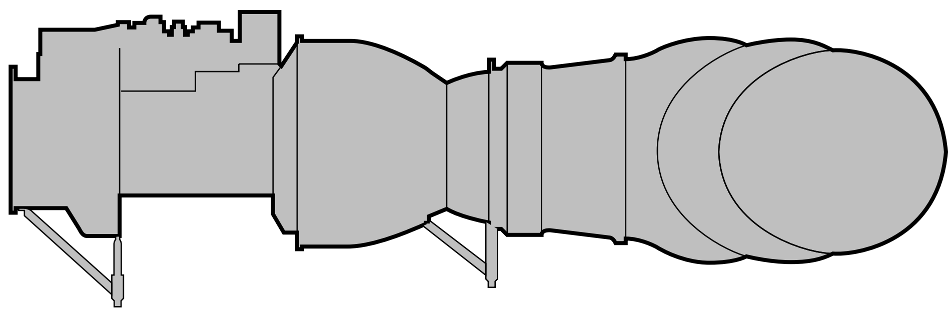
Note *: The accessories either have a TBO or are on condition.*

LIST OF ACCESSORIES

- Identification
- Method of attachment
- Remarks

PROCEDURE

- Maintenance manual



PRECAUTIONS

- Warning
- Caution
- Notes

CONSUMABLE OR REPAIRABLE COMPONENTS

- Consumable components
- Repairable components
- TBO / on-condition

REMOVAL AND INSTALLATION OF THE ACCESSORIES

REMOVAL AND INSTALLATION OF THE ACCESSORIES

List of the engine accessories.

ACCESSORIES	ATTACHMENT	REMARKS
Engine attachment rods	Bolted to engine and airframe	
Front leg	Screwed onto oil tank casing	
Rear legs	Secured by screws on module M05 casing	
Rear lifting ring	2 screws on module M05 casing	
Heat shield sections	Wire-locked together	
Breather pipe collector	2 screws and nuts	
Plugs on hot section borescope check points	Screwed	
Pipes	Nuts and clamps	
Several line unions	Nuts, lock-nuts and screws	
O'ring seals	Housed in casings, or mounting flanges	
Exhaust pipe	Clamp	
Exhaust pipe drain	3 screws	
Self sealing union for compressor washing	2 screws on support	
Compressor washing spraying manifold	Screw and nut	
Spraying jet	2 screws	
Linking tube	Ring of bolts on power turbine module + ring of bolts on MGB	
Combustion chamber drain valve	Screwed into turbine casing	
Drain collector	Banjo union and clamp	

REMOVAL AND INSTALLATION OF THE ACCESSORIES (CONTINUED)

List of oil system accessories.

ACCESSORIES	ATTACHMENT	REMARKS
Oil tank filler cap	3 screws	Different positions according to right or left engine
Oil pump	4 screws on accessory gearbox	
Oil filter unit	Threaded cover	Special tool
Pre-blockage indicator	Screwed into housing	
Strainers	Spring clips	
Magnetic plug	Bayonet type attachment	
Chip detector	Bayonet type attachment + electrical plug	
Heat exchanger	2 clamps	Different types of clamps according to standard
Oil pressure transmitter	Screwed into union	
Low oil pressure switch	3 screws on union	
Oil temperature probe	Screwed into pipe	

List of air system accessories.

ACCESSORIES	ATTACHMENT	REMARKS
Compressor bleed valve	Clamp	
Bleed valve filter	In the valve with screw and spring	
Off-set threshold electro-valve	Banjo union	
P2 air tapping for customer bleed	Clamps	
P1' air tapping union for labyrinth pressurisation	Screwed into counter-casing with lock-nut	
Sand-trap restrictor	Screwed into the casing	Penetration and orientation adjustable

REMOVAL AND INSTALLATION OF THE ACCESSORIES (CONTINUED)

List of fuel system accessories.

ACCESSORIES	ATTACHMENT	REMARKS
Fuel Control Unit	2 half-shells + clamp	
Fuel filter	3 screws on cover	
Pre-blockage indicator	Screwed into FCU	
FCU inlet self sealing union	Screwed into FCU	
Start servo-valve	2 clamps	Different types of clamps according to standard
Injector electro-valve	2 screws on support	
Start injectors	2 screws on casing	
Check valve	Banjo union	
Drain and overspeed valve	Clamp on support and union	
Ball valve assembly	Thread and lock nut	
Injection union	Screw on casing + nut	

List of control system accessories.

ACCESSORIES	ATTACHMENT	REMARKS
Pressure reducing valve	3 screws on FCU	
Power turbine control servo-valve	4 screws on FCU	
DECU		Installed on aircraft
Board in the DECU	Board plugged in the DECU	
OEI flag unit	2 screws on support	Removal of the support first : 1 screw

REMOVAL AND INSTALLATION OF THE ACCESSORIES (CONTINUED)

List of indicating system accessories.

ACCESSORIES	ATTACHMENT	REMARKS
N1 speed sensor	2 screws on accessory gearbox	
N2 speed sensor	2 clamps on linking tube	
Thermocouple probe	Screwed into turbine casing	
Electrical harness	Screw, supports and clamps	
Homogenisation resistor	2 screws in t4 box	
Fire detector	3 screws on support	

List of start system accessories.

ACCESSORIES	ATTACHMENT	REMARKS
Starter	2 half shells and clamp	
Ignition unit	3 nuts on support	
Igniter plug	2 screws on casing + cable connector	Re-install the same washers
Control and monitoring harness	Clamps screwed on support	
Starter free wheel	On accessory drive shaft	Special tool
Lip seal on starter shaft	Fitted in the support cage	Special tool
Clamps	Screw attached	
	Nuts and lock-nut	
Support plates	Screw	

REMOVAL AND INSTALLATION OF ENGINE MODULES

Modular design

The engine is of modular construction. This concept avoids the return of the complete engine to a specialized workshop and thus provides a higher operational availability and a reduction of maintenance costs.

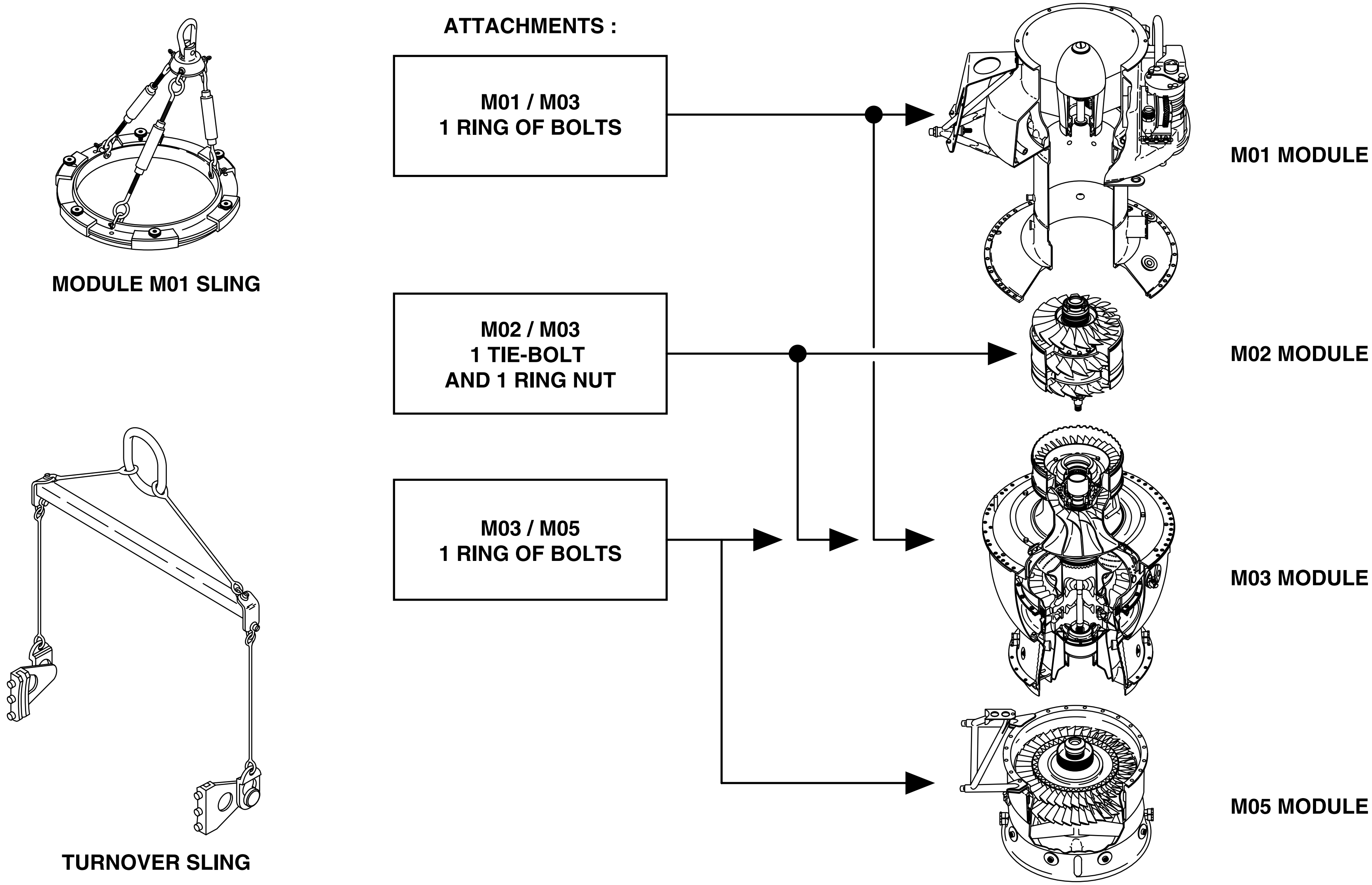
Module replacement

Each module is a unit which can be replaced without balancing or adaptation work.

However, some precautions must be taken when replacing a module. This page mentions the main points :

- Reasons for module removal
  - Inspection (access to some components)
  - Replacement
- Module identification
  - Identification plate on module
  - Compatibility table
  - Engine log book
- Removal and installation conditions
  - Engine installed (or not) in the aircraft
  - Installation on working stand
  - No modules can be removed horizontally
- Tools
  - Standard tools
  - Special tools
- Inspection after replacement
  - Ground run check
  - Condition checks
  - Functional checks
  - Performance checks
- Module follow-up
  - Engine log book (module log cards)
- Interfaces
  - Intermodular parts
  - Equipment
  - Mounting.

Note **:** *Refer to maintenance manual.*



REMOVAL AND INSTALLATION OF ENGINE MODULES

REPAIR AND OVERHAUL

Overhaul

Overhaul is a maintenance operation which is carried out when the engine (or module) has reached the end of its TBO, either operating hours or cycles.

The overhauled engine (or module) is then put back into service with zero hours for a new TBO.

Repair

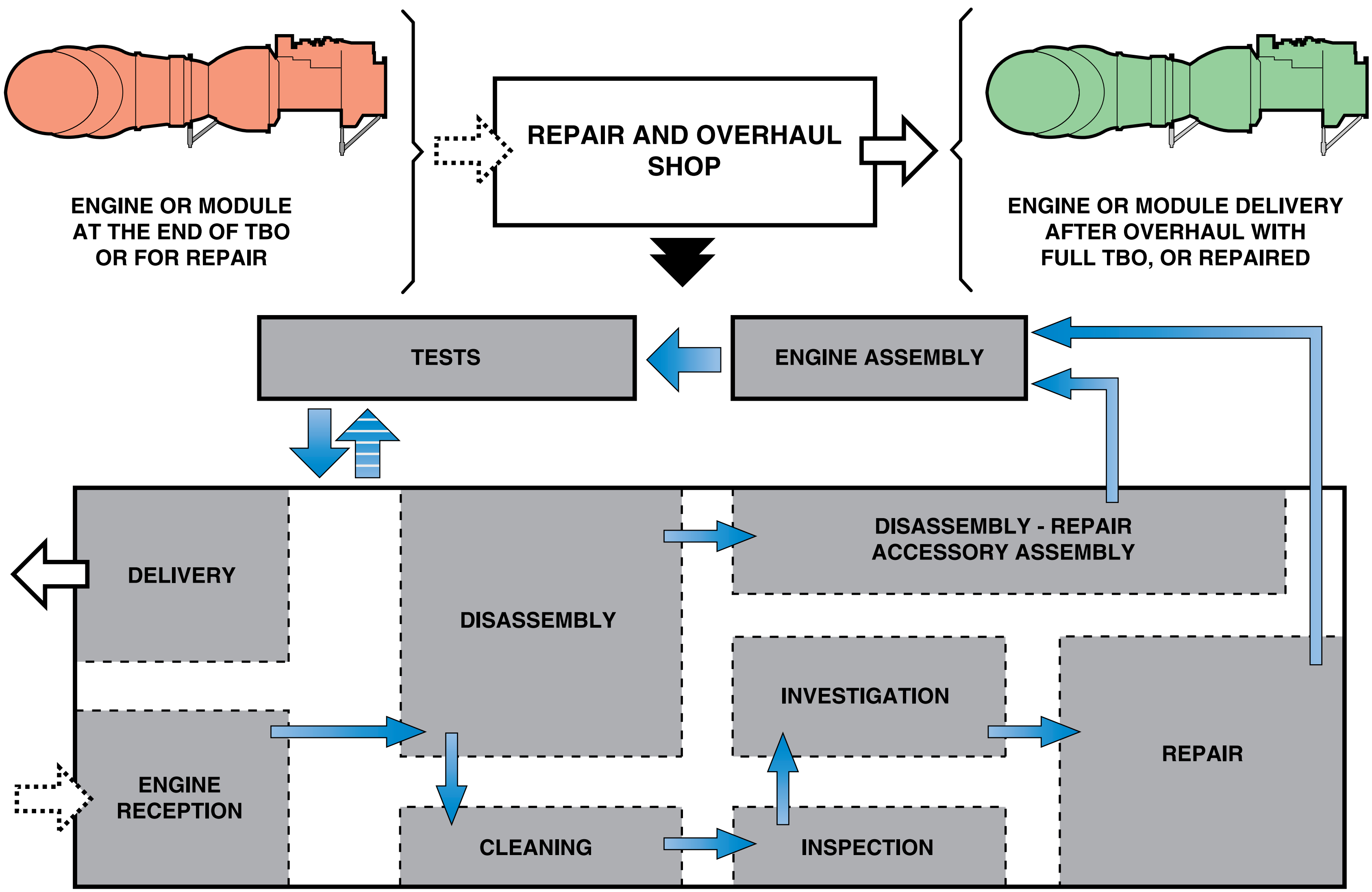
Repair is a maintenance operation which must be carried out when the engine (or module) is unserviceable.

After a repair the engine (or module) is put back into service with its old TBO.

Note *: TBO : Time Between Overhaul*

Main procedure steps

- Engine reception
- Disassembly
- Cleaning
- Inspection
- Investigation
- Repair
- Installation (of engine and accessories)
- Tests
- Delivery.



REPAIR AND OVERHAUL

15 - FAULT ANALYSIS AND TROUBLE SHOOTING

FAULT ANALYSIS

General

Fault analysis is based on a school hypothesis which will bring about a better knowledge of the engine and will prepare the technician for all events.

Fault analysis involves finding the effects of a given failure, even if it is unlikely to happen or results from particular circumstances.

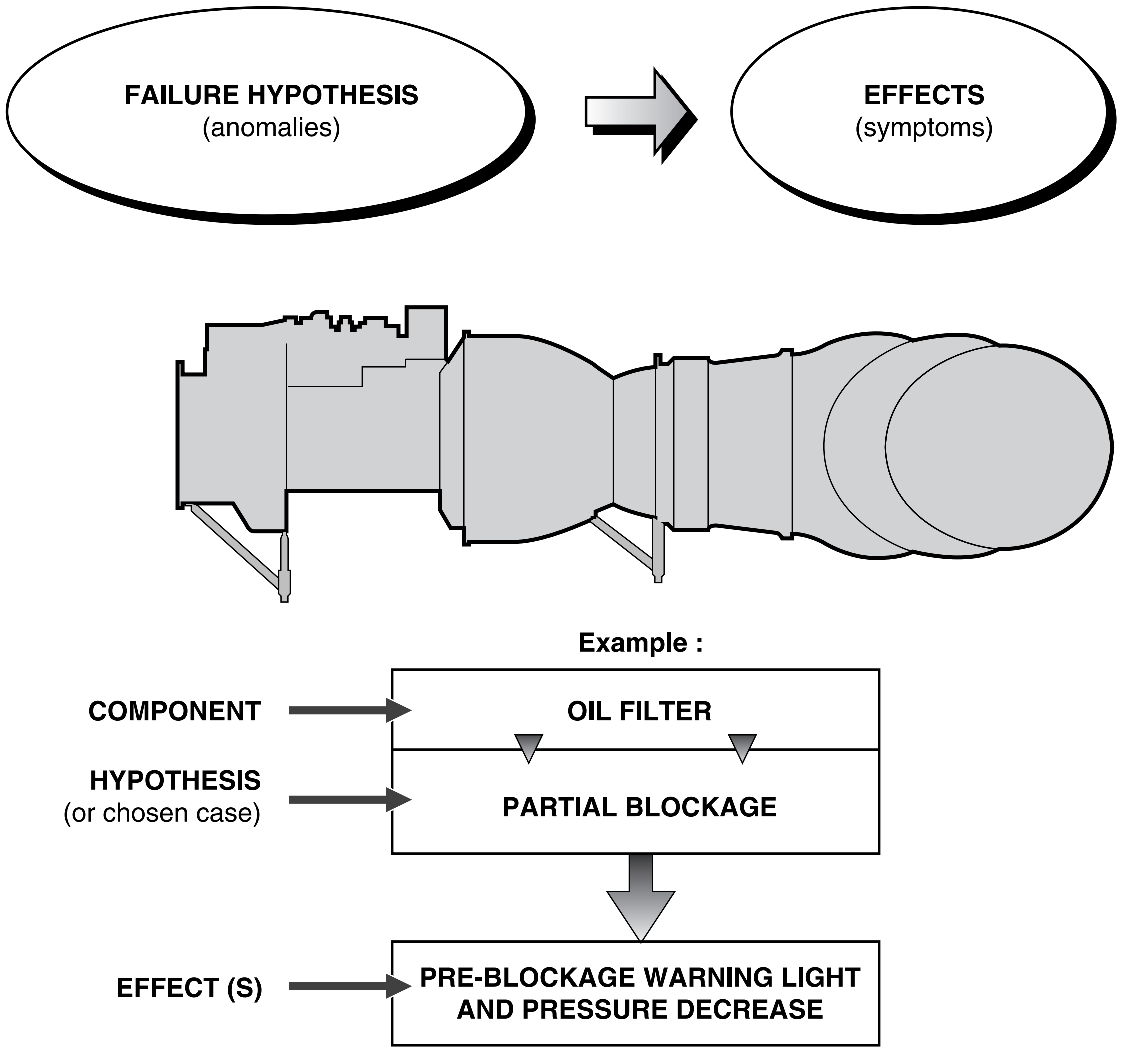
During a training course, each case is commented on and discussed with the trainees.

The analysis can be made at the end of each chapter or in the section devoted to maintenance.

Fault analysis

The faults analysed in this chapter concern :

- The bare engine
- The oil system
- The air system
- The fuel system
- Engine control
- Engine indicating
- Starting
- The electrical system
- The engine installation.



FAULT ANALYSIS

FAULT ANALYSIS - BARE ENGINE (1)

Dirt in the air path

Dirt in the air path causes a reduced air flow and then a lower supplied power with a higher gas temperature and a reduced surge margin.

Compressor in bad condition

Two main causes :

- Erosion : it has the same effect as dirt with reduced strength of the components
- Corrosion : it also causes reduced strength of the components.

Combustion chamber

According to the combustion chamber anormalies (deformation, cracks…) : starting difficulties, overheat, instability of control system or, in the extreme, flame out.

Foreign object ingestion

The damage of course depends upon the object ingested.

The effects can be : power loss, vibration and in the extreme, engine run-down.

Fuel injection system

A partial blockage can cause control instability, starting difficulties, and loss of power (max N1 unobtainable).

Turbines

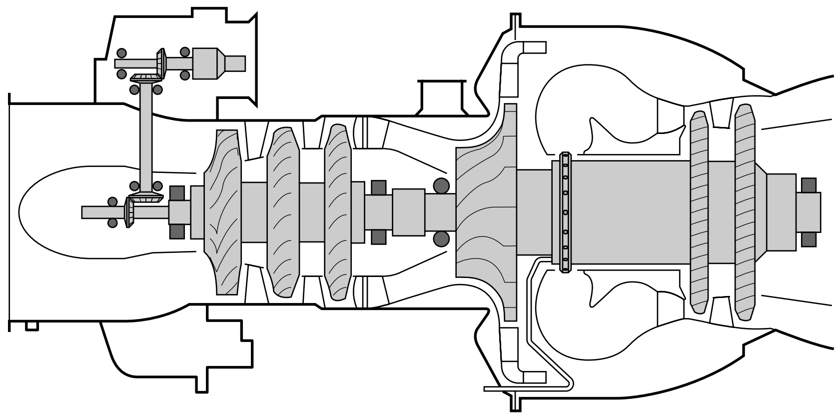
Erosion of the blades causes a loss of power, and corrosion of the blades causes reduced strength of the components.

Blade creep can cause rubbing which causes abnormal noises and a short run-down time.

In the event of blade failure, the broken parts are retained by the containment shield.

AIR PATH
- Dirt

COMPRESSOR
- Erosion
- Corrosion



COMBUSTION CHAMBER
- Deformation
- Cracks

AIR INTAKE
- Foreign object ingestion

FUEL INJECTION SYSTEM
- Partial blockage

TURBINES
- Erosion
- Corrosion
- Blade creep
- Blade failure

FAULT ANALYSIS - BARE ENGINE (1)

FAULT ANALYSIS - BARE ENGINE (2)

Gas exhaust

Any obstruction or damage to the exhaust system affects the engine operation : performance drop, tendency to surge.

