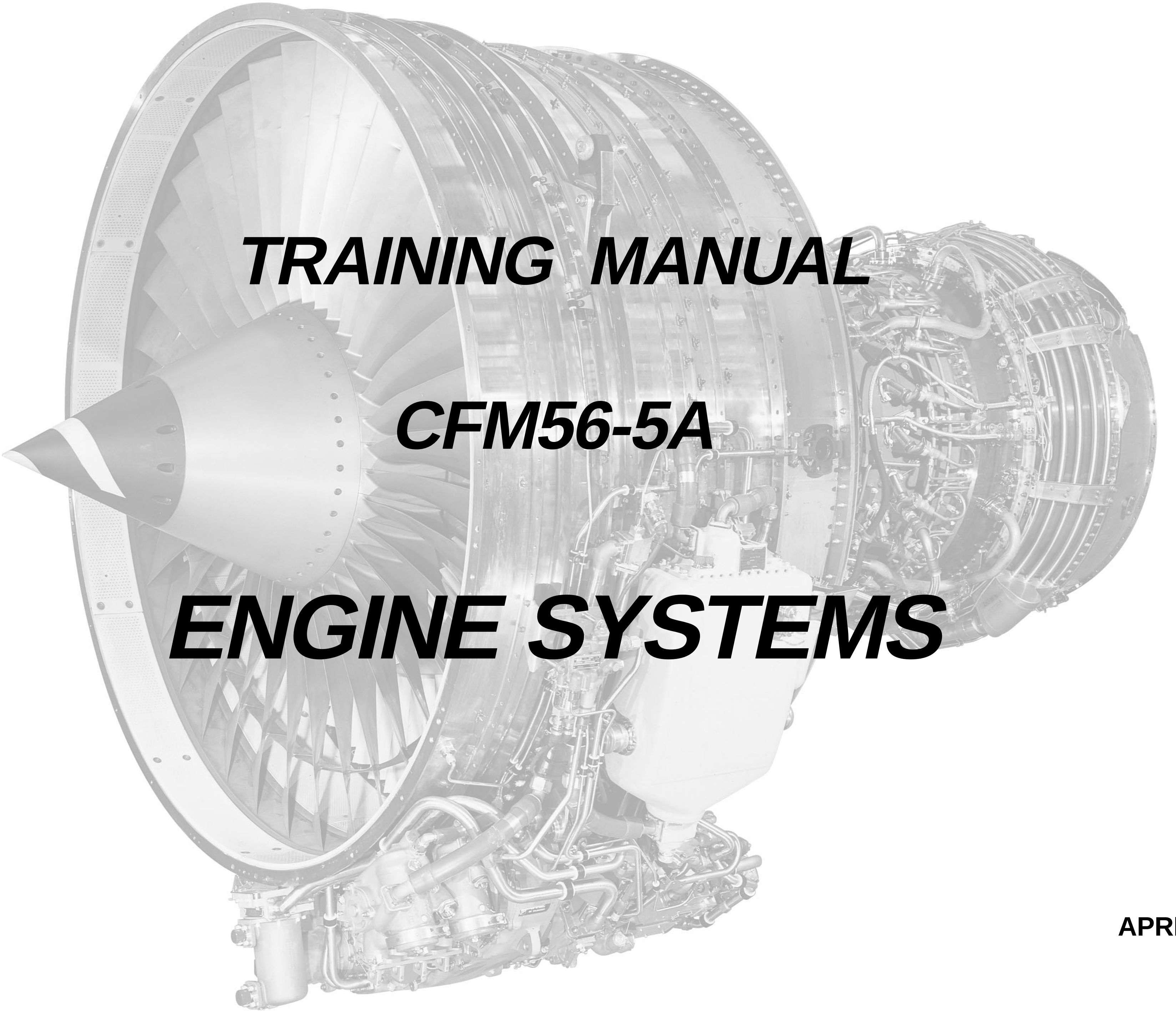
THE POWER
OF FLIGHT



TRAINING MANUAL

CFM56-5A

ENGINE SYSTEMS

APRIL 2000

CTC-045 Level 4

ENGINE SYSTEMS

THE POWER OF FLIGHT

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ABBREVIATIONS & ACRONYMS

A

A/C	AIRCRAFT
AC	ALTERNATING CURRENT
ACARS	AIRCRAFT COMMUNICATION ADDRESSING and REPORTING SYSTEM
ACMS	AIRCRAFT CONDITION MONITORING SYSTEM
ACS	AIRCRAFT CONTROL SYSTEM
ADC	AIR DATA COMPUTER
ADEPT	AIRLINE DATA ENGINE PERFORMANCE TREND
ADIRS	AIR DATA AND INERTIAL REFERENCE SYSTEM
AGB	ACCESSORY GEARBOX
AIDS	AIRCRAFT INTEGRATED DATA SYSTEM
ALF	AFT LOOKING FORWARD
ALT	ALTITUDE
AMB	AMBIENT
AMM	AIRCRAFT MAINTENANCE MANUAL
AOG	AIRCRAFT ON GROUND
APU	AUXILIARY POWER UNIT
ARINC	AERONAUTICAL RADIO, INC. (SPECIFICATION)
ATA	AIR TRANSPORT ASSOCIATION
ATHR	AUTO THRUST
ATO	ABORTED TAKE-OFF

B

BITE	BUILT IN TEST EQUIPMENT
BMC	BLEED MONITORING COMPUTER
BSI	BORESCOPE INSPECTION
BSV	BURNER STAGING VALVE
BVCS	BLEED VALVE CONTROL SOLENOID