Bearings

Abnormal wear causes oil contamination, detected by the magnetic plugs and the analysis of oil samples.

A bearing failure causes vibration, instability of control and performance drop. A failure or major anormaly can also cause engine hang up during start or blockage of the rotating assembly.

Accessory drive

A failure of the main shaft will cause an engine shut-down (fuel pump stop, oil…).

A failure of one accessory drive shaft will cause an effect according to the accessory concerned.

An anormaly of the starter free wheel either :

- Free wheel does not engage : no start, starter runaway
- Free wheel seized : overspeed of the starter.

Abnormal wear of the bearings and gears causes oil contamination which can be detected by magnetic plugs and by oil analysis. A more serious anormaly will cause vibration and possibly an accessory drive failure.

Power transmission

A failure of the power shaft causes overspeed and automatic shut-down.

Imbalance of the shaft will cause vibration.

Sealing

An abnormal internal seal causes either a fluid or gas leak ; consequences according to the system concerned.

An abnormal external seal will cause a visible leak.

GAS EXHAUST

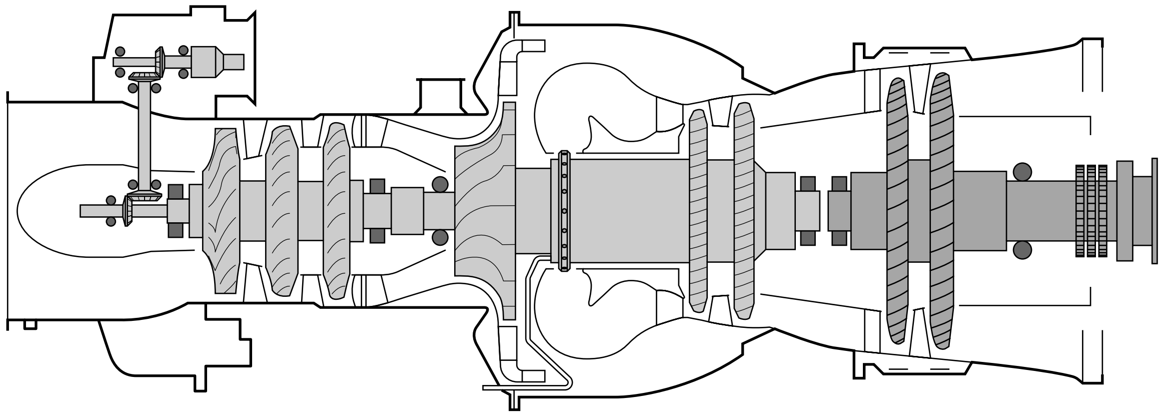
- Deformation
- Obstruction

BEARINGS

- Wear
- Failure

ACCESSORY DRIVE

- Main shaft failure
- Accessory shaft failure
- Free wheel blocked
- Wear of the gears and bearings



SEALING

- Internal anomaly :
  Gas, air, oil, fuel
- External anomaly

POWER TRANSMISSION

- Failure
- Imbalance

FAULT ANALYSIS - BARE ENGINE (2)

FAULT ANALYSIS - OIL SYSTEM (1)

Oil tank

When the oil level is too high, the expansion volume becomes insufficient, and could cause a leak through the air vent.

When the oil level is too low, there is a risk of lubrication anomaly (the loss of pressure is obviously indicated).

An increase of oil level suggests a dilution of the oil by fuel.

Oil filter

A partial blockage is indicated by the pre-blockage indicator.

When a complete blockage occurs, the lubrication is ensured through the by-pass valve, with a risk of system contamination.

Oil pumps

A drive shaft failure causes a rapid pressure drop and lubrication failure.

The seizing of a pump causes shaft overtorque with the risk of failure.

If the pump pressure relief valve is jammed :

- Open : loss of pressure
- Closed : dormant fault.

Heat exchanger

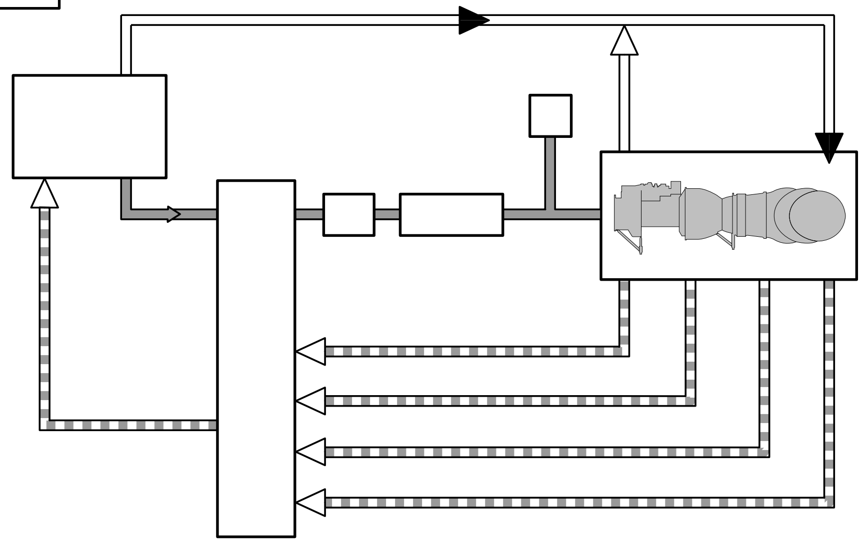
If the cooling coil is obstructed, the flow is ensured through the by-pass valve and induces increase of oil temperature.

An internal sealing anormaly causes a dilution of the oil by fuel.

Note : *In case of a pressure drop being confirmed by the indicating system, the engine should be shut-down to prevent more serious damage. An increase of pressure also indicates a fault in the system (obstruction of jets for example).*

OIL TANK
- Oil level too high
- Oil level too low
- Dilution

OIL FILTER
- Partial blockage
- Complete blockage



HEAT EXCHANGER
- Cooling coil obstructed
- Internal sealing

OIL PUMPS
- Drive shaft failure
- Pump seizing
- Pressure relief valve : open, closed

FAULT ANALYSIS - OIL SYSTEM (1)

FAULT ANALYSIS - OIL SYSTEM (2)

Internal supply

A local anormaly of lubrication results in a rather quick process of deterioration.

It can be detected by an abnormal pressure and/or temperature, by particles on magnetic plugs or by the oil sampling analysis.

Breathing

The obstruction of a breathing line (or anormaly of the centrifugal breather) may cause overpressure, lubrication anormaly, or leak through the sealing system…

The obstruction of the general air vent causes foaming in the tank.

Sealing

An "external" anormaly is indicated by a visible leak and increased oil consumption.

An "internal" anormaly causes an oil leak into the air system, increased consumption, pressure fluctuations, smoke…

Note *: Particular attention must be paid to the turbine pressurisation pipes.*

Oil contamination

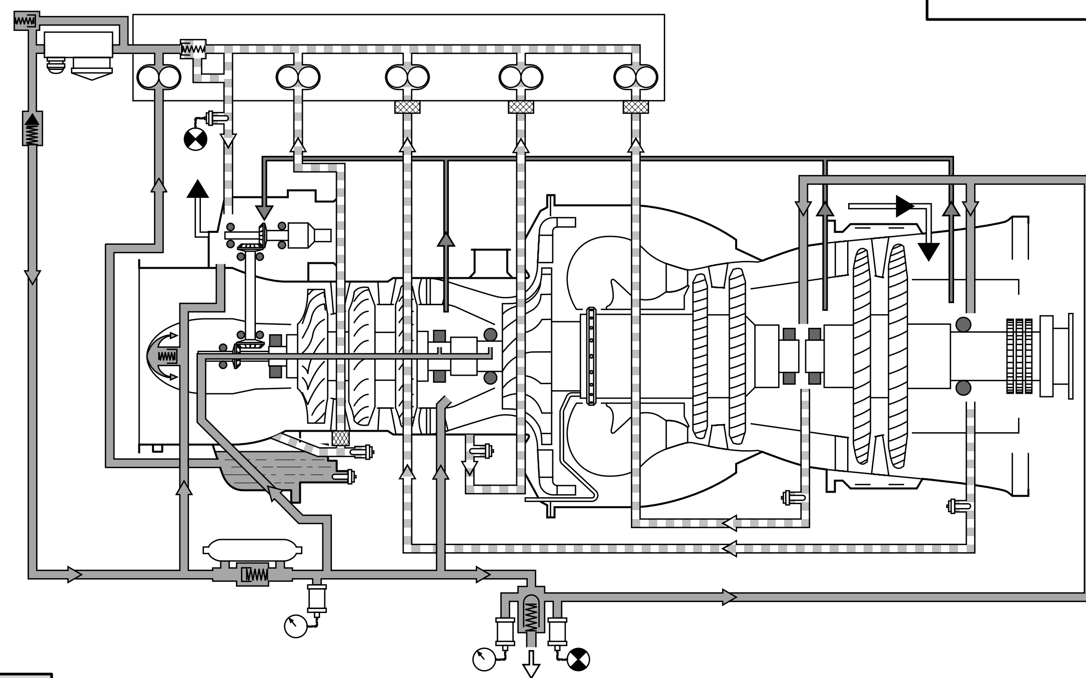
It is already the consequence of a fault. Example : fuel dilution of the oil, oil contamination, particles on magnetic plugs or in the filter, oil sampling analysis results.

INTERNAL SUPPLY

- Local anomaly (obstruction of jet)

BREATHING

- Breathing line obstruction
- Centrifugal breather
- Air vent line obstruction



OIL CONTAMINATION

- Dilution
- Contamination
- Particles on magnetic plugs
- Oil sampling analysis results

SEALING

- "External" sealing
- "Internal" sealing

FAULT ANALYSIS - OIL SYSTEM (2)

FAULT ANALYSIS - AIR SYSTEM

Internal pressurisation system

Any anormaly (obstruction, abnormal clearance) will result in operating problems :

- Internal oil leak (as labyrinth pressurisation is affected)
- Local overheat (as the system is used to cool the internal parts)
- Loss of power if too much air is tapped.

Turbine bearing pressurisation

A failure or obstruction of the P1' air pipe causes loss of the pressurisation of the labyrinth seals ; the oil leaks into a very hot zone and this causes smoke emission and high oil consumption.

Aircraft air tapping

If there is an air supply anomaly : refer to aircraft system concerned.

If too much air is tapped, it affects the engine performance (W, t4, CH…).

FCU air supply

An abnormal P2 air supply to the FCU due to a leak, pipe failure or obstruction causes an incorrect signal which affects the acceleration and deceleration control.

If there is no signal (e.g. : pipe failure) the N1 speed decreases considerably.

Start injector supply

If the P2 air tapping becomes blocked, there is no more ventilation which will lead to injector blockage.

Ball valve of the injector electro-valve

The valve jammed "open" causes a fuel leak in the P2 pipe and problems during starting (high t4).

The valve jammed "closed" (very remote probability) prevents the ventilation of injectors.

Bleed valve

If the valve remains open, it causes a permanent air discharge and a decrease of available power.

If the valve remains closed, it can lead to engine surge at low N1 speeds.

A failure of the off-set threshold electro-valve could cause surge in the hover with a strong tail wind.

Note : *The operation of this valve is indicated by an indicating light.*

INTERNAL PRESSURISATION SYSTEM

- Abradable lining wear
- Labyrinth damage

AIRCRAFT AIR TAPPING

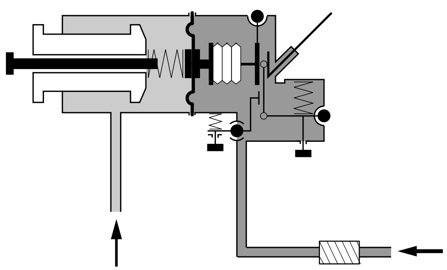
- Aair supply (leak)
- Excessive tapping

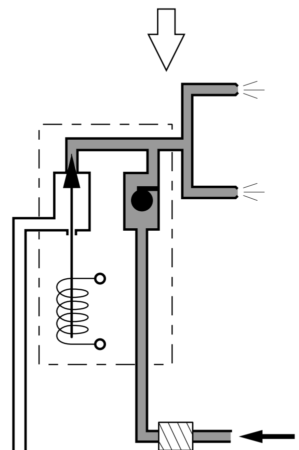
TURBINE BEARING PRESSURISATION

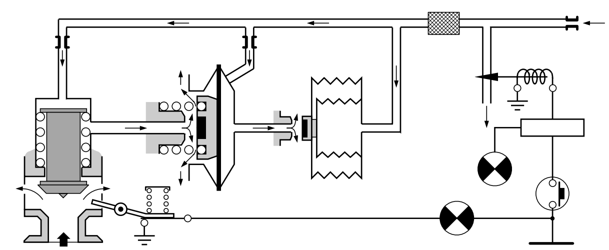
- Failure or external leak

START INJECTOR SUPPLY

- Blockage of the P2 tapping
- Air leak







FCU AIR SUPPLY

- Pipe failure
- Leak from the pipe

BALL VALVE OF THE INJECTOR ELECTRO-VALVE

- Valve jammed open
- Valve jammed closed

BLEED VALVE

- Valve remains open
- Valve remains closed
- Off-set threshold electro-valve

FAULT ANALYSIS - AIR SYSTEM

FAULT ANALYSIS - FUEL SYSTEM (1)

Aircraft fuel system

A booster pump anomaly may cause starting to be difficult or impossible.

Blockage of the fuel filter causes the fuel to flow to the engine through the by-pass valve. This could cause contamination of the system, N1 fluctuation and power loss.

Check valve jammed :

- Closed : no start
- Open : risk of system draining, next start difficult or impossible.

The shut-off valve being partially open could cause an N1 limitation.

Note *: Refer to aircraft system for all these components.*

Engine pump

In case of drive shaft failure, the fuel supply stops : engine shut-down, or impossible to start.

Pressure relief valve jammed :

- Closed : dormant fault
- Open : no start.

FCU filter

In case of partial blockage : indication by the pre-blockage indicator.

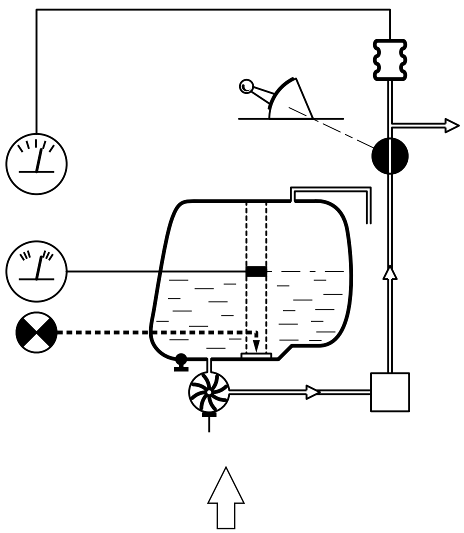
In case of blockage : by-pass flow with possible fluctuations.

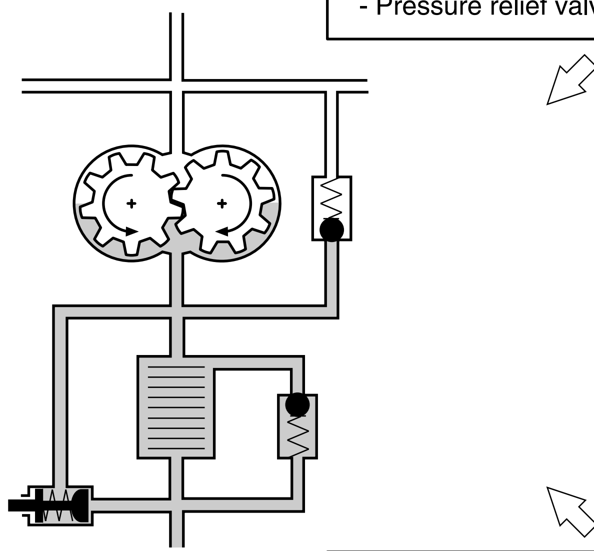
By-pass valve jammed :

- Closed : dormant failure
- Open : by-pass flow with system contamination.

ENGINE PUMP

- Drive shaft failure
- Pressure relief valve jammed closed
- Pressure relief valve jammed open





AIRCRAFT FUEL SYSTEM

- Booster pump
- Filter
- Check valve
- Shut-off valve

FCU FILTER

- Partial blockage
- Blockage
- By-pass valve jammed closed
- By-pass valve jammed open

FAULT ANALYSIS - FUEL SYSTEM (1)

FAULT ANALYSIS - FUEL SYSTEM (2)

Start injectors

Partial blockage will cause starting problems.

An incorrect position in relation to the igniter plugs also causes starting problems.

A ventilation anomaly causes a blockage after a certain operating time.

Note *: Start is possible with only one injector.*

Start electro-valve

In case of solenoid anomaly, the valve remains closed ; no supply to the injectors, no engine starting. For the ball valve refer to "air system" section.

Drain and overspeed valve

Pressurising valve jammed closed : no supply to the injection wheel and therefore no engine starting. However, fuel is supplied to the injectors, and this causes a slight gas temperature increase.

Pressurising valve jammed open : premature supply to the injection wheel which causes difficult ignition.

Double valve jammed in drain position : start impossible.

Overspeed electro-valve anomaly : no shut-down in case of overspeed, it's a dormant failure.

Fuel injection wheel

Abnormal sealing of the labyrinth seals causes an internal fuel leak with possible contamination of P2 air and coking of internal parts.

In case of fuel manifold blockage : fuel flow limitation, and OEI N1 can not be reached.

Note *: Refer to the inspection and correction procedures in the maintenance manual.*

START INJECTORS

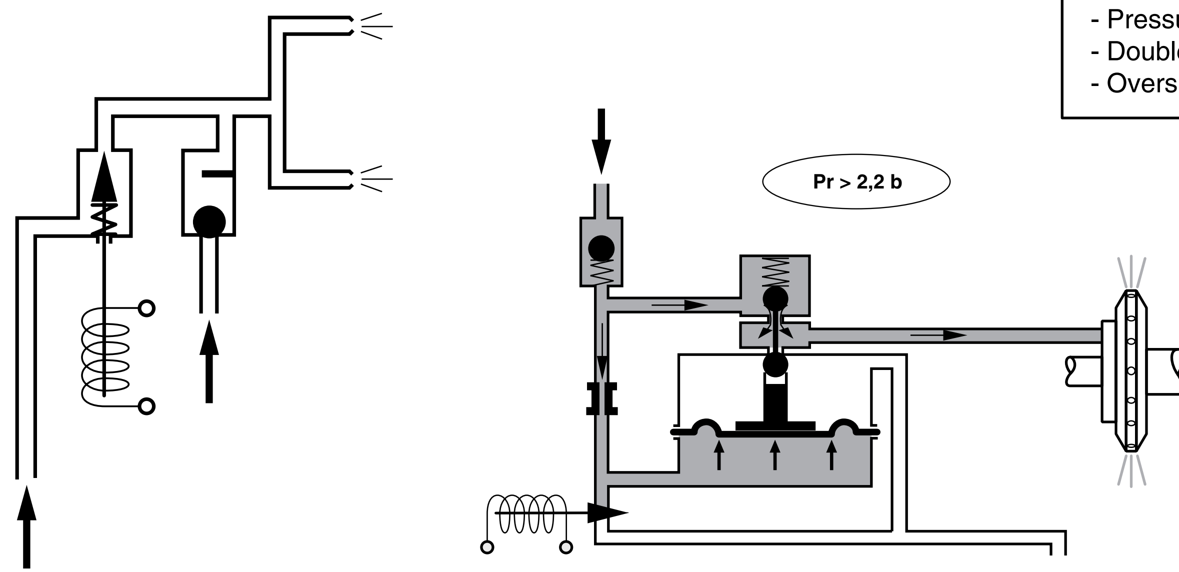
- Blockage
- Incorrect position
- Ventilation

START ELECTRO-VALVE

- Solenoid
- P2 ball valve

DRAIN AND OVERSPEED VALVE

- Pressurising valve jammed "closed"
- Pressurising valve jammed "open"
- Double valve in drain position
- Overspeed electro-valve



FUEL INJECTION WHEEL

- Sealing
- Injection wheel blockage

FAULT ANALYSIS - FUEL SYSTEM (2)

FAULT ANALYSIS - CONTROL SYSTEM (1)

Gas generator governor

A drive shaft failure causes the engine acceleration to the maximum fuel flow and an overspeed is possible (this case is extremely remote, because the shear section of the drive is on the fuel pump shaft).

In case of a temperature compensating device anomaly, the control system will compensate to within 1 % N1, the GOV light will illuminate and an failure code will be displayed on the maintenance display showing a drift of static droop.

A hydraulic system failure will cause engine instability or N1 and power drift, which causes engine desynchronisation.

Fuel metering device

Any anormaly (e.g. : jamming of the metering valve or the constant ΔP valve) causes incorrect fuel metering, which causes rating instability and loss of power.

Start servo-valve

Any operating anormaly (or blockage) of the servo-valve causes starting difficulties : start impossible or slow, rapid start with overheat.

Power turbine governor

Three electronic system failures are possible :

- Redundancy failure
- Minor fault
- Major fault or total failure.

These three cases are treated in the "ELECTRICAL SYSTEM" chapter.

A hydraulic system failure causes incorrect modulated pressure which causes, incorrect RPM with possible fluctuations.

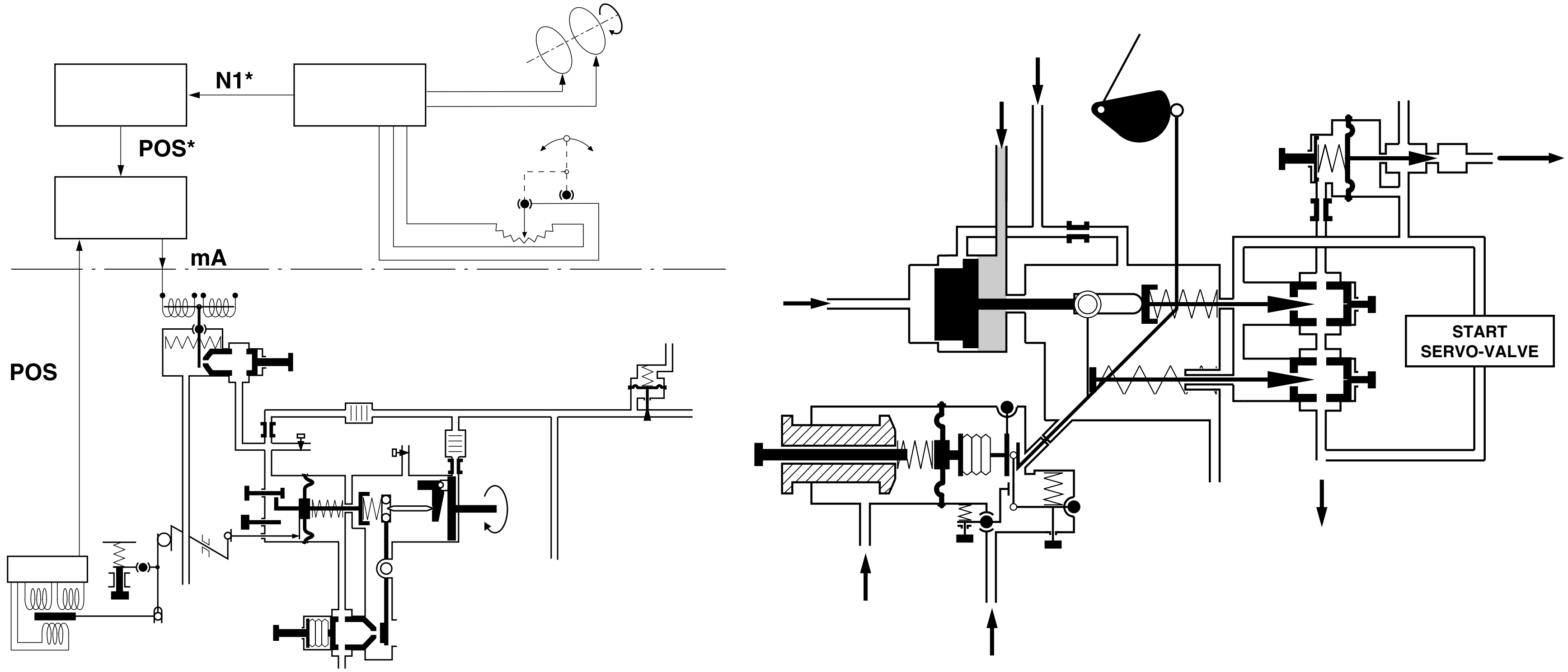
Acceleration controller

In case of P2 air supply failure, the engine decelerates to the minimum flow. The other engine accelerates to compensate.

Any P2 air supply anormaly will affect the acceleration time, and therefore, the response time.

GAS GENERATOR GOVERNOR
- Drive shaft failure - Compensating capsule - Hydraulic system

ACCELERATION CONTROLLER
- P2 air supply failure - P2 air supply anomaly



POWER TURBINE GOVERNOR
- Electronic system - Hydraulic system

FUEL METERING DEVICE
- Metering valve - Constant ΔP valve

START ELECTRO-VALVE
- Operating anomaly - Obstruction

FAULT ANALYSIS - CONTROL SYSTEM (1)

FAULT ANALYSIS - CONTROL SYSTEM (2)

Engine control lever

In case of failure or disconnection of the control linkage, the FCU lever does not move. Manual control is not possible for starting, shut-down or emergency.

A seizure of the mechanism or of the valves requires a greater effort to operate the control lever.

In case of incorrect adjustment of the lever, the position of the control lever does not correspond to the position on the FCU (resulting effect depends on the direction of the incorrect adjustment : for example, engine starting difficulties, max flow limitation…).

Anticipator control

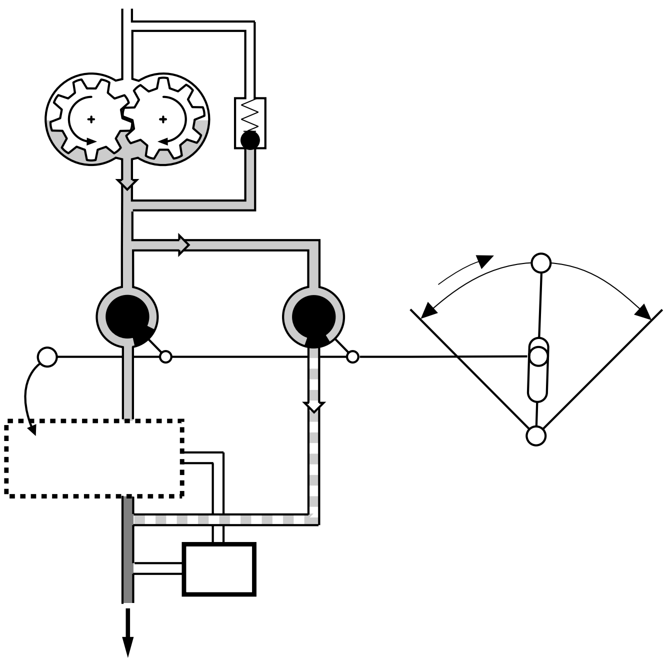
A failure of the collective pitch - FCU connection causes the operation of the control system on one static droop line. There is therefore no static droop compensation and the response time is longer.

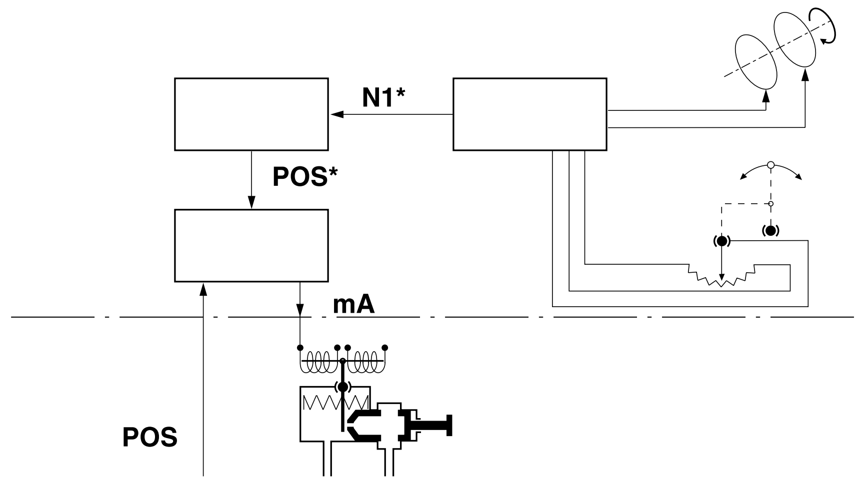
If the signal from a potentiometer is lost, this will result in a N1 desynchronisation which is indicated by the "N1 DIFF" indicating light.

If the control is incorrectly adjusted, the position of the control does not correspond to the position of the collective pitch. The rotor speed is affected. In twin-engine configuration, the N1 values of the two engines will be different if the datums are different. There is in this case an indication by the N1 DIFF/Power Loss indicating light.

ENGINE CONTROL LEVER

- Failure (or disconnecting) of the linkage
- Mechanism seizure
- Incorrect adjustment of the control lever





ANTICIPATOR CONTROL

- Failure of the collective pitch-FCU link
- Loss of a potentiometer signal
- Incorrect adjustment of the control

FAULT ANALYSIS - CONTROL SYSTEM (2)

FAULT ANALYSIS - ENGINE INDICATING

Rotation speed indication

Most of the failures lead to a complete loss of indication.

The other parameters must be checked to confirm the indicating system failure (refer to flight manual for the appropriate procedures).

- N1 speed : a sensor failure causes the loss of the indication and the illumination of the N1 DIFF warning light
- N2 speed : the loss of the F1 and F2 signals causes complete failure of the engine control system ; loss of the F2' or F3' signals causes a failure of the overspeed circuit, and loss of the F1' signal causes a loss of N2 indication.

Note *: One sensor failure has no effect (redundancy).*

Gas temperature indication

A thermocouple probe failure can alter the indication ; the average value of the 3 remaining thermocouples is read.

A broken wire in the pyrometric harness causes a total loss of the indication and/or a loss of start t4 control.

A loose thermocouple probe, or a thermocouple probe with incorrect insulation causes fluctuations or incorrect indication.

A conformation resistance failure causes an abnormal temperature reading.

Oil pressure indication

In case of low pressure switch failure, there are two possibilities :

- The indicating light does not switch on
- The indicating light stays on permanently.

Note *: Check the oil pressure indication to confirm the low pressure switch failure.*

In case of pressure transmitter failure, there are two possibilities :

- No indication
- Abnormal indication.

Note *: Check the low oil pressure indication to confirm the transmitter failure.*

Oil temperature indication

A probe failure, or a short-circuit causes full scale deflection of the indicator.

The oil pressure should be monitored in flight.

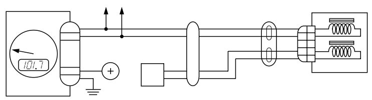
During maintenance it is necessary to establish whether the fault is in the probe or the transmitter.

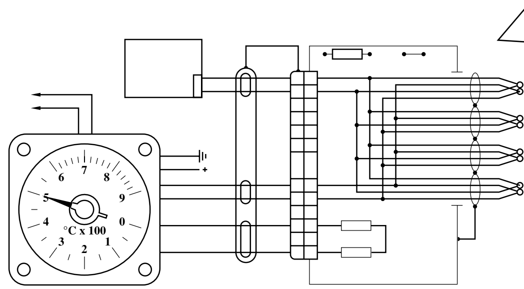
Miscellaneous indications

- "Power Loss" indication : refer to "ELECTRICAL SYSTEM" chapter
- Compressor bleed valve indication : in case of microswitch failure, the light remains permanently "on" (or "off")
- Miscellaneous indications : analysis according to versions and aircraft installations (refer to aircraft systems).

N1 SPEED

- Indication sensor
- Control sensor



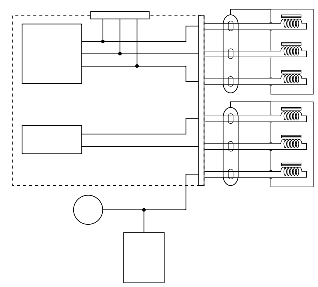


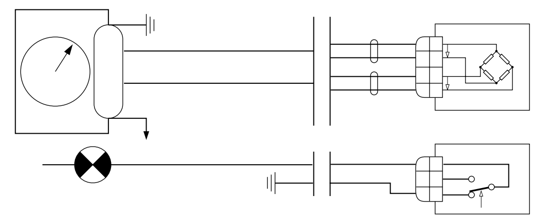
GAS TEMPERATURE INDICATION

- Thermocouple failure
- Loose thermocouple (or incorrect insulation)
- Incorrect conformation resistance

N2 SPEED

F1 - F2 : sensors (1 or 2)
F2' - F3' : sensors (1 or 2)
F1' : sensor



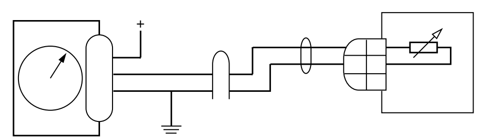


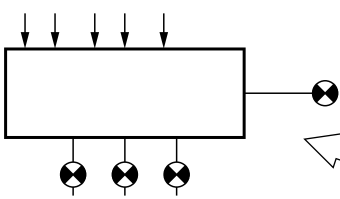
OIL PRESSURE INDICATION

- Low pressure switch
- Pressure transmitter

OIL TEMPERATURE INDICATION

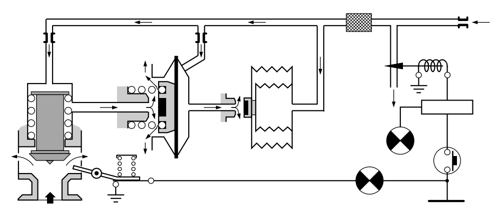
- Failure (or short-circuit of the probe)





MISCELLANEOUS INDICATIONS

- Engine "Power Loss" indication
- Compressor bleed valve indication
- Miscellaneous indications



FAULT ANALYSIS - ENGINE INDICATING

FAULT ANALYSIS - STARTING

Electrical power supply

A low DC supply voltage will cause difficult engine starting and excessive gas temperature.

Note *: The voltage should not decrease below 15 Volts during starting.*

Starter

In case of a starter failure :

- Insufficient torque during starting, slow acceleration with high gas temperature
- No starting

Two types of free wheel failure:

- Free wheel : the engine is not cranked
- Jammed : starter overspeed with possible shear shaft failure.

Ignition unit

A High Energy ignition unit failure causes no ignition at all or insufficient energy to obtain the correct pulse rate.

Note *: Starting is nevertheless possible with one unit inoperative.*

Igniter plug

In case of an igniter plug anomaly, no sparks are produced, or the sparks do not have enough energy to ignite the fuel.

Note *: Starting is possible with one plug inoperative.*

Starting control system

With a total power supply failure there is no voltage on the controlled accessories (DECU…) so no cranking and no ignition.

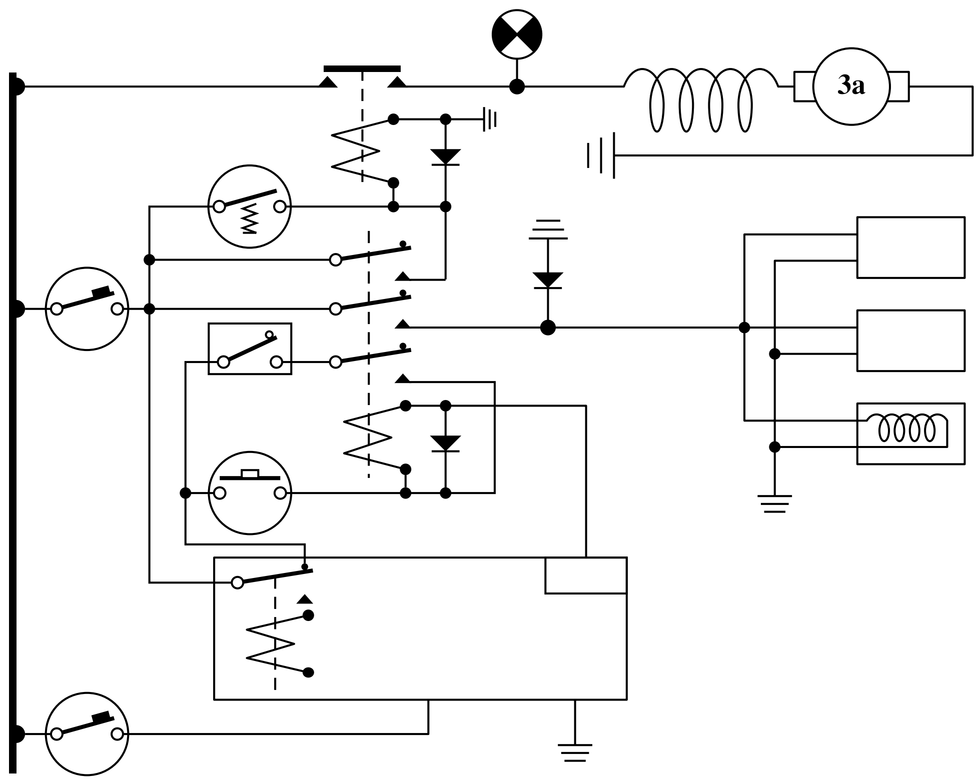
With a starter power supply anomaly, there is no cranking ; but the ignition operates (only the audible operation of the ignition system can be heard).

With an ignition power supply anomaly, there is no ignition ; but the starter operates.

ELECTRICAL POWER SUPPLY
- Insufficient DC supply voltage

STARTER
- Starter motor - Free wheel

STARTING CONTROL SYSTEM
- Total failure of the power supply - Starter power supply - Ignition power supply



IGNITION UNIT
- HE ignition unit

IGNITER PLUG
- Igniter

FAULT ANALYSIS - STARTING

FAULT ANALYSIS - ELECTRICAL SYSTEM (1)

Electrical power supply

With a DC supply failure during starting, there is no starting, or difficult starting : slow starting, high gas temperature.

In normal operation :

- Total failure : the engine continues to operate, with fuel control at N1 ≈ 85 %
- BUS bar failure : supply by another BUS bar.

An internal supply failure of the DECU implies the loss of one or many functions (effects according to the case).

Anticipator transmitter

Depending on the anormaly :

- Static droop out of tolerance or
- Rotor speed N out of tolerance or
- "Power Loss" indication.

PPNG position transmitter

Depending on the anormaly :

- Instability and ΔN1
- Stabilisation at N1 ≈ 85 % with indication by the Power Loss indicating light.

Pressure and temperature sensors

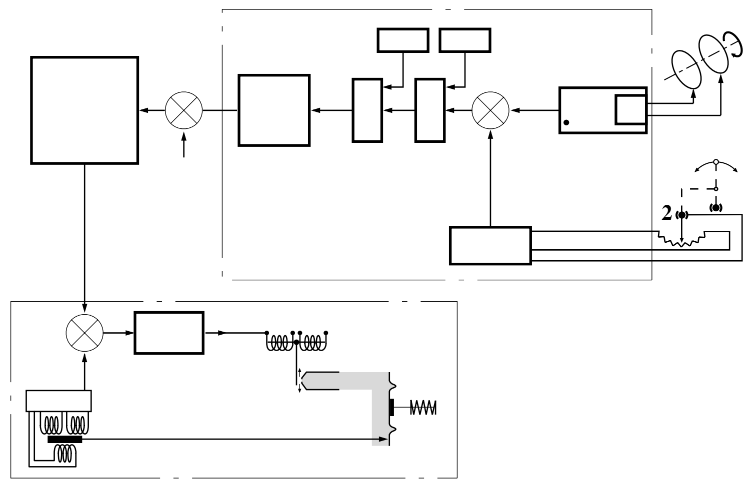
In case of air data system anomaly, other sensors or recovery laws are used (redundancy).

ELECTRICAL POWER SUPPLY

- DC supply during starting
- Supply in "normal operation"
- BUS bar failure
- Internal supply of the DECU

PRESSURE AND TEMPERATURE SENSORS

- Air data system
- Failure of engine sensors



ANTICIPATOR TRANSMITTER

- Electrical supply failure
- Incorrect adjustment

POSITION TRANSMITTER - PPNG

- Electrical supply failure
- Incorrect adjustment

FAULT ANALYSIS - ELECTRICAL SYSTEM (1)

FAULT ANALYSIS - ELECTRICAL SYSTEM (2)

Speed sensors

- Loss of F1 and F2 signals : engine rating set at 85 % of N1
- Loss of F1' signal : loss of indication
- Loss of F2' signal and/or F3' signal : no overspeed control system
- Loss of N1 signal (1st channel) : no engine starting, no bleed valve control
- Loss of N1 signal (2nd channel) : no N indication, but the "DIFF Ng" is operated by the "Power Loss".

Digital Engine Control Unit

Any anomaly, internal or external, is indicated by the indicating system.

Trouble shooting on the harness wiring is carried out using a test set.

Overspeed electro-valve

With an electro-magnet anomaly, there is no engine shut-down in case of overspeed. This is a dormant failure which can be detected during a periodic test.

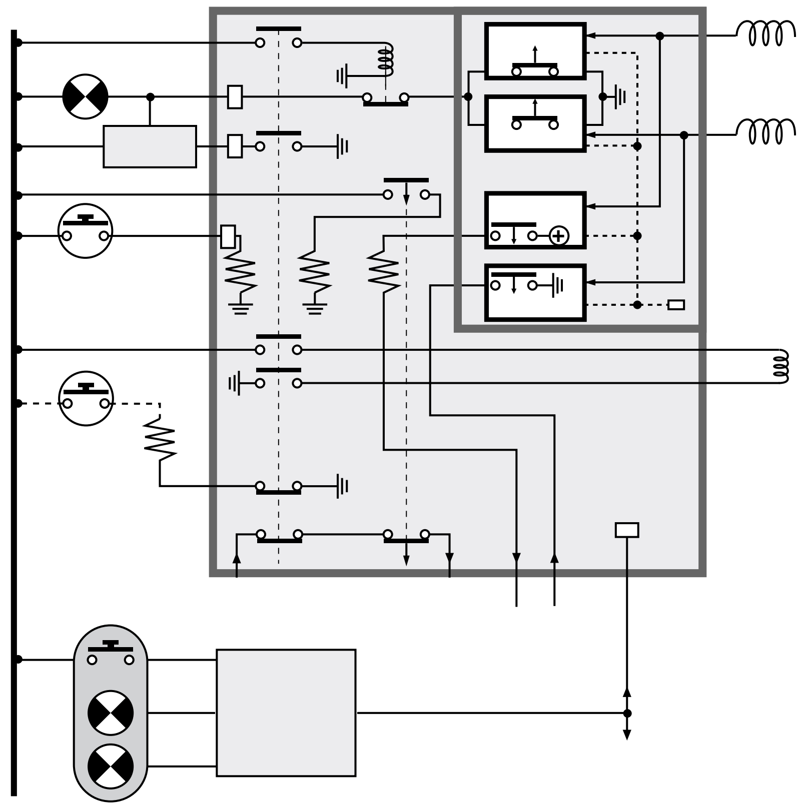
With the valve jammed "open" : there is no starting (remote probability).

Overspeed sensors

In case of a F2' or F3' sensor anomaly, the failure is indicated by the "overspeed" indicating light, which remains on above 25 % of N2 and by the test logic.

DECU

- Internal anomaly
- Harness



SPEED SENSORS

F1 - F2
F1'
F2' - F3'
N1 (1st channel)
N1 (2nd channel)

OVERSPEED ELECTRO-VALVE

- Electro-magnet
- Valve jammed open

FAULT ANALYSIS - ELECTRICAL SYSTEM (2)

FAULT ANALYSIS - ENGINE INSTALLATION

Engine compartment

Ventilation anomaly can cause an increase of temperature which can be, in extreme cases, detected by the fire detection system.