C

CBP	(HP) COMPRESSOR BLEED PRESSURE
CCDL	CROSS CHANNEL DATA LINK
CCFG	COMPACT CONSTANT FREQUENCY GENERATOR
CCU	COMPUTER CONTROL UNIT
CCW	COUNTER CLOCKWISE
CDP	(HP) COMPRESSOR DISCHARGE PRESSURE
CFDIU	CENTRALIZED FAULT DISPLAY INTERFACE UNIT
CFDS	CENTRALIZED FAULT DISPLAY SYSTEM
CFMI	JOINT GE/SNECMA COMPANY (CFM INTERNATIONAL)
Ch A	channel A
Ch B	channel B
CMC	CENTRALIZED MAINTENANCE COMPUTER
CMM	COMPONENT MAINTENANCE MANUAL
CG	CENTER OF GRAVITY
cm.g	CENTIMETER x GRAMS
CHATV	CHANNEL ACTIVE
CIP(HP)	COMPRESSOR INLET PRESSURE
CIT(HP)	COMPRESSOR INLET TEMPERATURE
CODEP	HIGH TEMPERATURE COATING
CPU	CENTRAL PROCESSING UNIT

CRT	CATHODE RAY TUBE
CSD	CONSTANT SPEED DRIVE
CSI	CYCLES SINCE INSTALLATION
CSN	CYCLES SINCE NEW
Cu.Ni.In	COPPER.NICKEL.INDIUM
CW	CLOCKWISE

D

DAC	DOUBLE ANNULAR COMBUSTOR
DC	DIRECT CURRENT
DCU	DATA CONVERSION UNIT
DISC	DISCRETE
DIU	DIGITAL INTERFACE UNIT
DMC	DISPLAY MANAGEMENT COMPUTER
DMU	DATA MANAGEMENT UNIT
DPU	DIGITAL PROCESSING MODULE
DRT	DE-RATED TAKE-OFF

E

EBU	ENGINE BUILDUP UNIT
ECAM	ELECTRONIC CENTRALIZED AIRCRAFT MONITORING
ECU	ELECTRONIC CONTROL UNIT
EFH	ENGINE FLIGHT HOURS
EFIS	ELECTRONIC FLIGHT INSTRUMENT SYSTEM
EGT	EXHAUST GAS TEMPERATURE
EICAS	ENGINE INDICATING AND CREW ALERTING SYSTEM
EIS	ELECTRONIC INSTRUMENT SYSTEM
EIU	ENGINE INTERFACE UNIT
EMF	ELECTROMOTIVE FORCE
EMI	ELECTRO MAGNETIC INTERFERENCE
EMU	ENGINE MAINTENANCE UNIT
E(E)PROM	(ELECTRICALLY ERASABLE PROGRAMMABLE READ ONLY MEMORY
ESN	ENGINE SERIAL NUMBER

F

FAA	FEDERAL AVIATION AGENCY
FADEC	FULL AUTHORITY DIGITAL ENGINE CONTROL
FAR	FUEL/AIR RATIO
FDRS	FLIGHT DATA RECORDING SYSTEM
FEIM	FIELD ENGINEERING INVESTIGATION MEMO
FFCCV	FAN FRAME/COMPRESSOR CASE VERTICAL (VIBRATION SENSOR)
FI	FLIGHT IDLE (F/I)
FLA	FORWARD LOOKING AFT
FLX TO	FLEXIBLE TAKE-OFF
FMGC	FLIGHT MANAGEMENT AND GUIDANCE COMPUTER
FMS	FLIGHT MANAGEMENT SYSTEM

FMV FUEL METERING VALVE
FOD FOREIGN OBJECT DAMAGE
FPA FRONT PANEL ASSEMBLY
FPI FLUORESCENT PENETRANT INSPECTION
FRV FUEL RETURN VALVE
FWC FAULT WARNING COMPUTER
FWD FORWARD

G
GE GENERAL ELECTRIC
GEM GROUND-BASED ENGINE MONITORING
GI GROUND IDLE (G/I)
g.in GRAM x INCHES
GMT GREENWICH MEAN TIME
GSE GROUND SUPPORT EQUIPMENT

H
HCF HIGH CYCLE FATIGUE
HDS HORIZONTAL DRIVE SHAFT
HMU HYDROMECHANICAL UNIT
HP HIGH PRESSURE
HPC HIGH PRESSURE COMPRESSOR
HPCR HIGH PRESSURE COMPRESSOR ROTOR
HPSOV HIGH PRESSURE SHUTOFF VALVE
HPT HIGH PRESSURE TURBINE
HPTC HIGH PRESSURE TURBINE CLEARANCE
HPT(A)CC HIGH PRESSURE TURBINE (ACTIVE) CLEARANCE CONTROL
HPTCCV HIGH PRESSURE TURBINE CLEARANCE CONTROL VALVE
HPTR HIGH PRESSURE TURBINE ROTOR
Hz HERTZ (CYCLES PER SECOND)

I
IDG INTEGRATED DRIVE GENERATOR
ID PLUG IDENTIFICATION PLUG
IFSD IN FLIGHT SHUT DOWN
IGB INLET GEARBOX
IGN IGNITION
IGV INLET GUIDE VANE
in. INCH
I/O INPUT/OUTPUT
IOM INPUT OUTPUT MODULE
IR INFRA RED

K
K X 1000

L
lbs. POUNDS, WEIGHT
LCF LOW CYCLE FATIGUE
LE (L/E) LEADING EDGE
L/H LEFT HAND
LP LOW PRESSURE
LPC LOW PRESSURE COMPRESSOR
LPT LOW PRESSURE TURBINE
LPTC LOW PRESSURE TURBINE CLEARANCE

LPT(A)CC	LOW PRESSURE TURBINE (ACTIVE) CLEARANCE CONTROL
LPTR	LOW PRESSURE TURBINE ROTOR
LRU	LINE REPLACEABLE UNIT
LVDT	LINEAR VARIABLE DIFFERENTIAL TRANSFORMER