Engine attachment

Incorrect adjustment, abnormal clearance or misalignment cause vibration or abnormal stresses with all the usual consequences.

Air intake and gas exhaust

A partial obstruction affects the engine performance.

Particular instructions are given in the maintenance manual, for engine operation in a "hostile atmosphere" :

- Sand : erosion increase
- Salt : causes corrosion
- Pollution : both erosion and corrosion.

Power transmission

A failure of the power shaft causes a power turbine overspeed and automatic engine shut-down by the overspeed protection system.

Misalignment of the shaft causes vibration and possible failure.

Fire protection

In case of a detector anomaly : specious fire warning.

If there is an open circuit : fault warning.

Drains and air vents

In case of obstruction of a drain, effect according to the concerned drain system.

Particular attention to obstruction hazard caused by deformation done during engine removal and installation or caused by insects in some countries.

Connections

All the air, fuel, and electrical connections are treated in the corresponding sections.

Air tapping

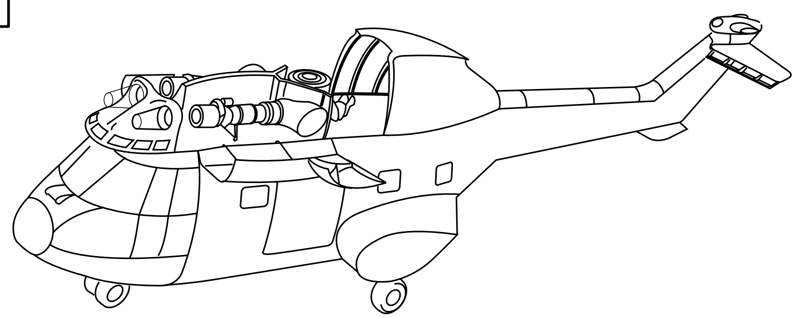
Any air tapping affects the engine performance. An excessive air tapping reduces the power available ; or increases the gas temperature for a given power rating.

ENGINE COMPARTMENT

- Ventilation

ENGINE ATTACHMENT

- Adjustment
- Abnormal clearance
- Misalignment



POWER TRANSMISSION

- Shaft failure
- Misalignment

AIR INTAKE AND GAS EXHAUST

- Partial obstruction
- Dirty atmosphere

FIRE PROTECTION

- Detector
- Wiring

AIR TAPPING

- Excessive air tapping

DRAINS AND AIR VENTS

- Obstruction

CONNECTIONS

- Sealing anomaly of the fluid connections
- Continuity anomaly of the electrical connectors

FAULT ANALYSIS - ENGINE INSTALLATION

TROUBLE SHOOTING

General

Trouble shooting is a very important aspect of maintenance.

Efficient diagnosis reduces the extra maintenance costs due to unjustified removals and additional diagnosis time.

In fact, even with a very high reliability product, failure is inevitable and required actions should be taken efficiently.

After the fault analysis which consists of finding the effect of a given failure, this section considers the case in reverse ; i.e. : finding the probable cause of a fault.

Repair procedure

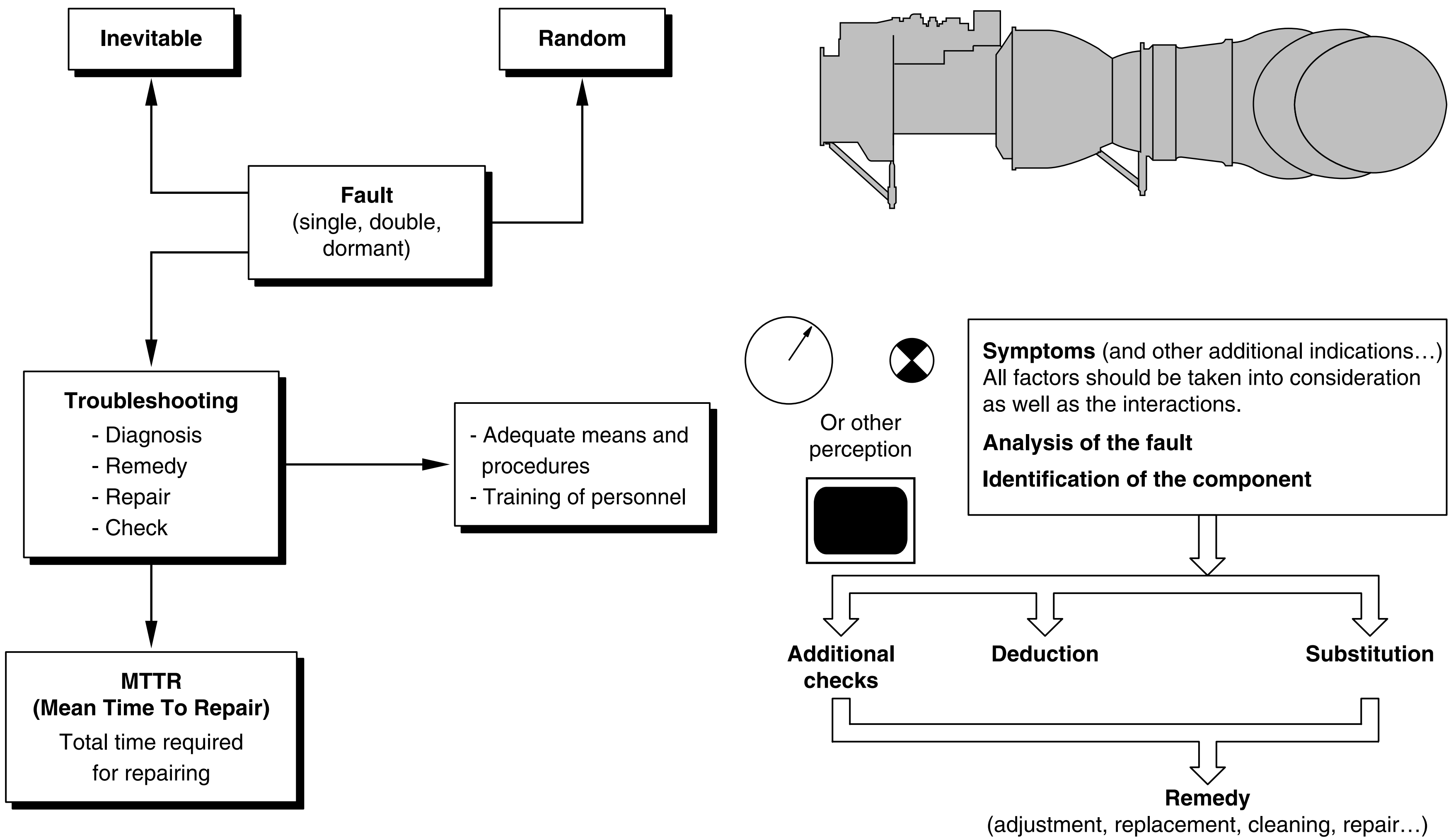
The repair procedure should be guided by two main considerations :

- Minimum downtime

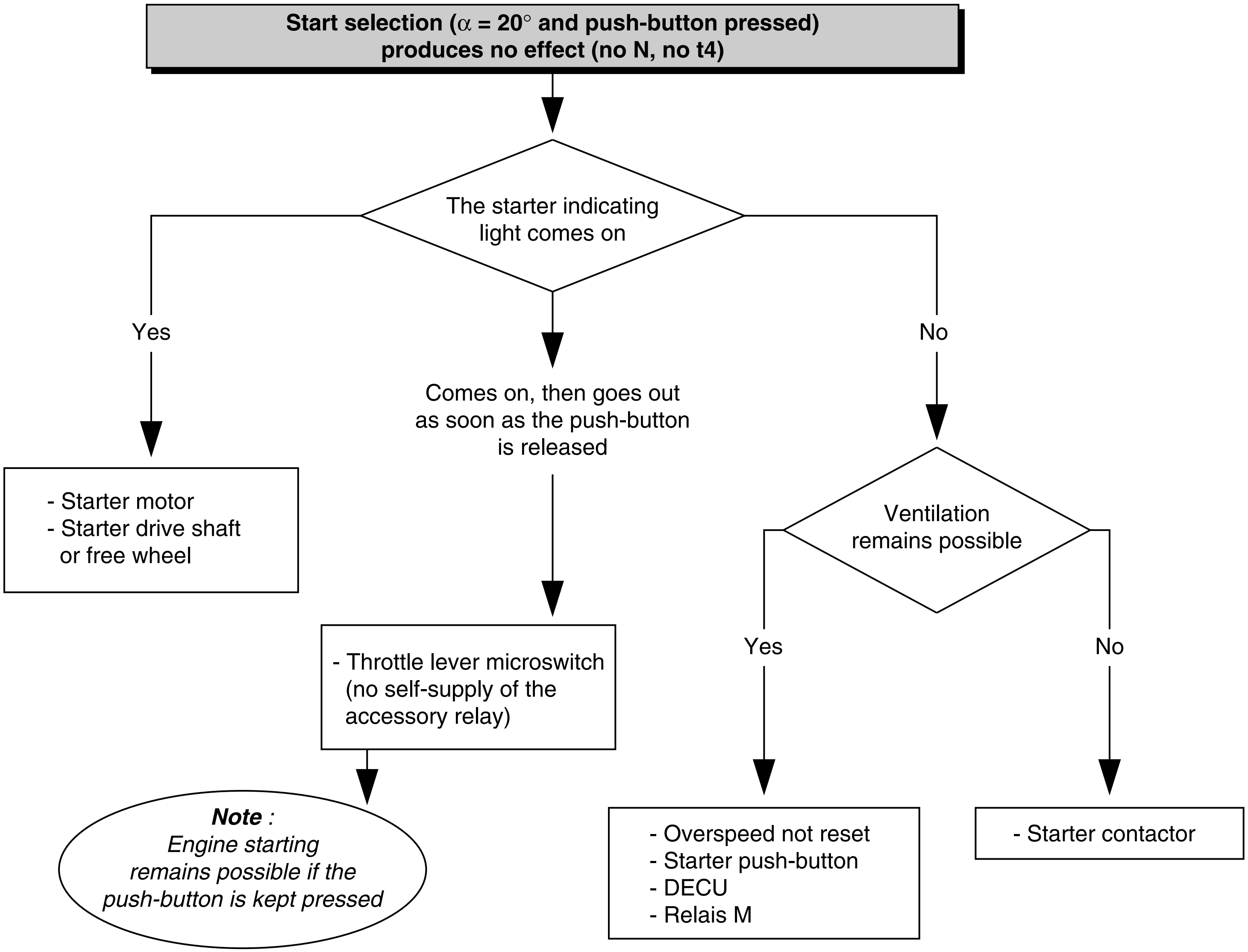
- Justified removal of components.

The procedure to be applied depends on the case but in general, a good knowledge of the product and a methodical research would permit a safe diagnosis and a quick corrective action.

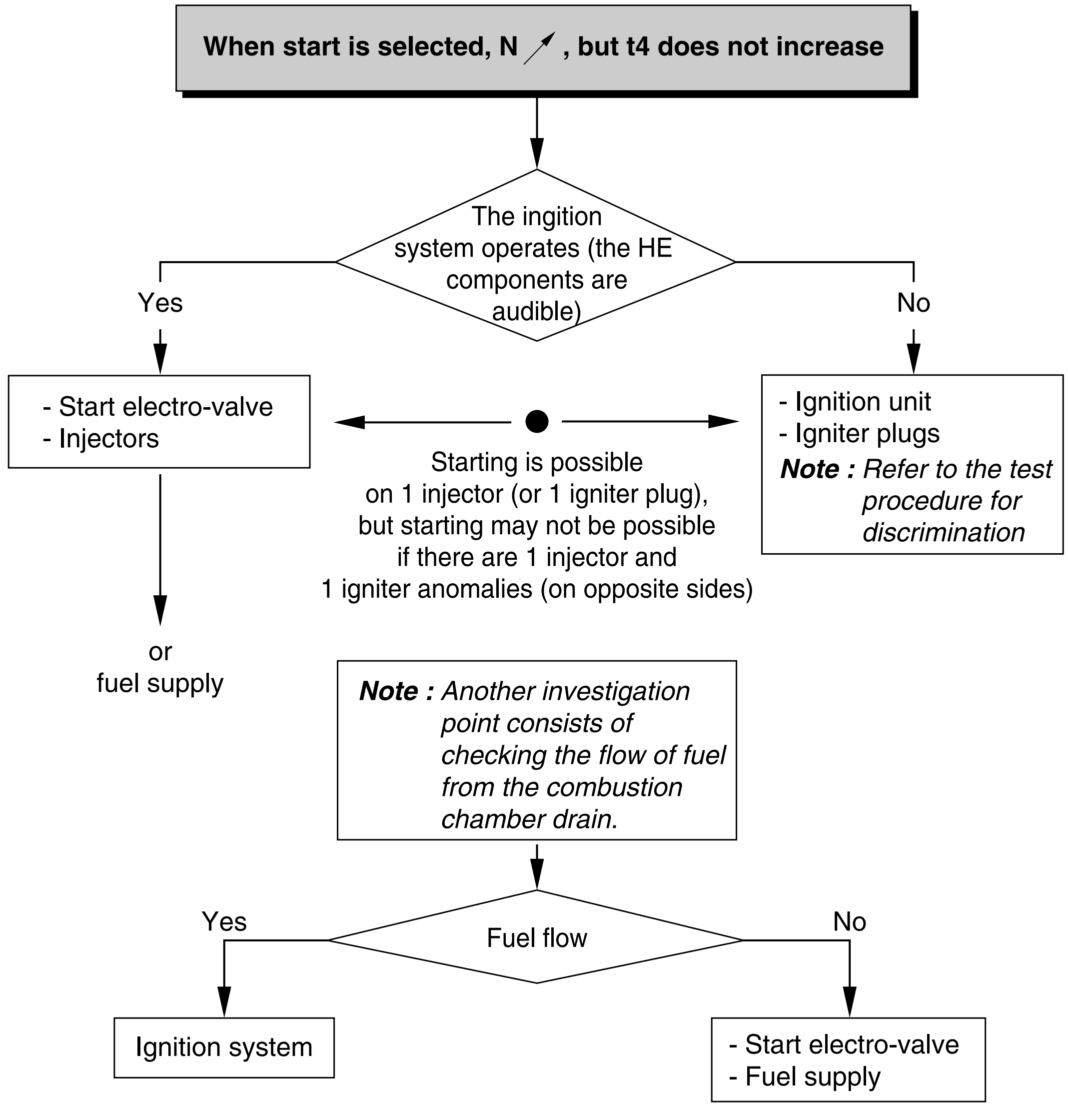
Generally, the procedure includes failure identification, its analysis, the isolation of the component, and the repair choice.



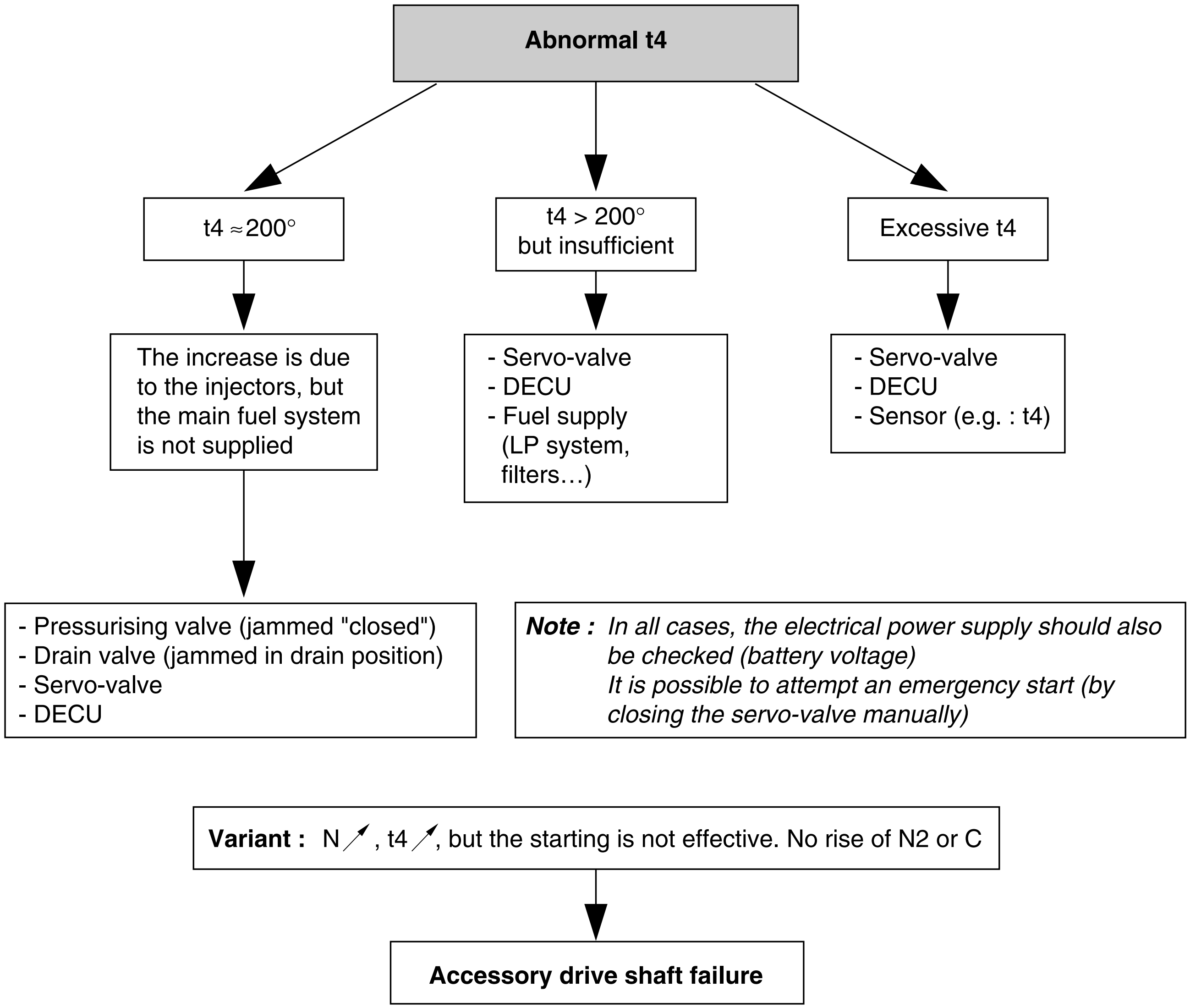
TROUBLE SHOOTING



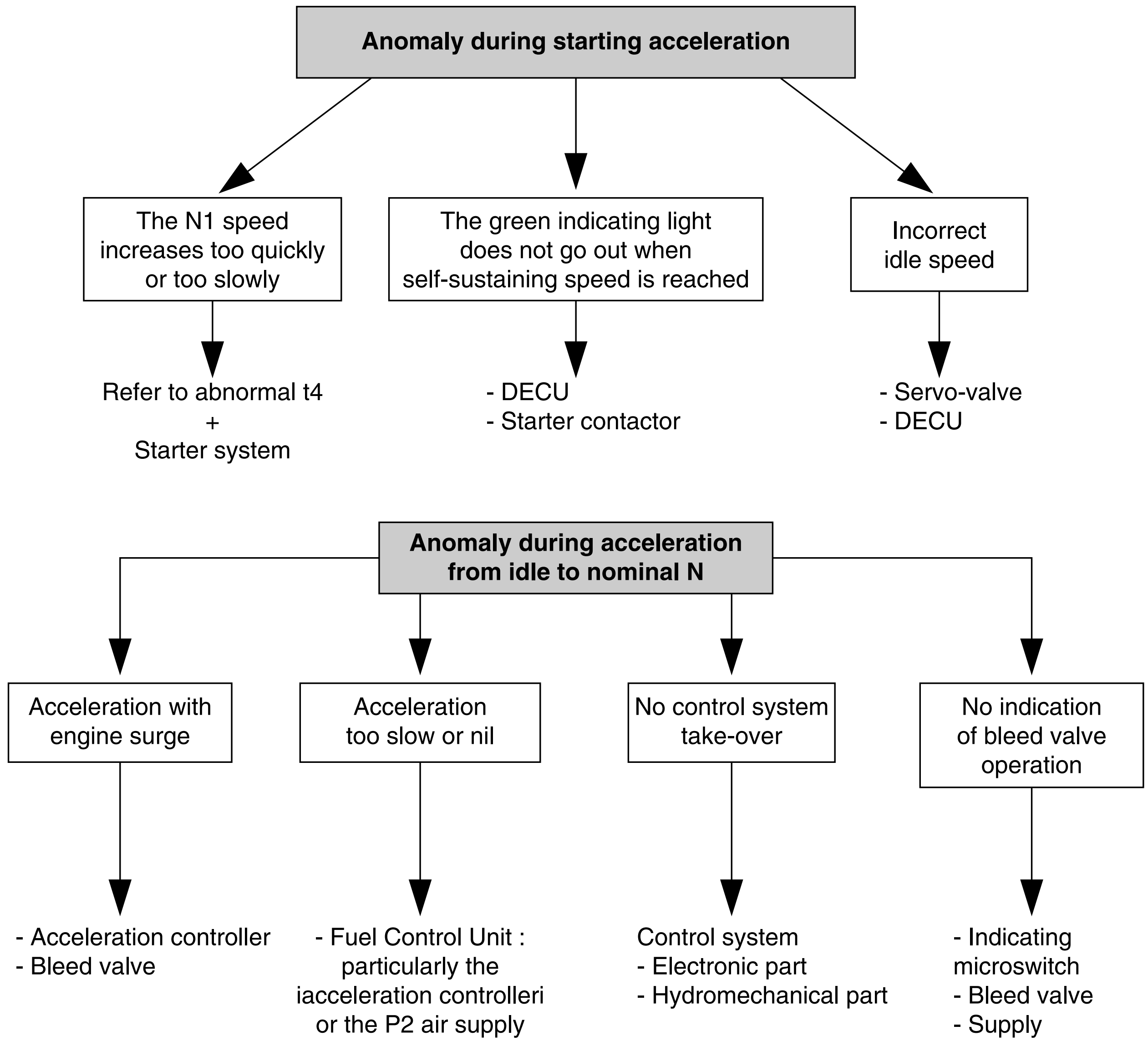
TROUBLE SHOOTING - STARTING FAULTS (1)



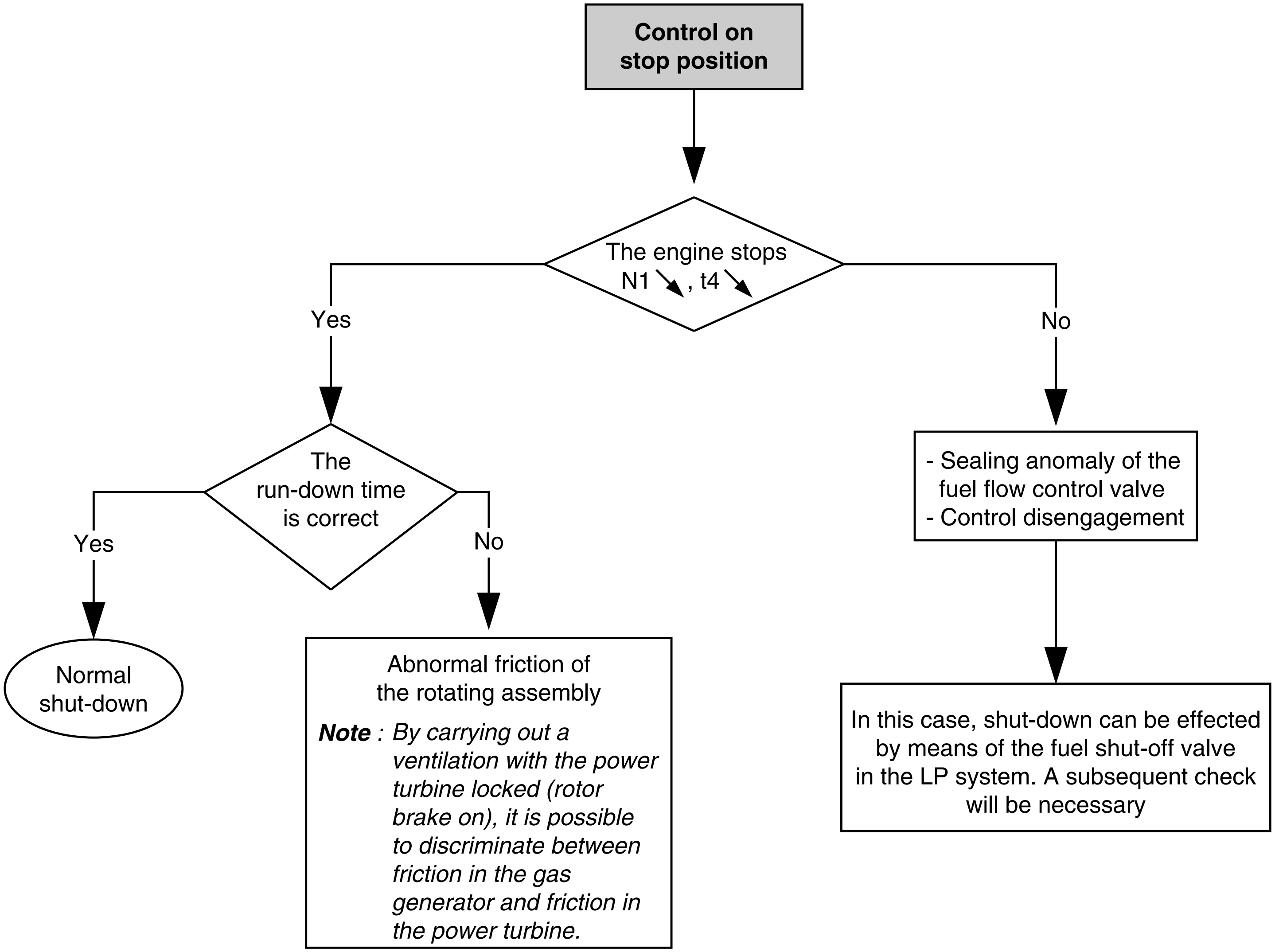
TROUBLE SHOOTING - STARTING FAULTS (2)



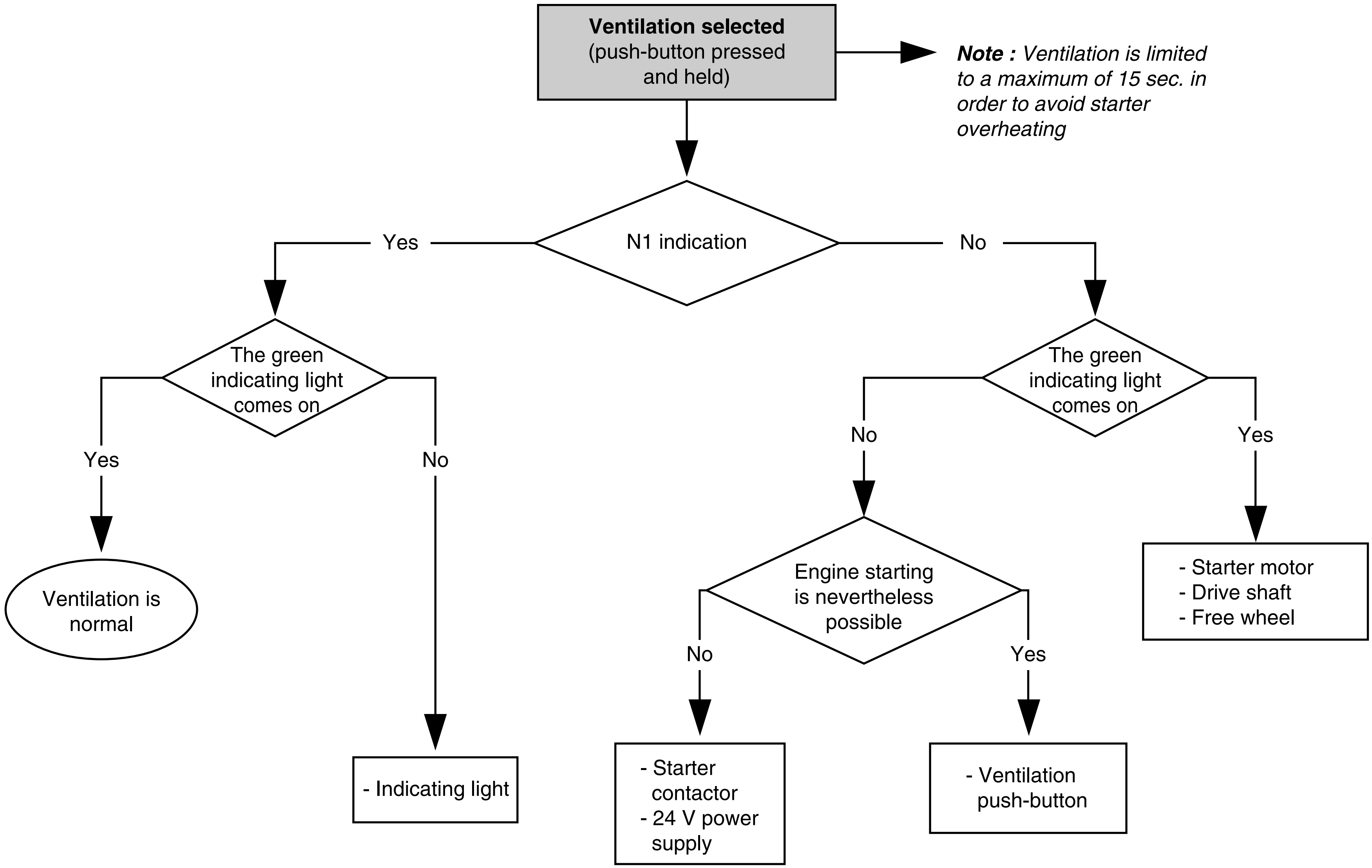
TROUBLE SHOOTING - STARTING FAULTS (3)



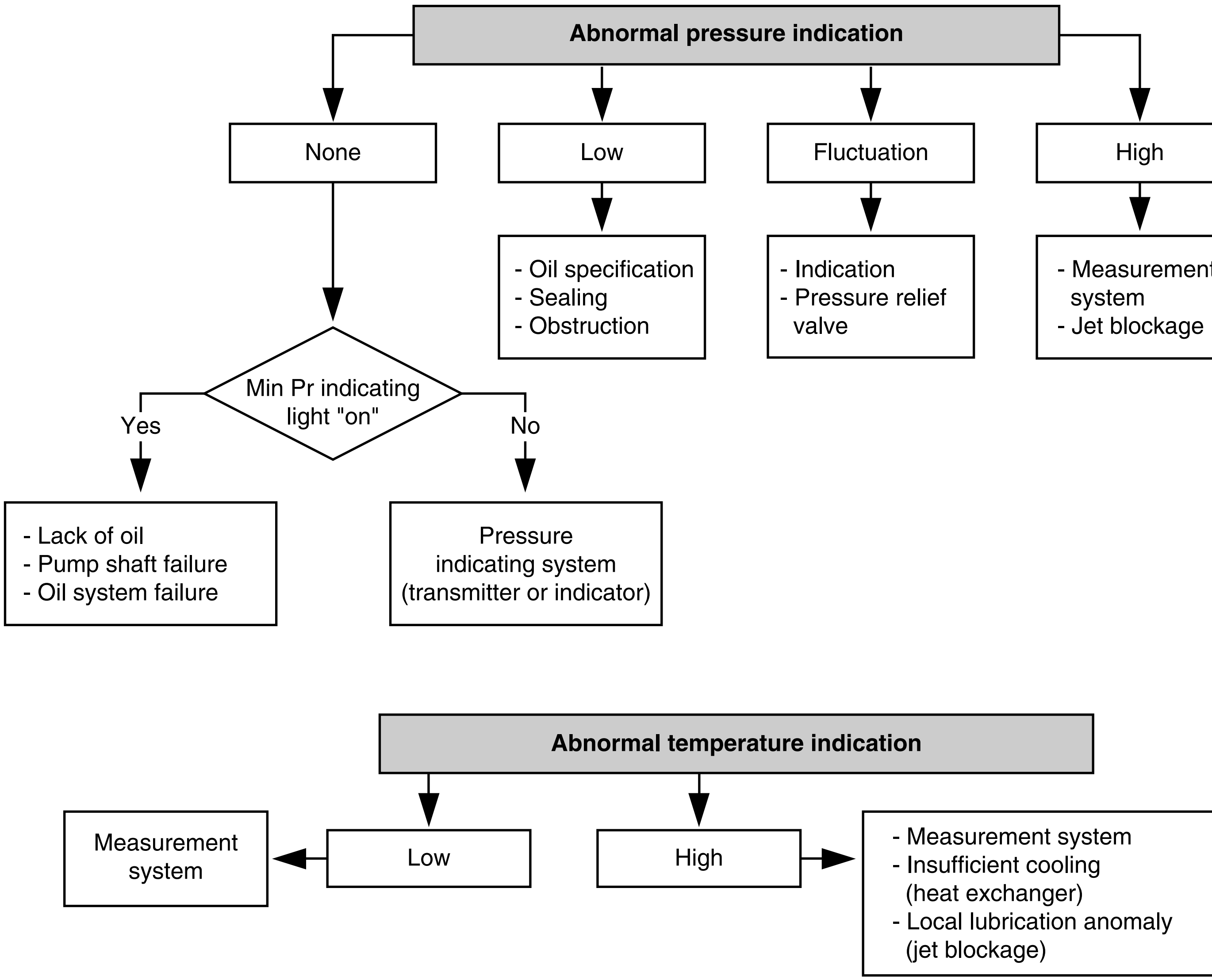
TROUBLE SHOOTING - STARTING FAULTS (4)



TROUBLE SHOOTING - FAULTS DURING SHUT-DOWN

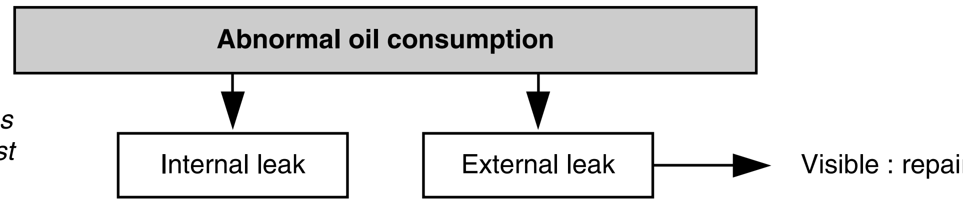


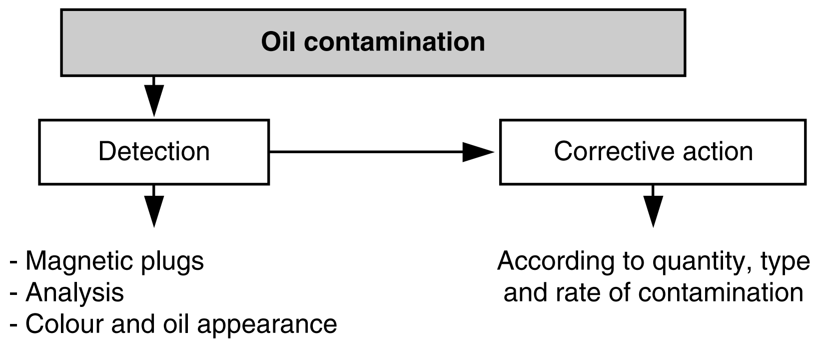
TROUBLE SHOOTING - FAULTS DURING VENTILATION



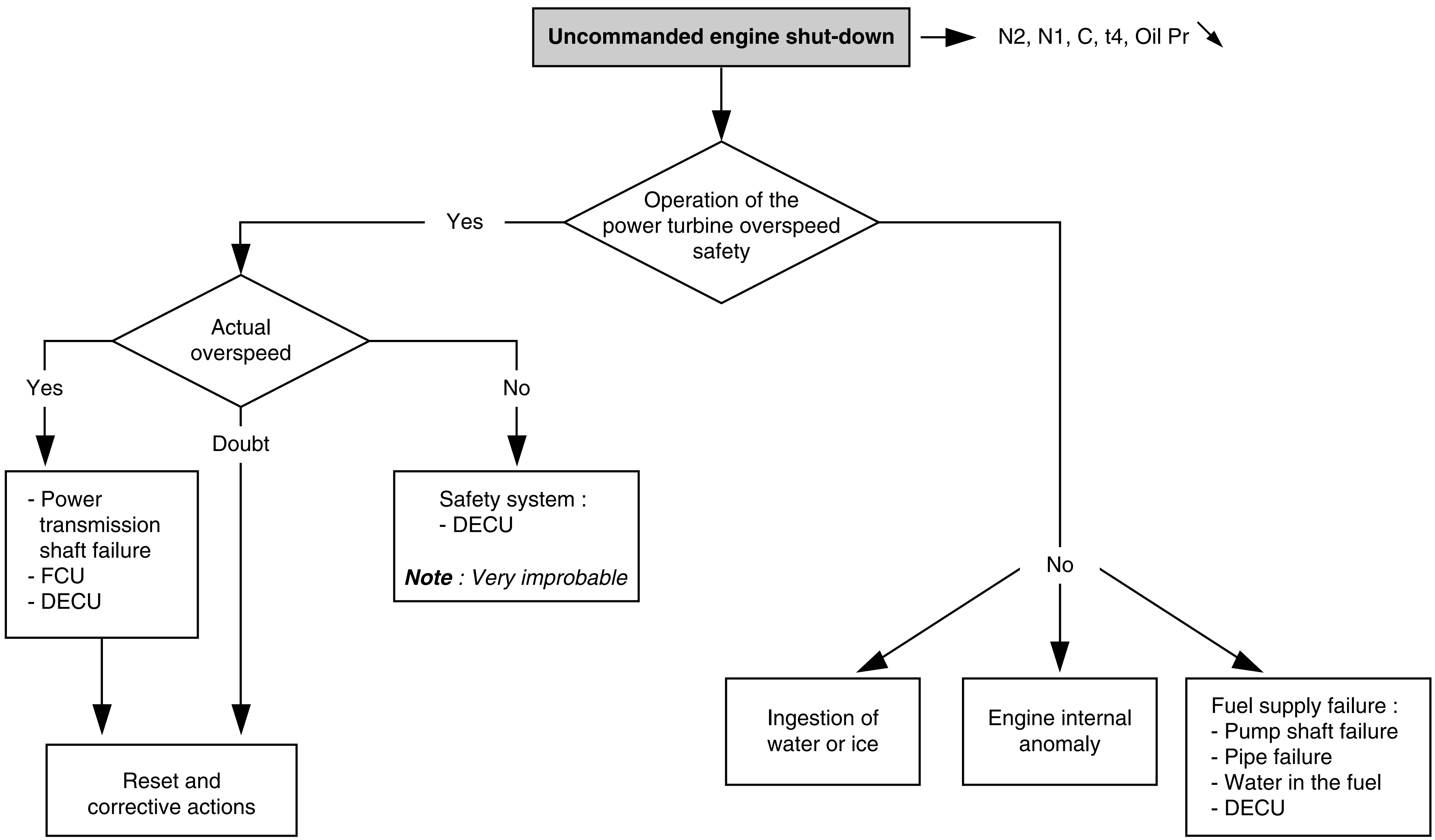
TROUBLE SHOOTING - LUBRICATION FAULTS (1)

***Note** : Smoke and traces of burnt oil in the exhaust pipe*

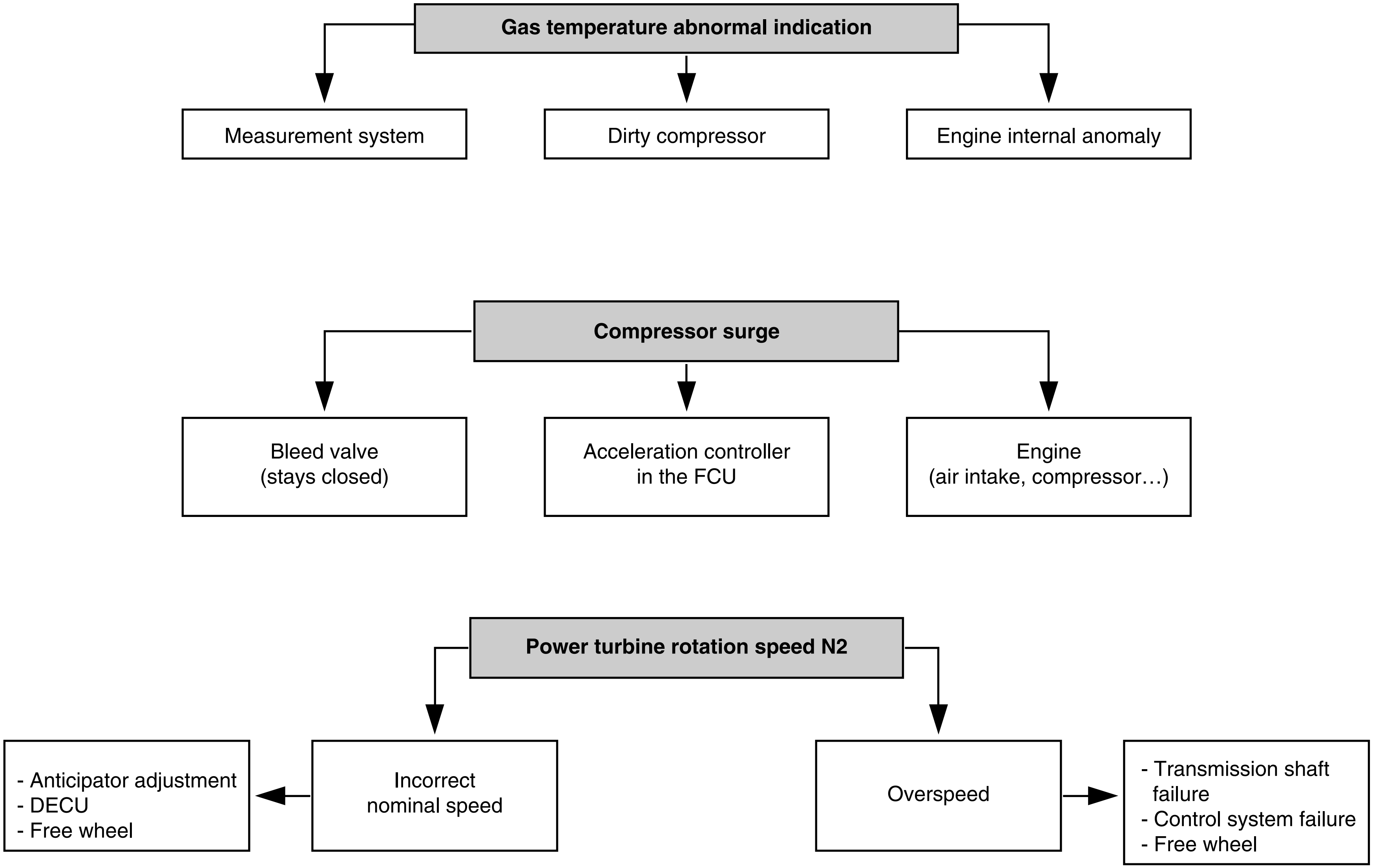




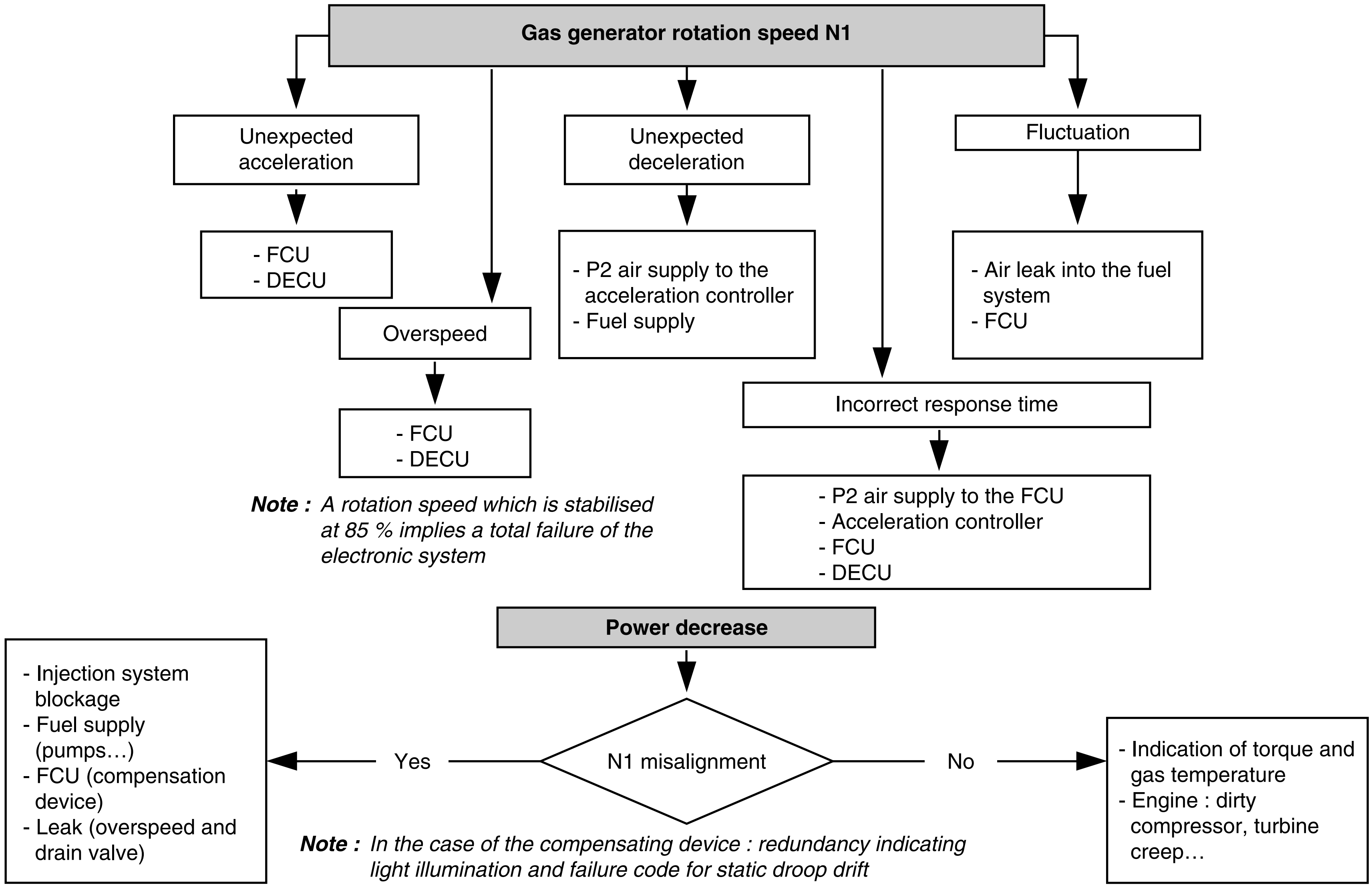
TROUBLE SHOOTING - LUBRICATION FAULTS (2)