M

MO	AIRCRAFT SPEED MACH NUMBER
MCD	MAGNETIC CHIP DETECTOR
MCDU	MULTIPURPOSE CONTROL AND DISPLAY UNIT
MCL	MAXIMUM CLIMB
MCT	MAXIMUM CONTINUOUS
MDDU	MULTIPURPOSE DISK DRIVE UNIT
mm.	MILLIMETERS
MMEL	MAIN MINIMUM EQUIPMENT LIST
MTBF	MEAN TIME BETWEEN FAILURES
MTBR	MEAN TIME BETWEEN REMOVALS

N

N1 (NL)	LOW PRESSURE ROTOR ROTATIONAL SPEED
N1ACT	ACTUAL N1
N1DMD	DEMANDED N1
N1CMD	COMMANDED N1
N1TARGET	TARGETED FAN SPEED
N2 (NH)	HIGH PRESSURE ROTOR ROTATIONAL SPEED
N2ACT	ACTUAL N2
NVM	NON VOLATILE MEMORY

O

OAT	OUTSIDE AIR TEMPERATURE
OGV	OUTLET GUIDE VANE
OSG	OVERSPEED GOVERNOR

P

P0	AMBIENT STATIC PRESSURE
P25	HP COMPRESSOR INLET TOTAL AIR TEMPERATURE
PCU	PRESSURE CONVERTER UNIT
PLA	POWER LEVER ANGLE
PMC	POWER MANAGEMENT CONTROL
PMUX	PROPULSION MULTIPLEXER
PS12	FAN INLET STATIC AIR PRESSURE
PS13	FAN OUTLET STATIC AIR PRESSURE
PS3HP	COMPRESSOR DISCHARGE STATIC AIR PRESSURE
psi	POUNDS PER SQUARE INCH
psia	POUNDS PER SQUARE INCH ABSOLUTE
psid	POUNDS PER SQUARE INCH DIFFERENTIAL

psig	POUNDS PER SQUARE INCH GAGE
PSM	POWER SUPPLY MODULE
PSS	(ECU) PRESSURE SUB-SYSTEM
PSU	POWER SUPPLY UNIT
PT	TOTAL PRESSURE
PT2	FAN INLET TOTAL AIR PRESSURE (PRIMARY FLOW)

Q

QAD	QUICK ATTACH DETACH
QTY	QUANTITY

R

RAM	RANDOM ACCESS MEMORY
RDS	RADIAL DRIVE SHAFT
R/H	RIGHT HAND
RPM	REVOLUTIONS PER MINUTE
RTD	RESISTIVE THERMAL DEVICE
RTV	ROOM TEMPERATURE VULCANIZING (MATERIAL)
RVDT	ROTARY VARIABLE DIFFERENTIAL TRANSFORMER

S

SAC	SINGLE ANNULAR COMBUSTOR
SAV	STARTER AIR VALVE
SB	SERVICE BULLETIN
SCU	SIGNAL CONDITIONING UNIT
SDI	SOURCE/DESTINATION IDENTIFIER (BITS) (CF ARINC SPEC)
SDU	SOLENOID DRIVER UNIT
SER	SERVICE EVALUATION REQUEST
SFC	SPECIFIC FUEL CONSUMPTION
SG	SPECIFIC GRAVITY
SLS	SEA LEVEL STANDARD (CONDITIONS : 29.92 in. Hg/59 F)
SMM	STATUS MATRIX
SMP	SOFTWARE MANAGEMENT PLAN
S/N	SERIAL NUMBER
SNECMA	SOCIETE NATIONALE D'ETUDE ET DE CONSTRUCTION DE MOTEURS D'AVIATION
SOL	SOLENOID
SOV	SHUT-OFF VALVE
S/R	SERVICE REQUEST
S/V	SHOP VISIT
SVR	SHOP VISIT RATE
SW	SOFTWARE

T

T12	FAN INLET TOTAL AIR TEMPERATURE
T25	HP COMPRESSOR INLET AIR TEMPERATURE
T3	HP COMPRESSOR DISCHARGE AIR TEMPERATURE
T49.5	EXHAUST GAS TEMPERATURE
T5	LOW PRESSURE TURBINE DISCHARGE TOTAL AIR TEMPERATURE
TAT	TOTAL AIR TEMPERATURE
TBD	TO BE DETERMINED

T/E	TRAILING EDGE
T/C	THERMOCOUPLE
TC (T Case)	HP TURBINE CASE TEMPERATURE
TCC	TURBINE CLEARANCE CONTROL
TCJ	TEMPERATURE COLD JUNCTION
TECU	ELECTRONIC CONTROL UNIT INTERNAL TEMPERATURE
TEO	ENGINE OIL TEMPERATURE
TGB	TRANSFER GEARBOX
Ti	TITANIUM
TLA	THROTTLE LEVER ANGLE
TM	TORQUE MOTOR
TMC	TORQUE MOTOR CURRENT
TO/GA	TAKE OFF/GO AROUND
T/O	TAKE OFF
T oil	OIL TEMPERATURE
TPU	TRANSIENT PROTECTION UNIT
T/R	THRUST REVERSER
TRA	THROTTLE RESOLVER ANGLE
TRDV	THRUST REVERSER DIRECTIONAL VALVE
TRPV	THRUST REVERSER PRESSURIZING VALVE
TSI	TIME SINCE INSTALLATION (HOURS)
TSN	TIME SINCE NEW (HOURS)
TTL	TRANSISTOR TRANSISTOR LOGIC

U

UER	UNSCHEDULED ENGINE REMOVAL

V

VAC	VOLTAGE, ALTERNATING CURRENT
VBV	VARIABLE BLEED VALVE
VDC	VOLTAGE, DIRECT CURRENT
VDT	VARIABLE DIFFERENTIAL TRANSFORMER
VRT	VARIABLE RESISTANCE TRANSDUCER
VSV	VARIABLE STATOR VANE

W

WDM	WATCHDOG MONITOR
WFM	WEIGHT OF FUEL METERED
WOW	WEIGHT ON WHEEL

ENGLISH/METRIC CONVERSIONS
METRIC/ENGLISH CONVERSIONS

1 mile = 1.609 km
1 km = 0.621 mile

1 ft = 0.3048 m or 30.48 cm
1 m = 3.281 ft. or 39.37 in.