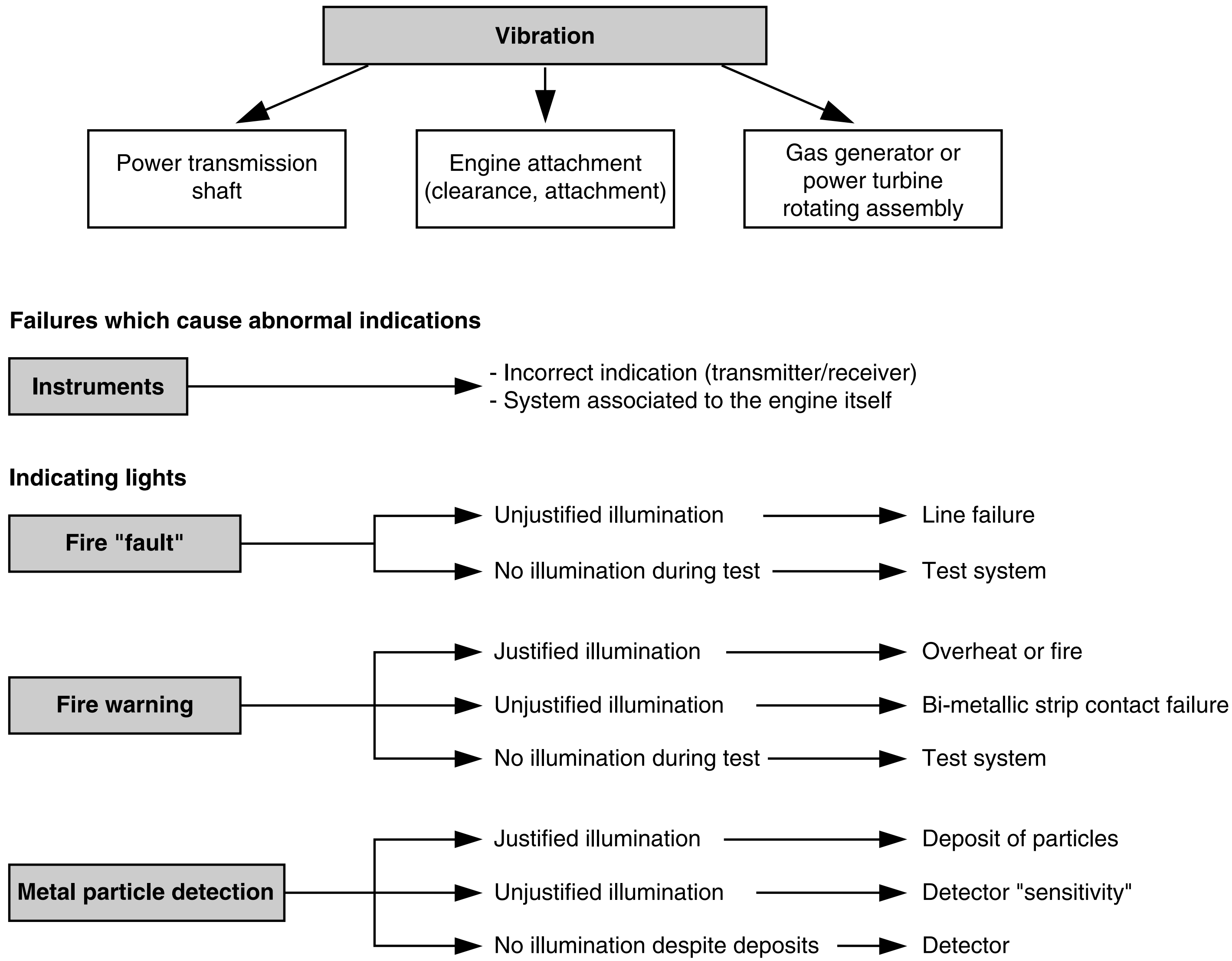
TROUBLE SHOOTING - FAULTS LEADING TO ENGINE SHUT-DOWN IN FLIGHT



TROUBLE SHOOTING - MISCELLANEOUS CASES (1)



TROUBLE SHOOTING - MISCELLANEOUS CASES (2)



TROUBLE SHOOTING - MISCELLANEOUS CASES (3)

Failures which cause abnormal indications

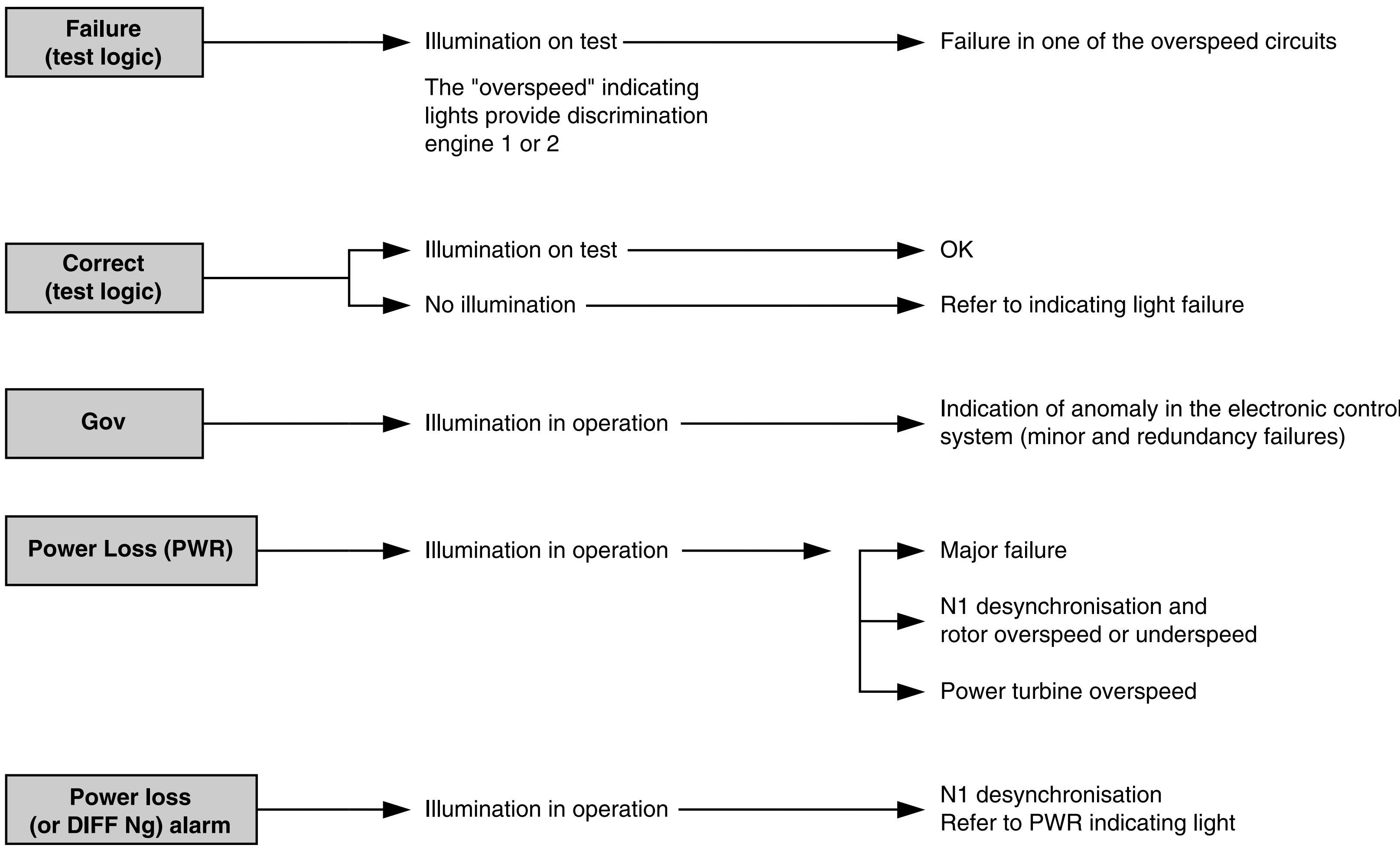
Indicating lights

Indicating light	Indication	Cause
Low oil pressure	Justified illumination	Pressure decrease
	Unjustified illumination	Pressure switch
	No illumination despite effective pressure decrease	Pressure switch
Starter	Does not come on when start selected	Starter contactor
	Does not go out at self sustaining speed	DECU, Starter contactor jammed
Bleed valve	Does not go out at N1 > ≈ 83 %	Bleed valve (microswitch, P2 supply valve)
	Does not go out at N1 < ≈ 81 %	Ditto
Off-set threshold	Does not illuminate when "SD" is selected	SD selector DECU
Overspeed "reset"	No illumination when energised	System failure
	Does not go out at N2 > 25 %	System failure (e.g. : sensors)
	Does not flash on overspeed shut-down	Flashing indication, Control system
	Flashing does not stop when reset	Rearming system
	Illumination on test (logic)	System failure

TROUBLE SHOOTING - MISCELLANEOUS CASES (4)

Failures which cause "abnormal indications"

Indicating lights



TROUBLE SHOOTING - MISCELLANEOUS CASES (5)

TROUBLE SHOOTING - FAULT FINDING (1) - EXAMPLE

General

The example chosen in the following pages serves to explain the use (reading/interpretation) of the maintenance sheets of the maintenance screen in the cockpit and the maintenance pages in the maintenance manual.

Naturally it is one example and it is evident that those faults which are not registered by the DECU have to be analysed differently.

Maintenance sheets 1 or 2 are available on the ground, engine stopped and up to 7 % N1 during start.

Description of the maintenance screen

Sheet 1

Described in chapter 8.

Page 2

This sheet provides the following information :

1- A real time display of P0, t1, collective pitch $\alpha 0$ and t4

2- Maintenance words MAINT 1 to 3, each in a 4 digit display

3- The state of logic inputs to the DECU (0 or 1, 1 = input active)

4- The state of logic outputs from the DECU (0 or 1, 1 = output active).

Description of maintenance words

MAINT 1 :

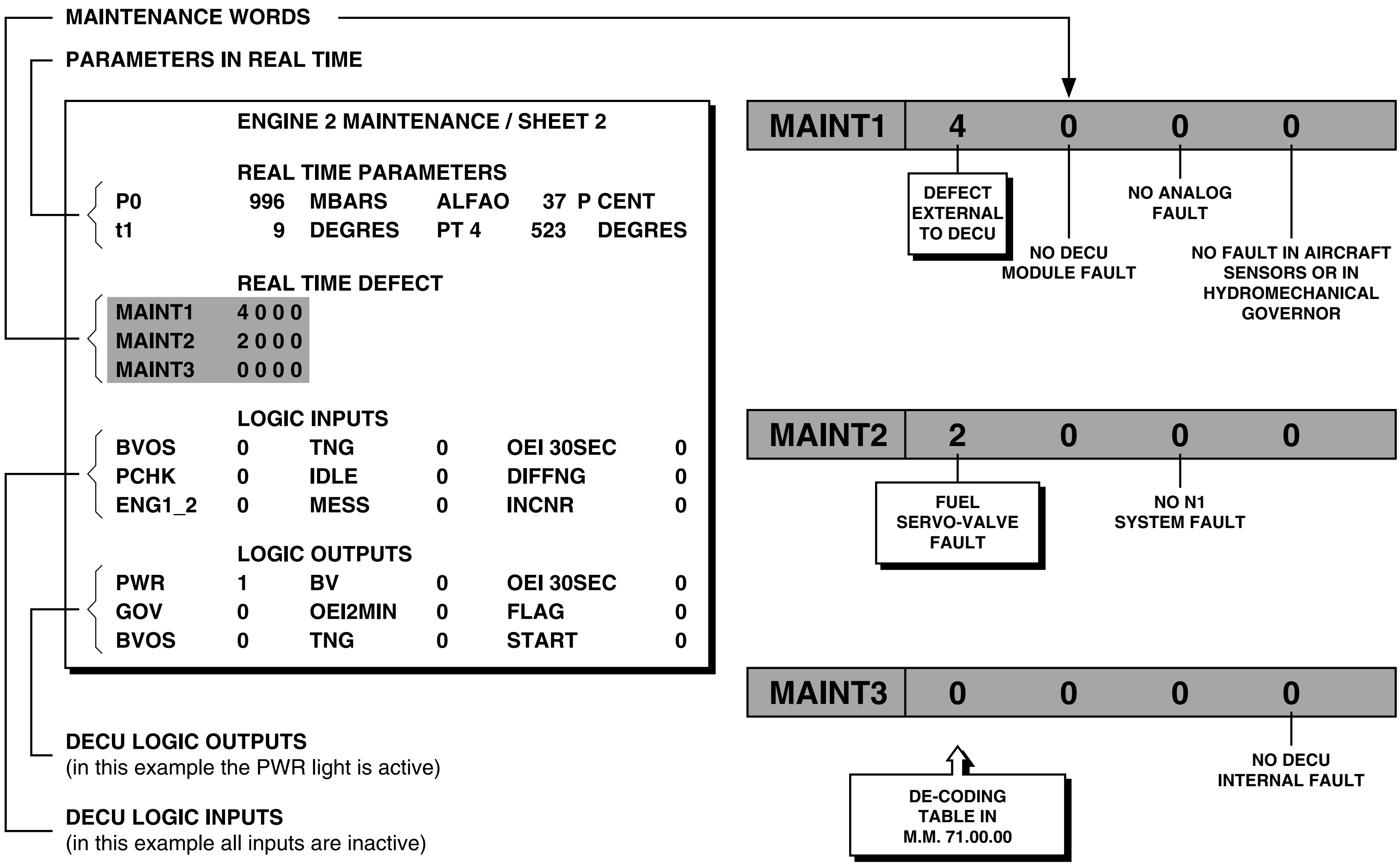
- 1st digit : the location of the fault in relation to the DECU (internal or external)
- 2nd digit : the failed DECU module
- 3rd digit : sensor anomaly, except N1 and N2
- 4th digit : helicopter sensor, except collective, and/or hydromechanical control.

MAINT 2 :

- 1st digit : LVDT or servo-valve anomaly
- 2nd digit : not used - always 0
- 3rd digit : one or several speed sensors
- 4th digit : not used - always 0.

MAINT 3 :

- 4th digit : type of DECU internal fault
- Digits 1 to 3 : not used - always 0.



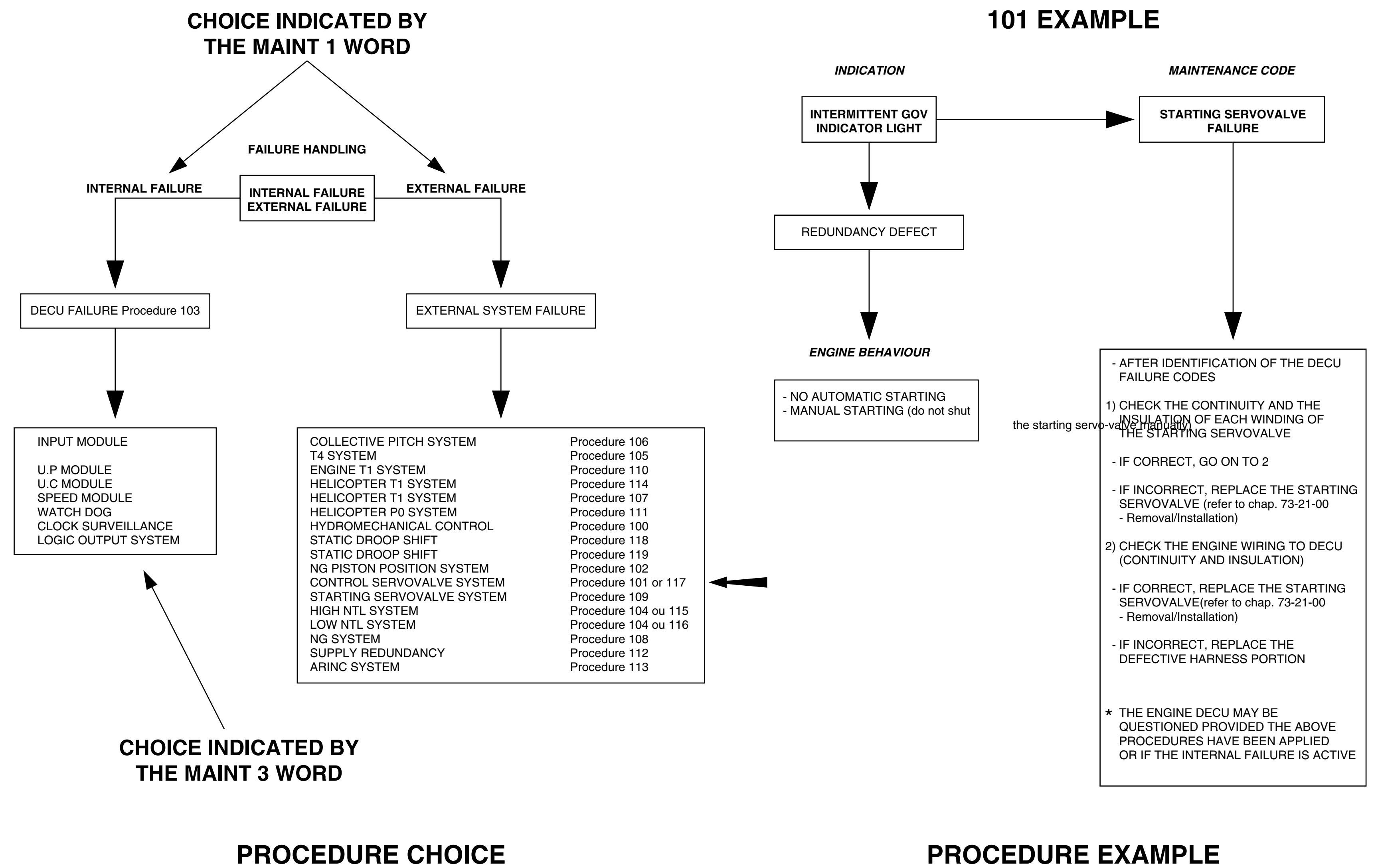
"MAINTENANCE SCREEN"
TROUBLE SHOOTING (EXAMPLE)

TROUBLE SHOOTING - FAULT FINDING (1) - EXAMPLE

Procedure

After noting the MAINT 1,2 or 3 codes refer to maintenance manual 71.00.00 to :

- Choose the procedure
- Investigate the fault following the procedure. In this example, procedure 101 or 117
- Carry out the actions detailed in the procedure (various chapters).



TROUBLE SHOOTING (EXAMPLE)

TROUBLE SHOOTING - CONCLUSION

Despite the high reliability of the product failures remain inevitable and happen at random. But their rate and effects can be reduced if the "enemies" of the engine are taken into consideration.

When the failure occurs, you have to be in a position to correct it.

"Enemies" of the engine

The traditional adverse conditions for this type of engine are :

- Supply (air, oil, fuel, electricity)

- Operation ("non respect" of instructions and procedures)

- Maintenance ("non respect" of inspection frequencies, and of the strict application of the procedures).