1 in. = 0.0254 m or 2.54 cm
1 cm = 0.3937 in.

1 mil. = 25.4 10-6 m or 25.4mm
1 mm = 39.37 mils.

1 in.^{2} = 6.45 cm^2
1 m^2 = 10.76 sq. ft.
1 cm^2 = 0.155 sq.in.

1 USG = 3.785 l (dm^3)

1 in.^{3} = 16.39 cm^3
1 m^3 = 35.31 cu. ft.
1 dm^3 = 0.264 US gallon
1 cm^3 = 0.061 cu.in.

1 lb = 0.454 kg
1 kg =2.205 lbs

1 psi = 6.890 kPa or 6.89 x 10^{-2} bar
1 Pa = 1.45 x 10^{-4} psi
1 kPa = 0.145 psi or 0.01 bar
1 bar = 14.5 psi

°F = 1.8 x °**C** + 32
°C = (°F - 32) /1.8

FADEC SYSTEM INTRODUCTION

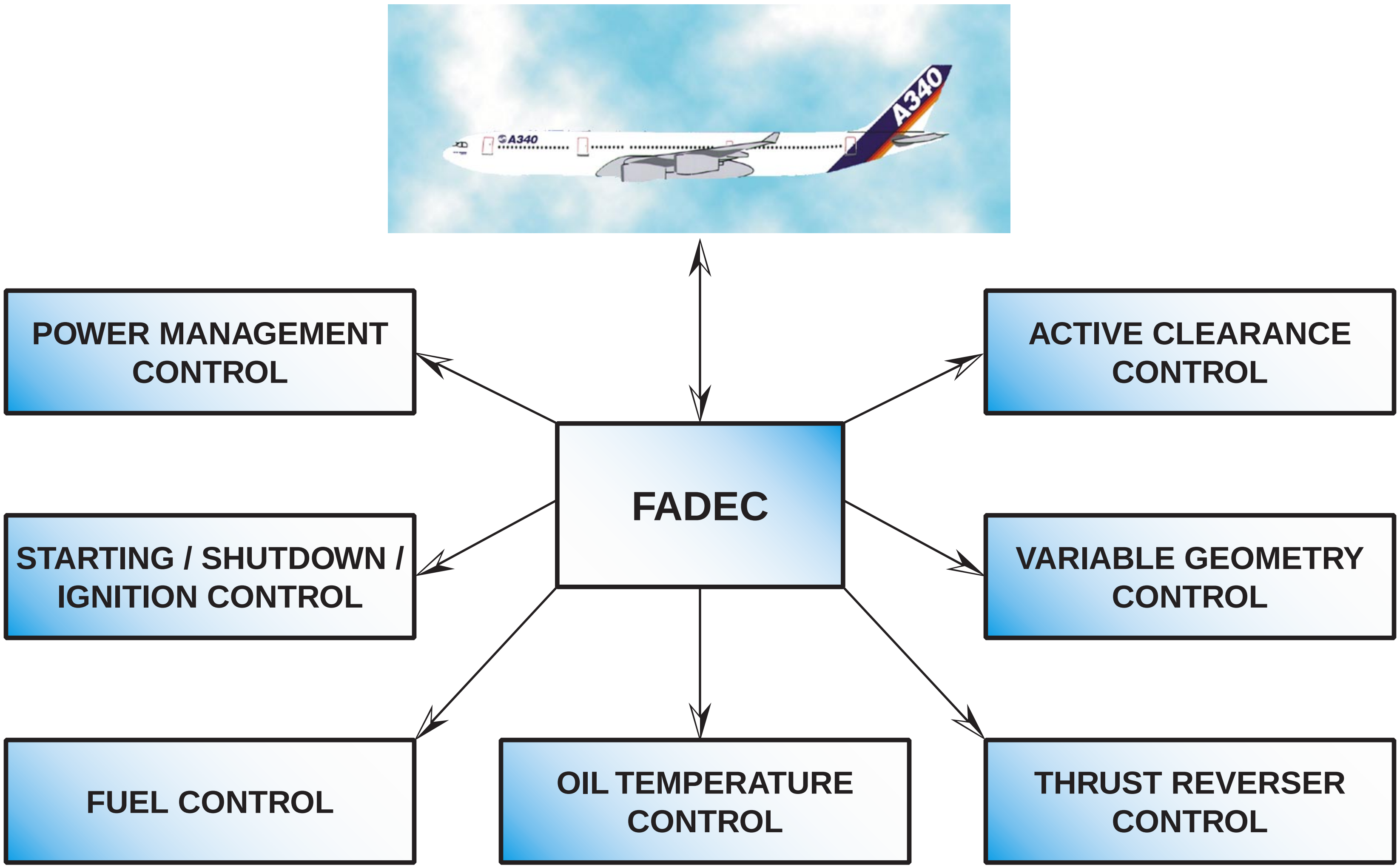
FADEC SYSTEM INTRODUCTION

FADEC purpose.

The CFM56-5A operates through a system known as FADEC (Full Authority Digital Engine Control).

It takes complete control of engine systems in response to command inputs from the aircraft. It also provides information to the aircraft for flight deck indications, engine condition monitoring, maintenance reporting and troubleshooting.