FUEL

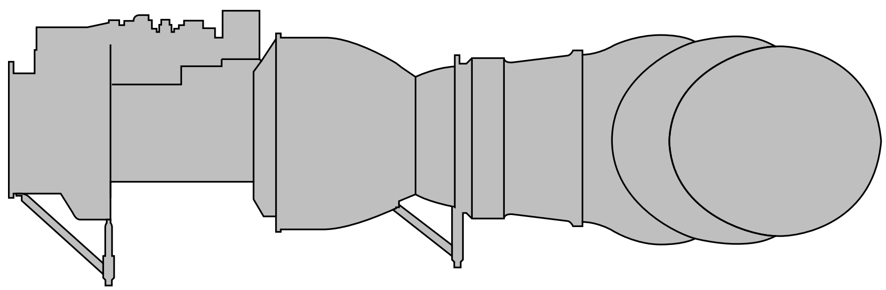
- Not in conformity with specifications
- Water in fuel
- Sulphur + salt in the air = sulfidation

AIR

- Sand
- Salt
- Miscellaneous pollution

OIL

- Not in conformity with specifications
- Miscellaneous contamination



OPERATION

- Non respect of instructions and procedures
- Severe operating conditions

ELECTRICITY

- Too low voltage during starting
- Interference

MAINTENANCE

- Non respect of inspection frequencies
- Various mistakes
- Wrong logistics

TROUBLE SHOOTING - CONCLUSION

16 - CHECKING OF KNOWLEDGE

INTRODUCTION

Method

Continuous checking helps to ensure the information is assimilated. It is more a method of work than a testing in the traditional sense.

Objectives of the questionnaires

The questionnaires permit a progressive assimilation and a long term retention. The questionnaires are a subject for discussion (effects of group dynamics). They also permit students to consider important subjects several times under different aspects.

Integration into the training programme

- First hour every day for revision of the subjects previously studied
- After each chapter (or module) of the course
- At the end of the training course.

Types of questionnaires

Several types of questionnaire can be employed during a course :

- Traditional written questionnaire
- "Short answer" questionnaire
- Multi Choice Questionnaire (MCQ)
- Oral questionnaire
- Learning Through Teaching (LTT ; the student has to explain a given subject).

Examination

The final examination at the end of the course consists of three tests : written, oral and practical. A certificate and an approval card are given to the student if the results are satisfactory.

QUESTIONNAIRE 1

This traditional questionnaire is established according to the same plan as the Training Manual in which the answers can be found.

Power plant

1 - List the main functional components of the power plant.

2 - Explain the thermodynamic operation of the engine.

3 - State the following features (at take-off, in standard atmosphere) :

- Power on the shaft
- Specific fuel consumption
- Compression ratio
- Gas generator turbine entry temperature
- Gas generator maximum rotation speed
- Nominal power turbine rotation speed
- Output shaft rotation speed
- Mass of the engine with specific equipment
- Main overall dimensions of the engine.

4 - Explain the principle of engine adaptation to helicopter power requirements.

5 - Give a definition of the operating ratings.

6 - How do temperature and altitude affect the engine performance.

Engine

1 - List the main components of the gas generator.

2 - Describe the power turbine assembly.

3 - Describe the fuel injection system in the combustion chamber.

4 - List the engine driven accessories.

5 - List the bearings which support the gas generator.

6 - Describe the system used for bearing sealing.

7 - Describe the modular construction of the engine.

8 - Describe the engine air intake.

9 - State the attachment of each component.

10 - List the manufacturing materials of the engine main components.

QUESTIONNAIRE 1 (continued)

Oil system

1 - Draw a simplified diagram of the oil system.

2 - Explain the general operation of the oil system.

3 - Describe the oil filter assembly.

4 - State the location of strainers and magnetic plugs.

Air system

1 - List the functions ensured by the internal air system (secondary system).

2 - List the function of the various air tappings.

3 - Why are the start injectors ventilated ?

4 - Explain the purpose and the operation of the compressor bleed valve.

Fuel system

1 - List the main functions of the fuel system.

2 - Describe the fuel pump.

3 - Describe the fuel metering unit.

4 - Purpose of the constant ΔP valve.

5 - Explain the principle of fuel injection (main and starting injection).

6 - Explain the purpose and the operation of the starting control system (DECU and servo-valve).

7 - Give the operating procedure for manual fuel flow control.

8 - Explain the operation of the system during starting.

Control system

1 - List the main functions of the control system.

2 - Explain the basic principle of the control system.

3 - Explain the operating principle of the speed control.

4 - List the components of the Digital Engine Control Unit.

5 - List the logic input signals of the DECU.

6 - List the analog input signals of the DECU.

7 - Describe and explain the operation of the overspeed safety system of the power turbine.

8 - Describe the Digital Engine Control Unit.

Indicating system and manual control

1 - Describe the manual control system.

2 - Describe the power turbine speed indicating system.

3 - Explain the principle of the torquemeter system.

4 - Describe the gas temperature indicating system.

QUESTIONNAIRE 1 (continued)

Starting

1 - Describe the cranking function of the engine.

2 - Describe the ignition system (ignition unit and igniter plugs).

3 - List the main phases of the starting cycle.

4 - Describe the starting control electrical system.

Electrical system

1 - List the engine electrical accessories.

2 - List the sensors used by the control system (state the type of signal produced).

3 - Describe the position and the attachment of the Digital Engine Control Unit.

4 - Describe the electrical harness and connectors.

Turboshaft engine installation

1 - Describe the attachment of the engine to the aircraft.

2 - List the various engine / aircraft connections.

3 - Describe the fire protection system of the engine.

Maintenance

1 - List the main operating limitations of the engine (explain the reason for each limit).

2 - Describe the engine starting procedure.

3 - List the main practices of a periodic inspection.

4 - List the means used for "on condition monitoring".

5 - Describe the procedure for engine removal.

6 - List the technical publications used for engine maintenance.

7 - Do the "fault analysis" exercises.

8 - Do the "troubleshooting" exercises.

QUESTIONNAIRE 2

The following questions require short and accurate answers.

The student can answer orally or in the space provided for the answers.

Questions	Answers
1 - MAKILA 1A2 power class ?	
2 - Power turbine rotation speed at 100 % ?	
3 - Type of start fuel injection ?	
4 - Number of engine modules ?	
5 - Number of power turbine stages ?	
6 - Meaning of AEO ?	
7 - Mass of the equipped engine ?	
8 - Power evolution when altitude increases ?	
9 - Specific fuel consumption at cruise rating ?	

Questions	Answers
10 - Flight envelope - Max altitude ?	
11 - Flight envelope - Max temperature ?	
12 - Start envelope - Max altitude ?	
13 - Engine air flow ?	
14 - Overall compression ratio ?	
15 - Max turbine entry temperature ?	
16 - Gas generator rotation speed at 100 % ?	
17 - Direction of rotation of the gas generator ?	
18 - Direction of rotation of the power turbine ?	
19 - Manufacturing material for the axial compressor ?	
20 - Type of axial compressor rear bearing ?	

QUESTIONNAIRE 2 (continued)

Questions	Answers
21 - How are modules M02 and M03 attached to each other ?	
22 - Axial compressor compression ratio ?	
23 - Manufacturing material for the centrifugal compressor wheel ?	
24 - Number of stages of the centrifugal compressor diffuser ?	
25 - Type of combustion chamber ?	
26 - Manufacturing material for the combustion chamber ?	
27 - Type of main fuel injection ?	
28 - Combustion chamber pressure loss ?	
29 - Number of stages of the gas generator turbine ?	

Questions	Answers
30 - Type of attachment for the turbine blades ?	
31 - Type of gas generator rear bearing ?	
32 - To which module does the turbine nozzle guide vane belong ?	
33 - Type of power turbine ?	
34 - Does the exhaust pipe belong to one module (yes or no) ?	
35 - Type of exhaust pipe attachment ?	
36 - Number of gears in the accessory gearbox ?	
37 - Rotation speed of the oil pump drive gear ?	
38 - Number of driven accessories in the accessory gearbox ?	
39 - Manufacturing material for the accessory gearbox?	

QUESTIONNAIRE 2 (continued)

Questions	Answers
40 - Is the oil pressure adjustable ?	
41 - Number of pumps in the oil pump pack ?	
42 - Type of oil pumps ?	
43 - Pressurising valve setting ?	
44 - Filtering ability of the oil filter?	
45 - Setting of the oil filter by-pass valve ?	
46 - Which bearings are squeeze film type ?	
47 - Type of seal for the gas generator rear bearing sealing ?	
48 - Max oil consumption ?	
49 - Type of oil pressure transmitter ?	

Questions	Answers
50 - Setting of the low oil pressure switch ?	
51 - Max oil temperature ?	
52 - Position of the centrifugal breather ?	
53 - Air tapping for the pressurisation of the power turbine front bearing ?	
54 - Air pressure at the centrifugal compressor outlet ?	
55 - Tapped air temperature at the centrifugal compressor outlet ?	
56 - When does the start injector ventilation begin ?	
57 - Max air tapping flow ?	
58 - Type of bleed valve ?	
59 - Position of the bleed valve during starting ?	

QUESTIONNAIRE 2 (continued)

Questions	Answers
60 - What are the bleed valve control signals ?	
61 - Position of the Fuel Control Unit ?	
62 - Current range of the start servo-valve ?	
63 - Filtering ability of the fuel filter ?	
64 - Setting of the fuel filter by-pass valve ?	
65 - Type of fuel pump ?	
66 - Position of the pump pressure relief valve in normal operation ?	
67 - Type of Fuel Control Unit ?	
68 - Position of the constant ΔP valve when the engine is stopped ?	
69 - Type of manual flow control ?	

Questions	Answers
70 - Min run-down time during engine stopping ?	
71 - Setting of the bleed valve in off-set threshold mode ?	
72 - Setting of the fuel pressurising valve?	
73 - Fuel flow through the start injectors ?	
74 - Number of start injectors ?	
75 - Position of the combustion chamber drain valve when the engine is stopped ?	
76 - Type of control system ?	
77 - Type of fixation of module M05 ?	
78 - Type of fixation of module M02 ?	
79 - Meaning of the abbreviation OEI ?	

QUESTIONNAIRE 2 (continued)

Questions	Answers
80 - How many phonic wheel for N2 measurement ?	
81 - Location of the OEI unit ?	
82 - Menaing of the abreviation LVDT ?	
83 - Position of the manual control in normal operation ?	
84 - Type of speed sensors ?	
85 - Number of N1 speed sensors ?	
86 - Number of N2 speed sensors ?	
87 - Number of thermocouple probes ?	
88 - Position of the t4 conformation box ?	
89 - How are the thermocouples connected (parallel or series) ?	

Questions	Answers
90 - Position of the torquemeter ?	
91 - Value (approx.) of the normal oil pressure ?	
92 - Setting of the oil pump pressure relief valve ?	
93 - Setting of the heat exchanger by-pass valve ?	
94 - Number of engine modules ?	
95 - Type of ignition ?	
96 - Gas generator speed at starter cut-off ?	
97 - Number of igniter plugs ?	
98 - Max duration of a ventilation ?	
99 - Is the ignition cable integral with the igniter plug ?	

QUESTIONNAIRE 2 (continued)

Questions	Answers
100 - Number of electrical connectors ?	
101 - Position of the alternator for the control system ?	
102 - Type of seal on the power shaft ?	
103 - Setting of the hot zone fire detectors ?	
104 - Number of engine drains ?	
105 - Engine operating envelope ; min and max altitude pressure?	
106 - Max N2 speed limitation ; OEI 30 sec. rating ?	
107 - Power turbine max overspeed ?	
108 - Max gas temperature during starting ?	

Questions	Answers
109 - Low oil pressure ?	
110 - Max oil temperature ?	
111 - Min electrical supply voltage before starting ?	
112 - Type of recommended lubricant ?	
113 - Meaning of IPC ?	
114 - Meaning of TBO ?	
115 - Is borescopic inspection of the combustion chamber possible ?	
116 - Procedure in case of operation in OEI 30 sec. rating ?	
117 - On which component is the static droop adjustment done ?	

QUESTIONNAIRE 3

This multi-choice questionnaire is used to review, in a relatively short time, certain important points and to test the acquired knowledge.

Answers to the questions can be found at the end of the questionnaire.

1 - The MAKILA 1A2 engine is :
a) a free turbine turboshaft engine
b) a turbo-jet engine
c) a fixed turbine turboshaft engine.

2 - Section of passage of the compressor diffusers :
a) regular
b) divergent
c) convergent.

3 - Type of combustion chamber :
a) annular with centrifugal injection
b) annular, reverse flow
c) annular, indirect flow.

4 - The 1st stage power turbine nozzle guide vane belongs :
a) to the module M05
b) to the power turbine module
c) to the gas generator module.

5 - Type of exhaust pipe attachment :
a) bolts
b) mounting pads
c) clamp.

6 - Number of bearings which support the gas generator :
a) 4
b) 2
c) 3.

7 - The turboshaft engine includes :
a) 4 modules
b) a hot section and a cold section
c) 3 modules.

8 - Type of oil system :
a) dry sump
b) constant pressure
c) lubrication by splashing.

9 - Setting of the oil filter pre-blockage switch :
a) lower than the by-pass valve
b) higher than the by-pass valve
c) the same as the pump valve.

10 - The oil strainers are located :
a) at the outlet of the pumps
b) on the inlet of the scavenge pumps
c) at the inlet of the lubricated components.

11 - Is there a max oil temperature :
a) yes, 60 °C
b) no
c) yes, 120 °C maxi.

QUESTIONNAIRE 3 (continued)

12 - P2 air is used for the pressurisation of :
a) some labyrinth seals
b) the tank
c) the pumps.

13 - Position of the bleed valve during flight ?
a) open
b) closed
c) depends on conditions.

14 - Ventilation of start injectors :
a) does not exist
b) is made with air from the compressor
c) is made with atmospheric pressure air.

15 - The injection centrifugal wheel is drained :
a) permanently
b) enable the ventilation cycle
c) during engine shut-down.

16 - The max speed of the gas generator is :
a) limited by a calculated stop
b) limited by a variable stop
c) not limited by the Fuel Control Unit.

17 - The clearance between the metering valve and the acceleration controller :
a) represents the instantaneous flow step
b) there is no such clearance
c) enables operation with a greater flexibility.

18 - With the anticipator, the static droop is :
a) compensated
b) cancelled
c) overcompensated.

19 - The thermocouples are wired :
a) in series
b) in parallel
c) on the turbine casing.

20 - The starter cut-out is made :
a) automatically
b) manually
c) with air pressure.

21 - Starting is possible with one igniter :
a) yes
b) no
c) yes, in emergency.

22 - The fuel system pressurising valve :
a) is electrically controlled
b) operates when overpressure occurs
c) gives priority to the injectors.

QUESTIONNAIRE 3 (continued)

23 - The anticipator is :
- a) the damping device
- b) the pitch / FCU link
- c) the throttle control link.

24 - Effect of the temperature on the control system :
- a) no effect
- b) compensated by a capsule
- c) compensated by a spring.

25 - Is there an "emergency" fuel limit :
- a) no
- b) yes, less than the normal limit
- c) yes, greater than the normal limit.

26 - The acceleration controller capsule :
- a) is subjected to P2 pressure
- b) is subjected to P1 pressure
- c) detects the fuel pressure.

27 - HE ignition means :
- a) Hot Electrode
- b) High Energy
- c) High Emission.

28 - Type of electronic control unit :
- a) digital
- b) analog
- c) Fadec.

29 - Number of power turbine N signals :
- a) 6
- b) 4
- c) 2.

30 - The reliability of the engine is :
- a) good
- b) fairly good
- c) extremely good.

Answers

1 - a	2 - b	3 - a	4 - c	5 - c
6 - a	7 - a	8 - a	9 - a	10 - b
11 - c	12 - a	13 - c	14 - b	15 - c
16 - a	17 - a	18 - c	19 - b	20 - a
21 - a	22 - c	23 - b	24 - b	25 - b
26 - a	27 - b	28 - a	29 - a	30 - abc ?

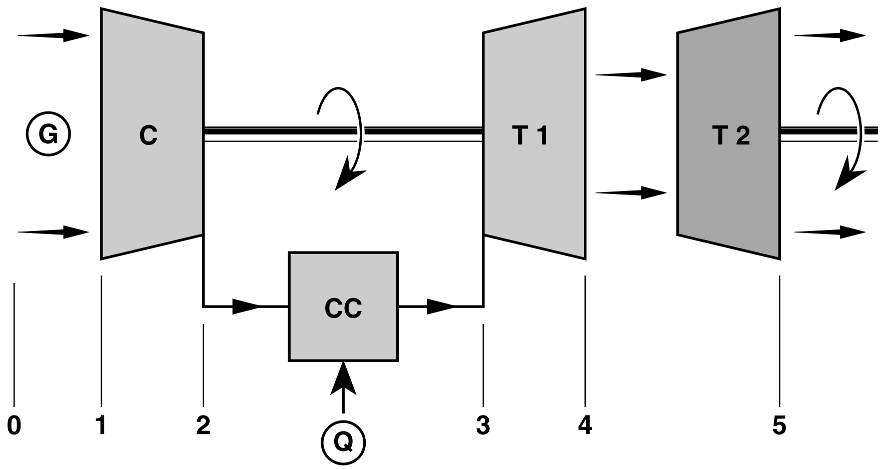
QUESTIONNAIRE 4

This questionnaire is a sort of drill which is also used to test and perfect the knowledge acquired.

1 - Complete this table (with values) :

Max take-off power	.... kW
OEI 30 sec. rating power	.... kW
Operating time at OEI ratings	....
Engine mass	.... kg
Air flow at take-off rating	....

2 - Indicate the reference stations :



0 - ....

1 - ....

2 - ....

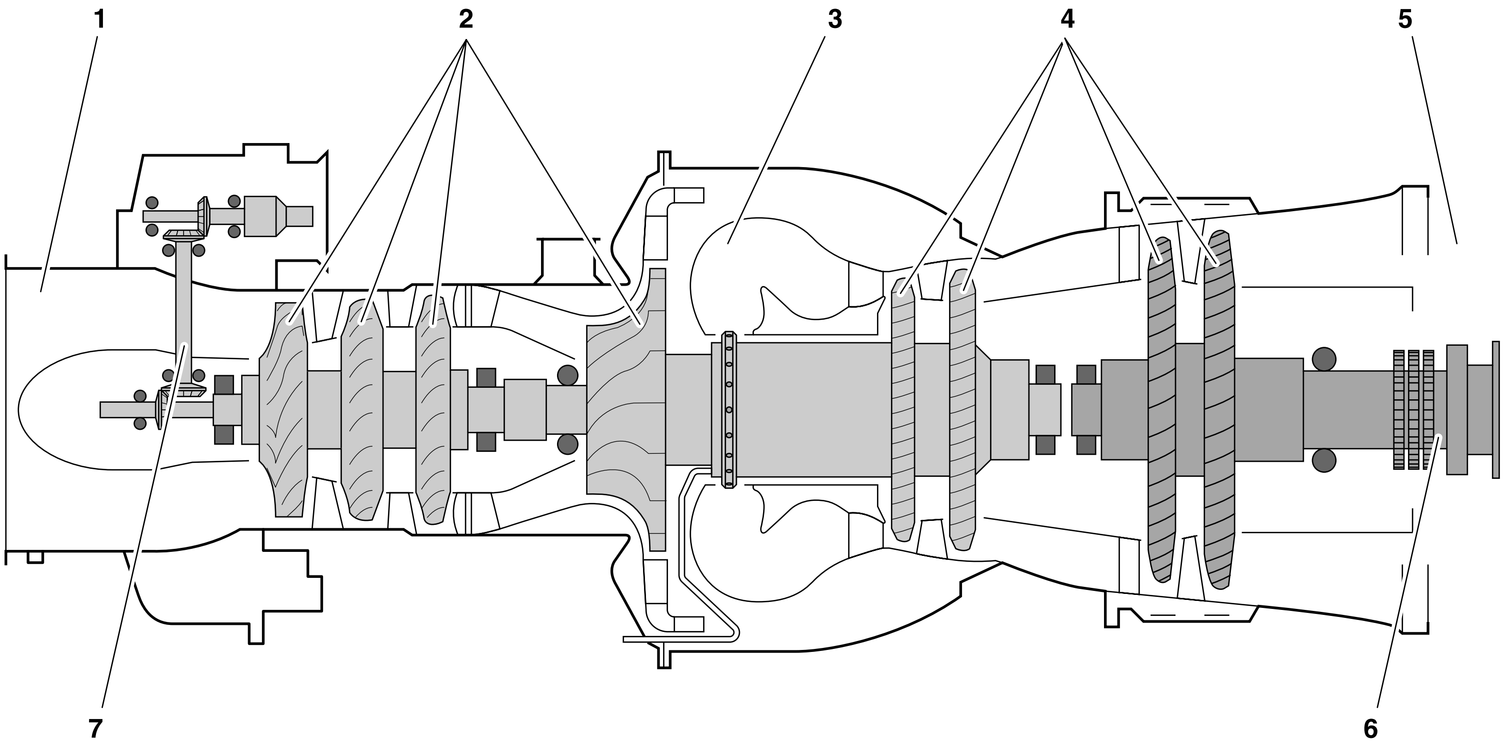
3 - ....

4 - ....

5 - ....

QUESTIONNAIRE 4 (continued)

3 - Engine description - Complete the legend of the diagram :



1 - ....

2 - ....

3 - ....

4 - ....