- It performs fuel control and provides limit protections for N1 and N2.
- It controls the engine start sequence and prevents the engine from exceeding starting EGT limits (aircraft on ground).
- It manages the thrust according to 2 modes: manual and autothrust.
- It provides optimal engine operation by controlling compressor airflow and turbine clearances.
- It completly supervises the thrust reverser operation.
- Finally, it controls IDG cooling fuel recirculation to the aircraft tank.



FADEC PURPOSE

CTC-045-001-00

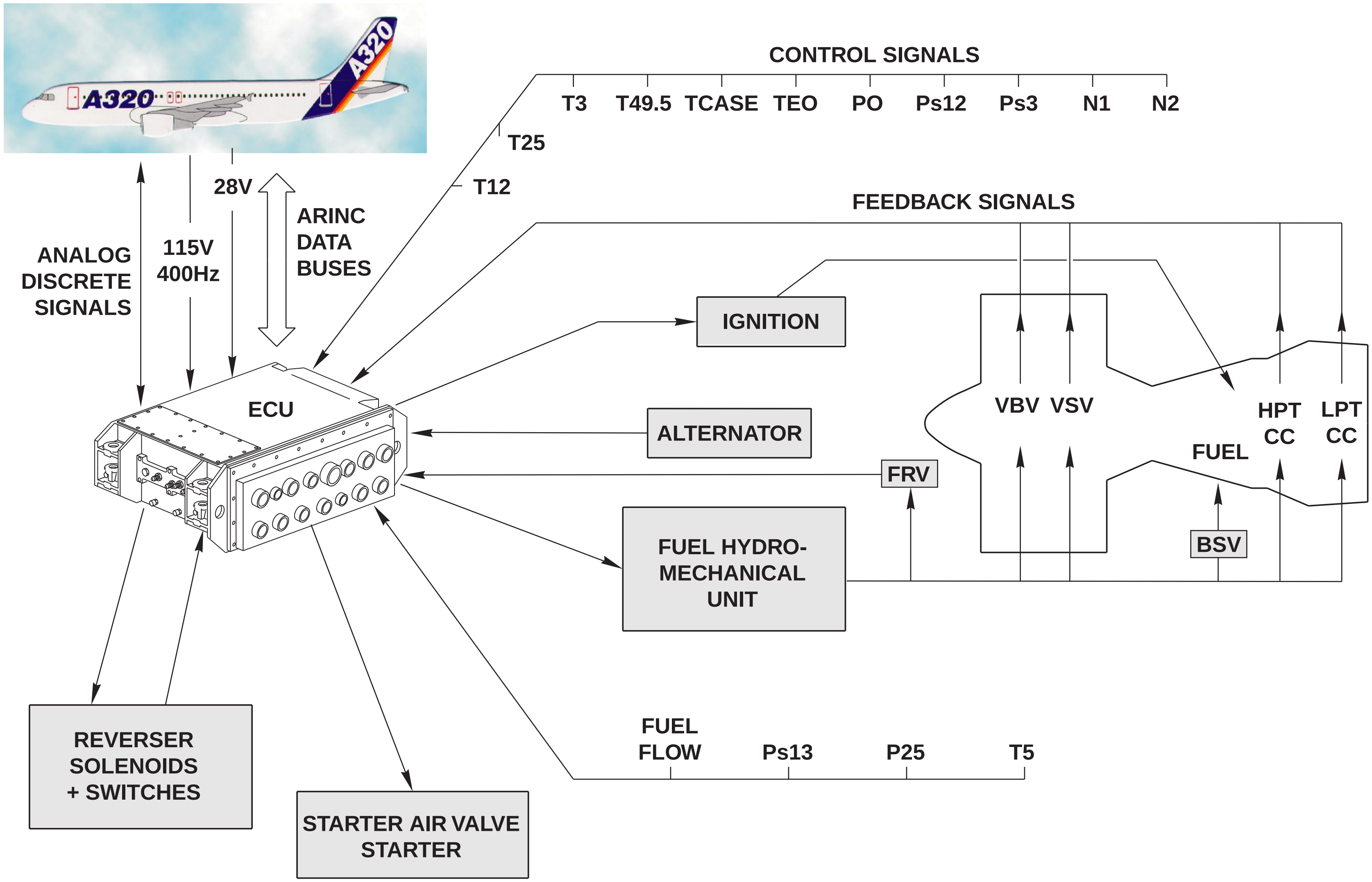
FADEC components.

The FADEC system consists of :

- -an Engine Control Unit (ECU) containing two identical computers, designated channel A and channel B. The ECU electronically performs engine control calculations and monitors the engine's condition.

- -a Hydro-Mechanical Unit (HMU), which converts electrical signals from the ECU into hydraulic pressures to drive the engine's valves and actuators.

- -peripheral components such as valves, actuators and sensors used for control and monitoring.



FADEC COMPONENTS

CTC-045-002-00

FADEC interfaces.

To perform all its tasks, the FADEC system communicates with the aircraft computers through the ECU.