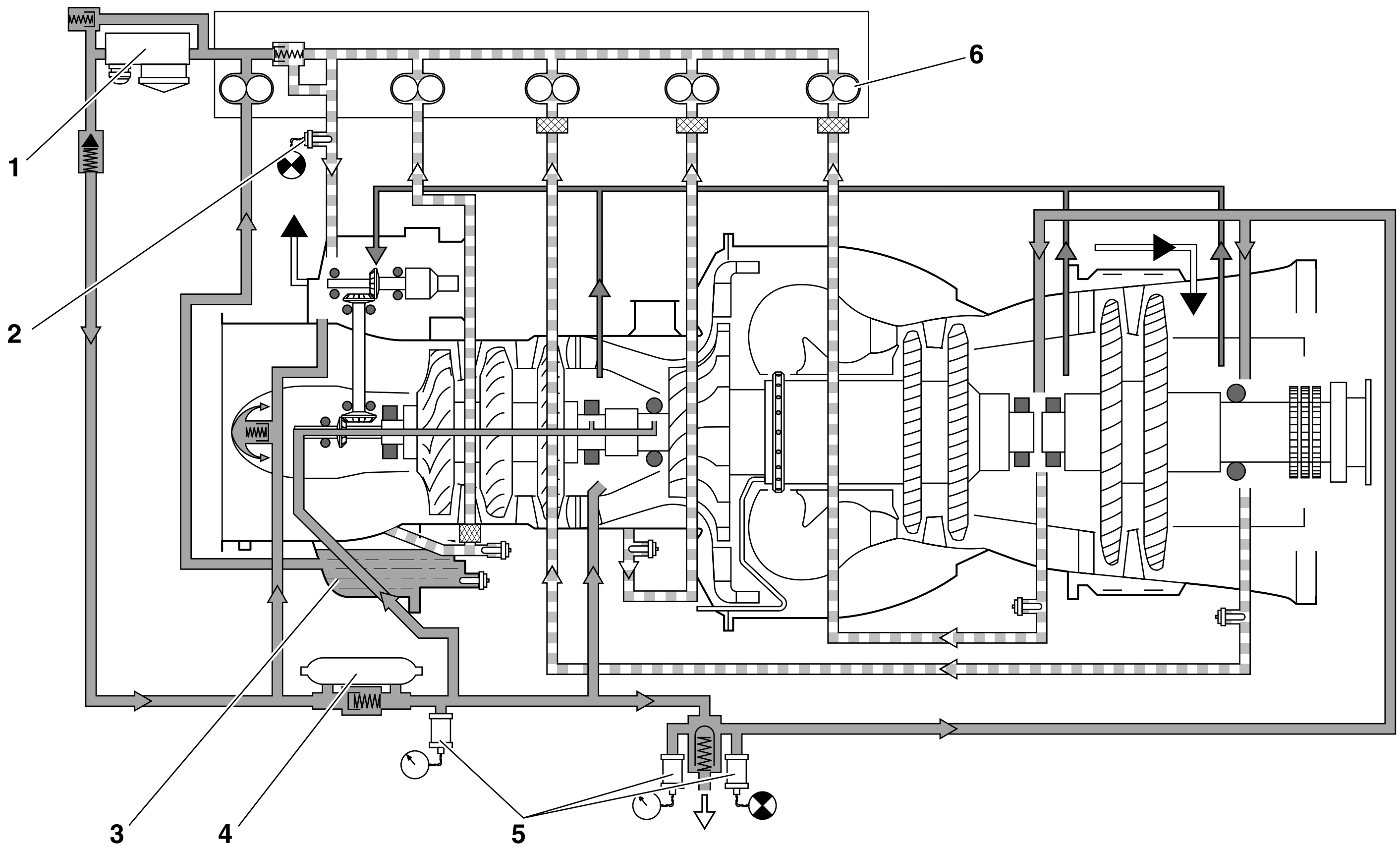
5 - ....

6 - ....

7 - ....

QUESTIONNAIRE 4 (continued)

4 - Oil system - Complete the legend of the diagram :



1 - ....
2 - ....
3 - ....
4 - ....
5 - ....
6 - ....

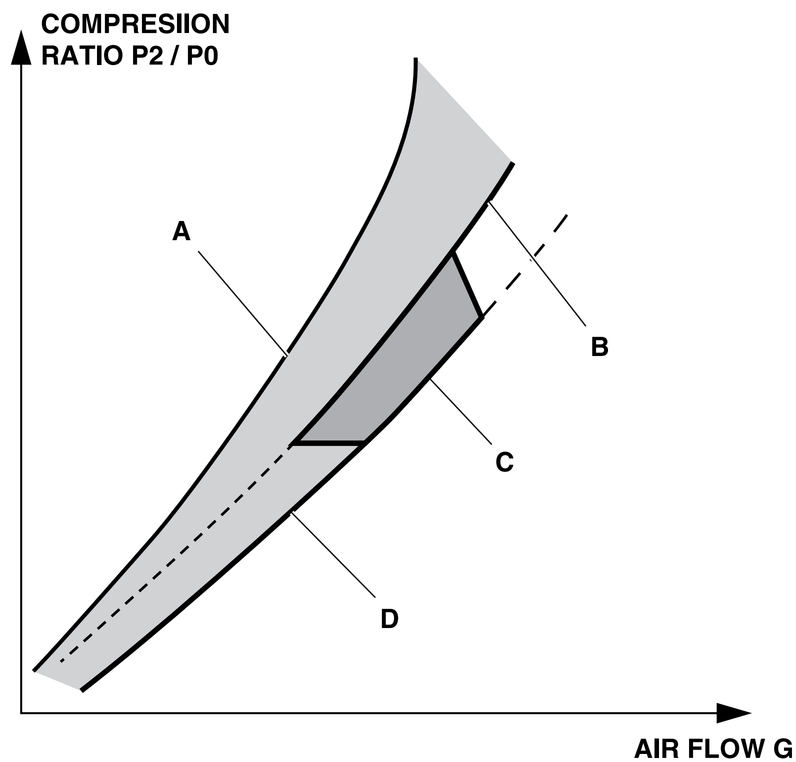
QUESTIONNAIRE 4 (continued)

5 - Complete the following table :

	P0	P1'	P2
Injector ventilation			
Acceleration control unit			
Bleed valve control pressure			
Injection wheel pressurisation			
Axial compressor bearing pressurisation			
Gas generator rear bearing cooling			
Power turbine front bearing pressurisation			
Gas generator turbine disc cooling			

QUESTIONNAIRE 4 (continued)

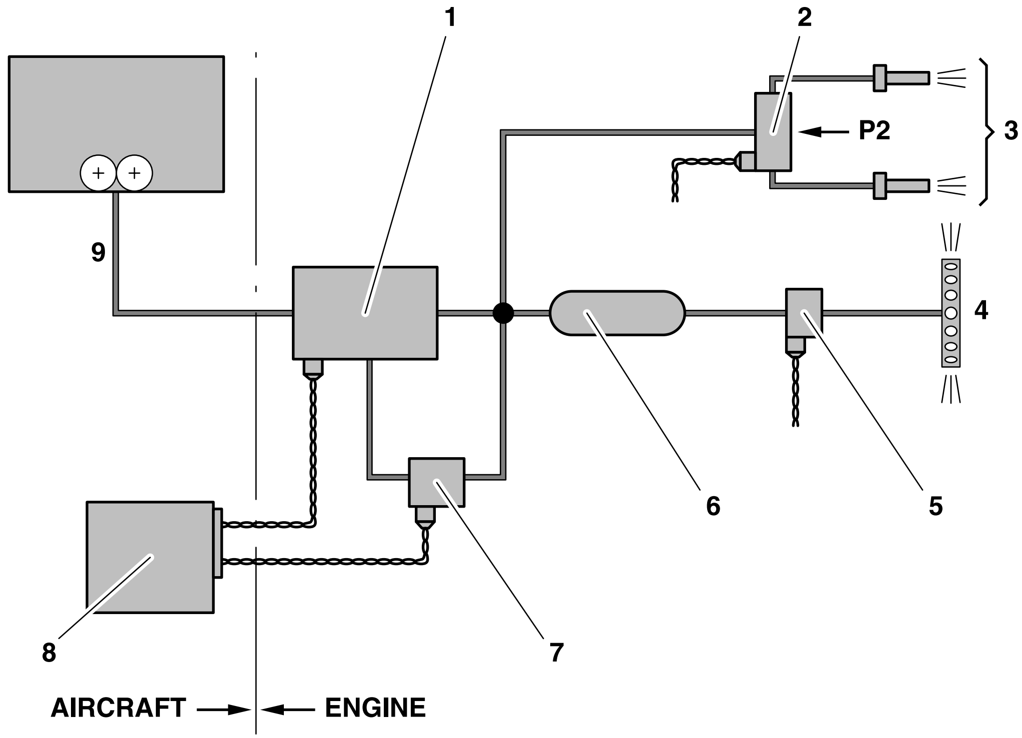
6 - Complete the legend of the compressor field diagram :



A - .... B - .... C - .... D - ....

QUESTIONNAIRE 4 (continued)

7 - Fuel system - List the components :



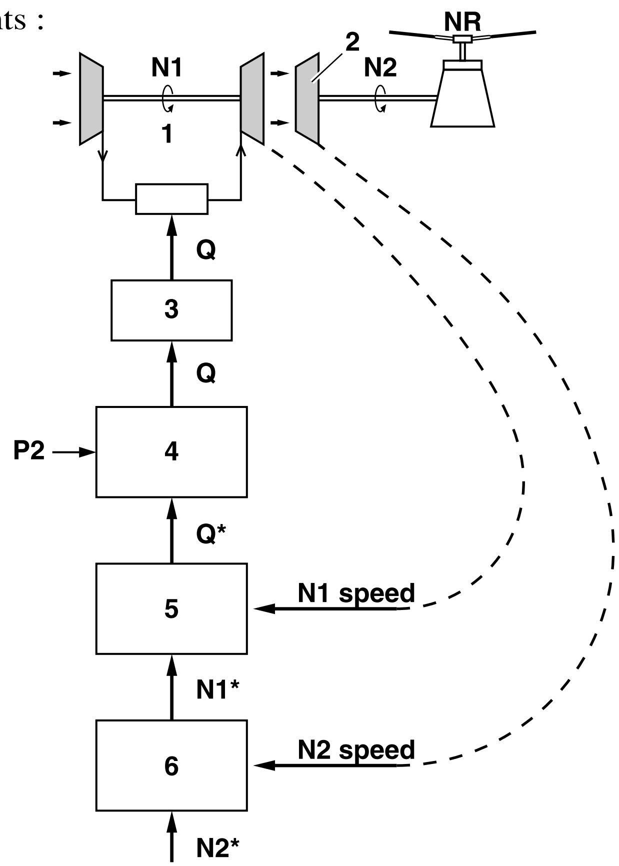
1 - .... 2 - .... 3 - ....

4 - .... 5 - .... 6 - ....

7 - .... 8 - .... 9 - ....

QUESTIONNAIRE 4 (continued)

8 - Control system - List the components :



1 - .... **2 -** .... **3 -** ....

4 - .... **5 -** .... **6 -** ....

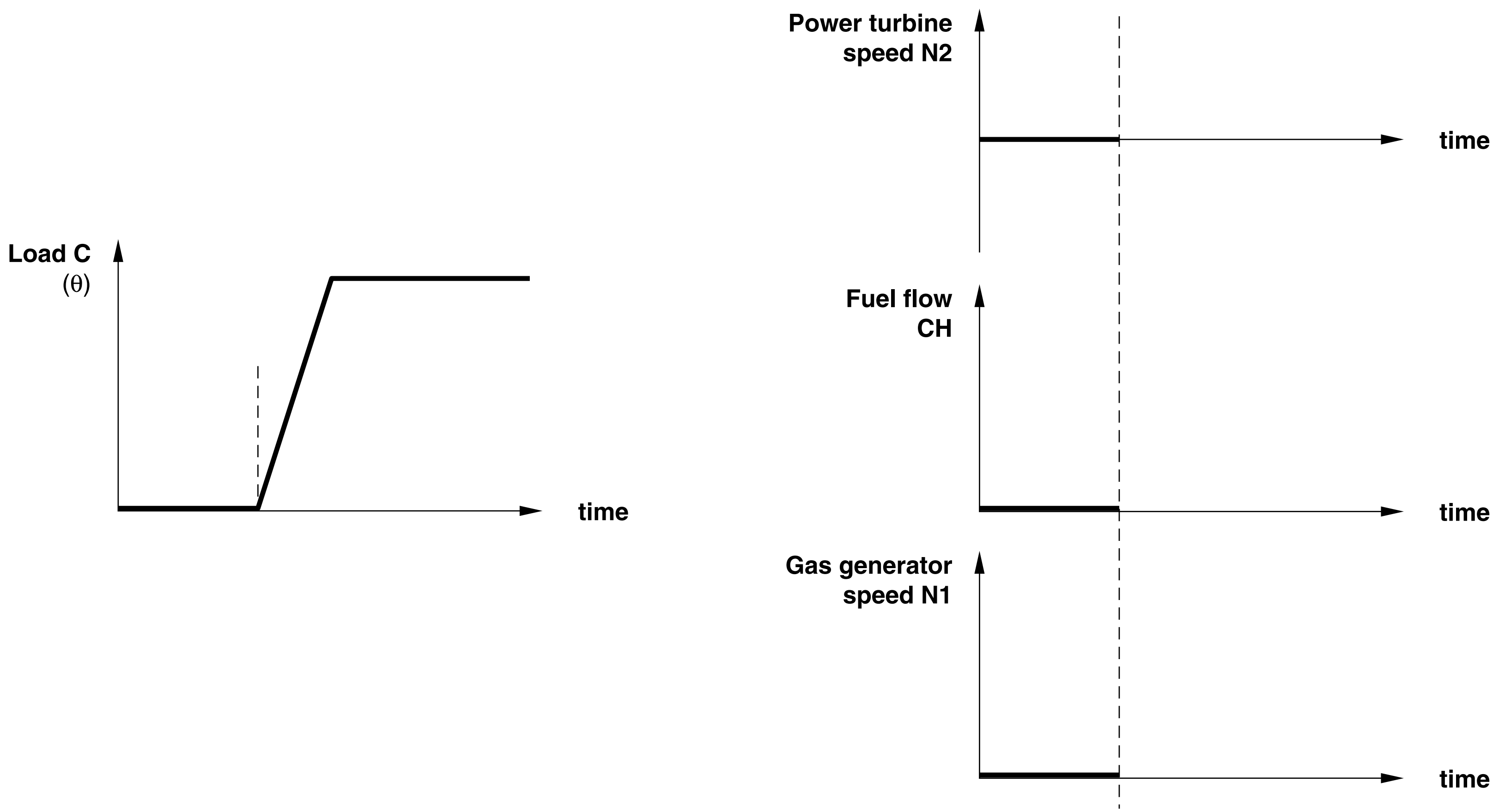
QUESTIONNAIRE 4 (continued)

9 - Complete the following table :

	Engine stopped	Engine in stabilised flight
Pump pressure relief valve		
Main valve		
Emergency valve		
Constant ΔP valve		
Metering valve		
Pressurising valve		
Pressure reducing valve		
Start injector electro-valve................................		
Overspeed electro-valve		
Combustion chamber drain valve		

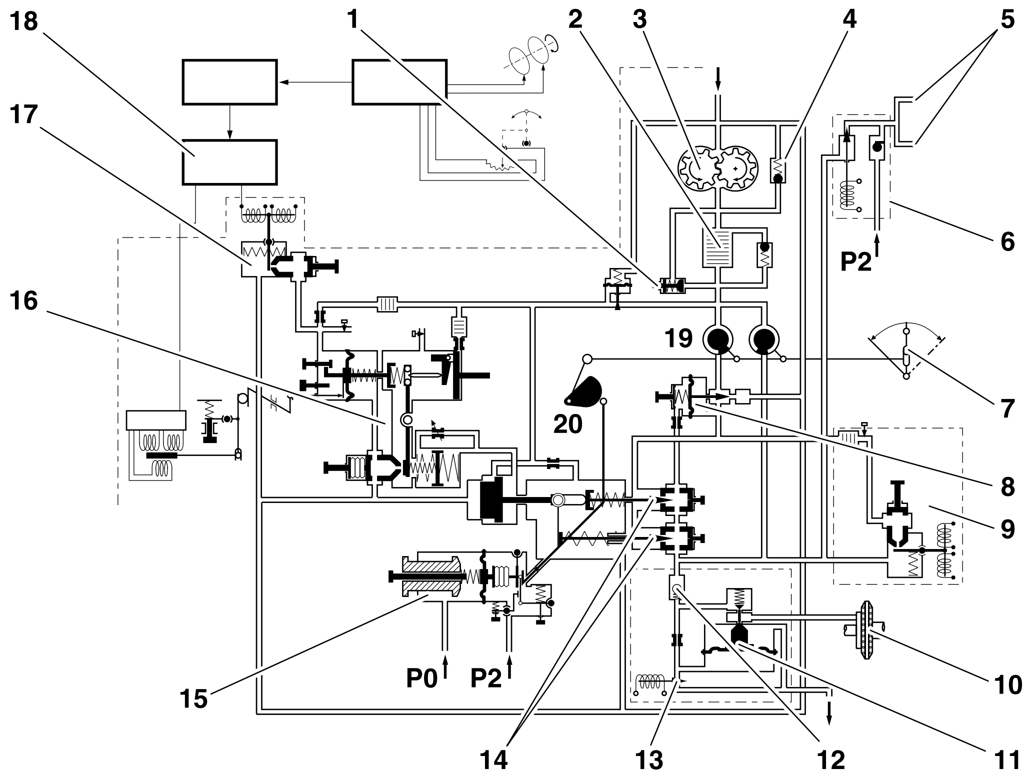
QUESTIONNAIRE 4 (continued)

10 - Complete the following curves during a load C increase :



QUESTIONNAIRE 4 (suite)

11 - Fuel system - List the components :



1 - ....

2 - ....

3 - ....

4 - ....

5 - ....

6 - ....

7 - ....

8 - ....

9 - ....

10 - ....

11 - ....

12 - ....

13 - ....

14 - ....

15 - ....

16 - ....

17 - ....

18 - ....

19 - ....

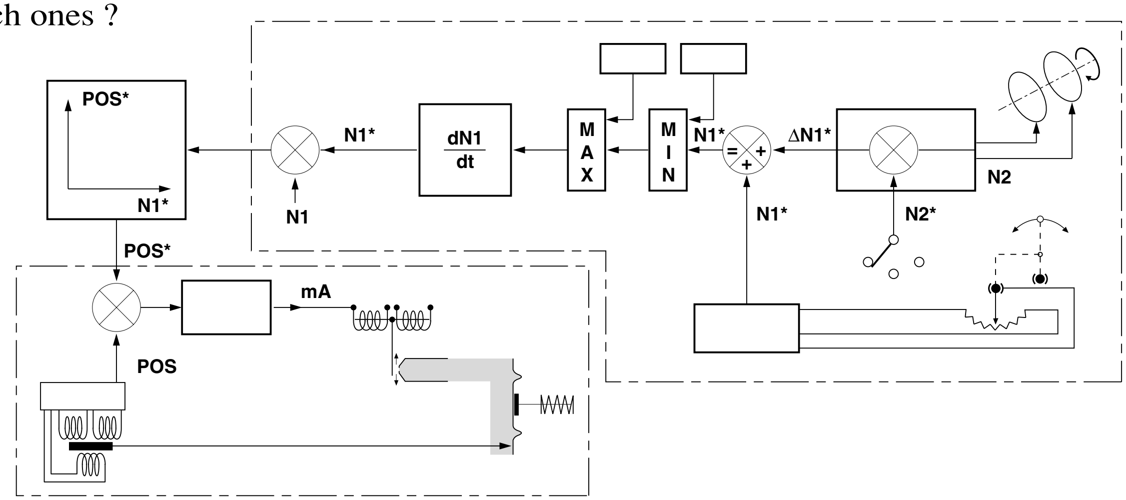
20 - ....

QUESTIONNAIRE 4 (continued)

12 - Choose the correct answers in the following table :

Type of gas generator governor ?	Hydromechanical	Electronic
Type of fuel pump ?	Centrifugal	Gear type
Reference parameters for the start fuel control unit ?	P2 - P3	N1 - t4
Reference parameters for the acceleration control unit ?	P2 - P0	t3 - Torque

13 - A number of the components of the circuit below cause the illumination of the red "engine power" indicator if they are defective. Which ones ?



1 - .... 2 - .... 3 - ....

QUESTIONNAIRE 4 (continued)

14 - Choose the correct answers in the following table :

Number of lifting points ?	2	4	8
Number of fire detectors ?	6	4	12
Setting of the cold section fire detectors ?	100 °C	1000 °C	300 °C
Setting of the hot section fire detectors ?	900 °C	400 °C	600 °C
Max air tapping flow for aircraft use?	20 g/s	300 g/s	180 g/s
Loss of power due to aircraft tapping ?	20 kW	200 kW	5 kW/h

15 - List the main resources for on condition monitoring :

1 - ....

2 - ....

3 - ....

4 - ....

5 - ....

6 - ....

7 - ....

8 - ....

QUESTIONNAIRE 4 (continued)

16 - Aim or definition of the following documents :

Maintenance manual	
Spare parts catalogue	
Tool catalogue	
Service bulletin	
Service letter	
Engine log book	
Flight manual	

END

of this manual and (maybe also) of the course

but not the END of your training
which must be continued,
harmonizing knowledge and experience.

THANK YOU for your kind attention.

Au revoir
Good bye
Adiós
Auf Wiedersehen
Adeus
Arrivederci
Farvel
Tot ziens
Adjö
Näkemiin
Antio
Ma salaam

REMARKS

Remarks (appreciations, criticisms, suggestions...) should be forwarded to :

TURBOMECA
CENTRE D'INSTRUCTION
40220 TARNOS - FRANCE

REMARKS CONCERNING THE TRAINING AIDS	REMARKS CONCERNING THE TRAINING COURSE

***Name* ....**

***Address* ....**

***Course* .... *from*............................... *to* ....**

TURBOMECA Training Centre

Turbomeca
snecma group

CENTRE D'INSTRUCTION

40220 TARNOS - FRANCE

Tel: *France* 05 59 74 40 07
International 33 5 59 74 40 07

Fax: *France* 05 59 74 45 16
International 33 5 59 74 45 16

E-mail: training.centre@turbomeca.fr

www.turbomeca-support.com