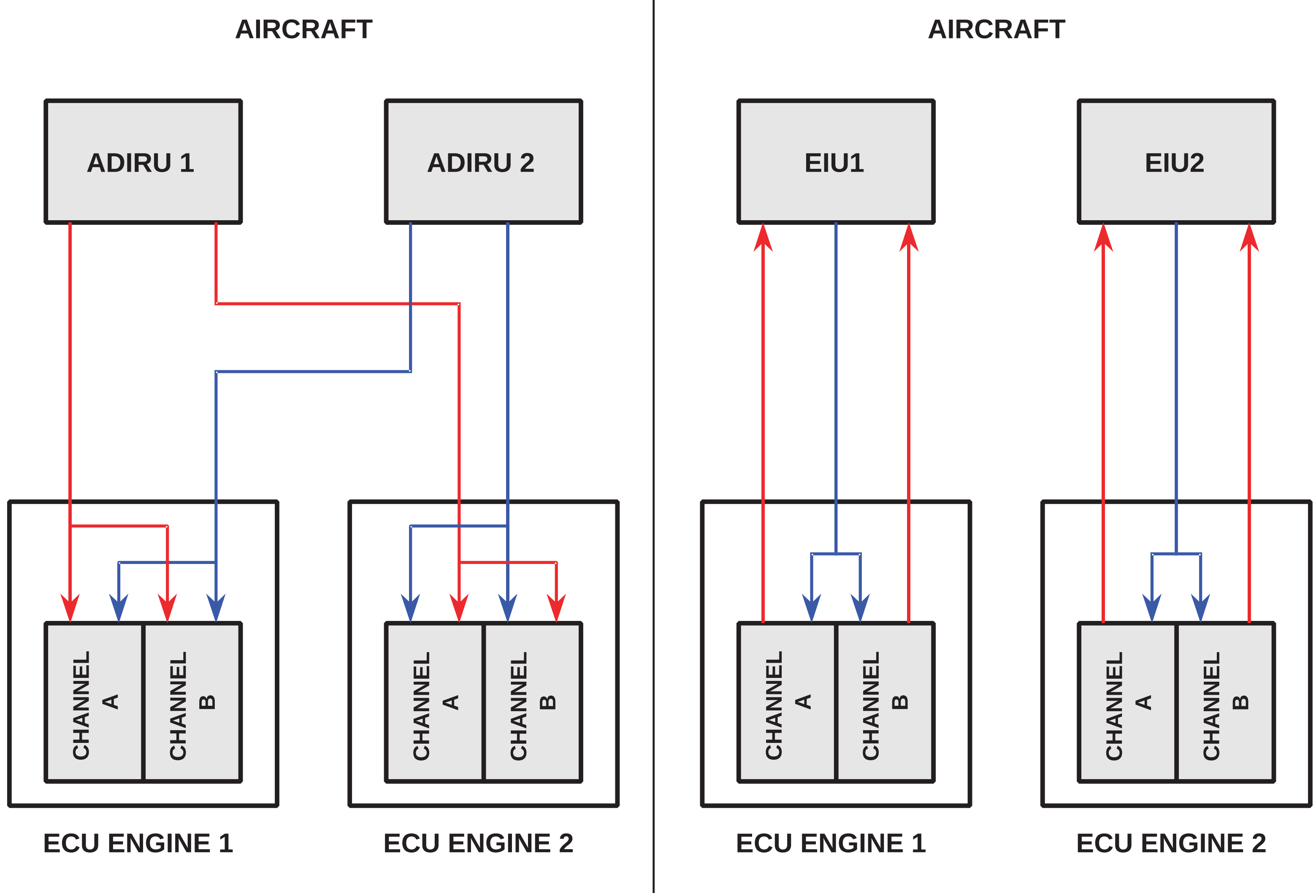
The ECU receives operational commands from the Engine Interface Unit (EIU), which is an interface between the ECU and aircraft systems.

It also receives:

- air data parameters (altitude, total air temperature, total pressure and mach number) for thrust calculation, from 2 Air Data and Inertial Reference Units (ADIRU), connected to both ECU channels.

- the position of theThrust Lever Angle (TLA).

The ECU also interfaces with other aircraft systems, either directly, or through the EIU.



FADEC INTERFACES

CTC-045-003-00

FADEC design.

The FADEC system is a Built In Test Equipment (BITE) system. This means it is able to detect its own internal faults and also external faults.

Dual channels:
The FADEC system is fully redundant and built around the two-channel ECU.
The valves and actuators are fitted with dual sensors to provide the ECU with feedback signals.
All control inputs are dual, but some parameters, used for monitoring and indicating, are single.

CCDL:
To enhance system reliability, all inputs to one channel are made available to the other, through a Cross Channel Data Link (CCDL). This allows both channels to remain operational even if important inputs to one of them fail.

Active / Stand-by:
The two channels, A and B, are identical and permanently operational, but they operate independently from each other. Both channels always receive inputs and process them, but only the channel in control, called the Active channel, delivers output commands. The other is called the Stand-by channel.

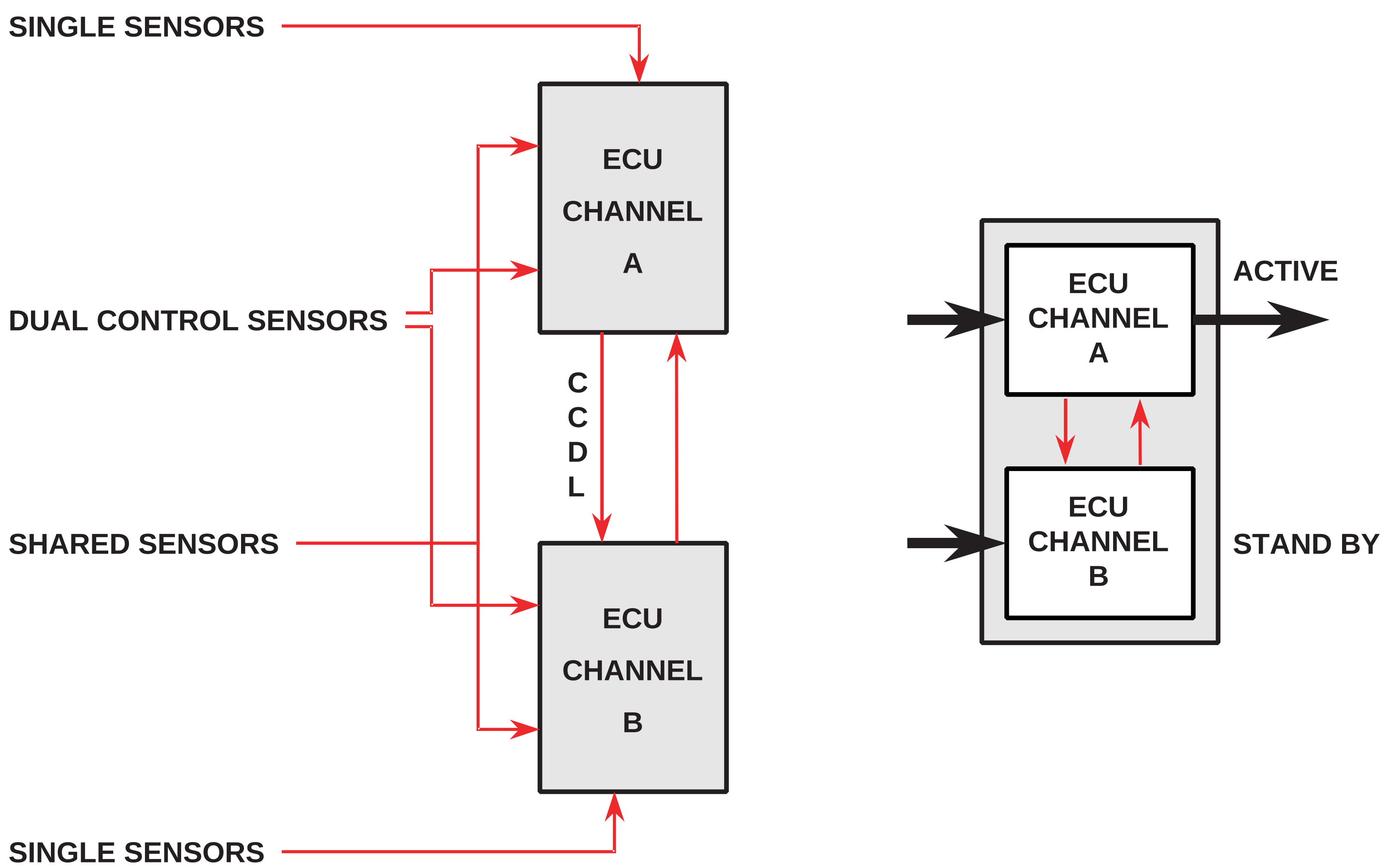
Channel selection and fault strategy:
Active and Stand-by channel selection is performed at ECU power-up and during operation.

The BITE system detects and isolates failures, or combinations of failures, in order to determine the health status of the channels and to transmit maintenance data to the aircraft.

Active and Stand-by selection is based upon the health of the channels and each channel determines its own health status. The healthiest is selected as the Active channel.

When both channels have an equal health status, Active / Stand-by channel selection alternates with every engine start, as soon as N2 is greater than 11000 RPM.

Failsafe control:
If a channel is faulty and the Active channel is unable to ensure an engine control function, this function is moved to a position which protects the engine, and is known as the failsafe position.



FADEC DESIGN

CTC-045-004-00

Closed loop control operation.

In order to properly control the various engine systems, the ECU uses an operation known as closed loop control.

The ECU calculates a position for a system component :
- the Command

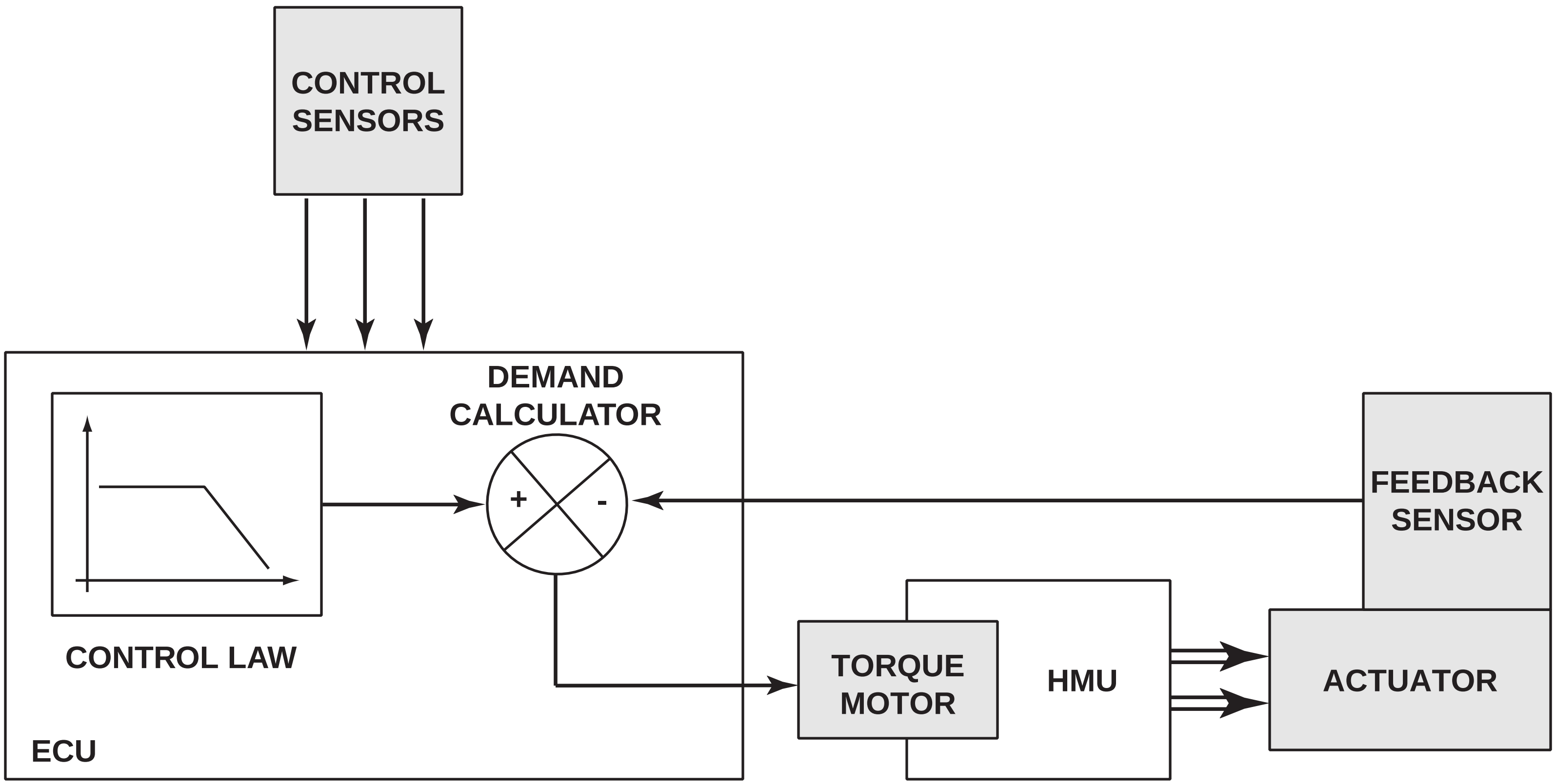
The ECU then compares the Command with the actual position of the component (feedback) and calculates a position difference :
- the Demand

The ECU, through the HMU, sends a signal to a component (valve, actuator) which causes it to move.

With the movement of the system valve or actuator, the ECU is provided with a feedback of the component's position.

The process is repeated until there is no longer a position difference.

The result completes the loop and enables the ECU to precisely control a system component on the engine.



CTC-045-005-00

CLOSED LOOP CONTROL PHILOSOPHY

Input parameters selection.

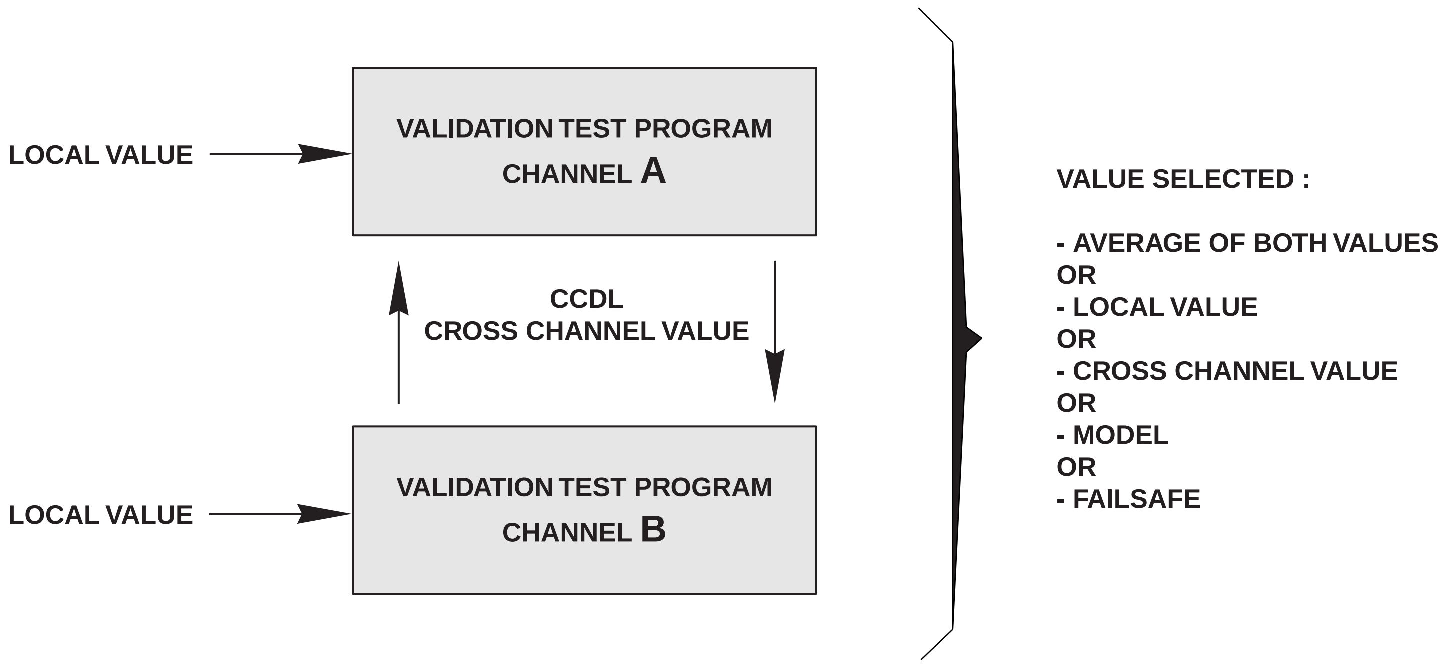
All sensors are dual (except T 49.5, T5, PS13, P25, WF).
To perform all its calculations, each channel receives:
- A local value.
- A cross channel value, through the CCDL.

Both values pass through a validation test program in each ECU channel. Then the right value to be used is selected depending on parameter validity. It can be :
- The average of both values.
- The local value.
- The cross channel value.

In case of a dual sensor failure, a model value, computed from other available parameters, is selected.
This is the case for parameters such as:
- N1, N2, PS3, T25, T3, FMV, VBV and VSV feedback position.

For other parameters, if the ECU is not able to select a valid value, failsafe values are selected.

A lost parameter does not generate an ECU channel change as long as the CCDL is operative.



CTC-045-006-00

INPUT PARAMETERS SELECTION

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ELECTRONIC CONTROL UNIT

ELECTRONIC CONTROL UNIT

ECU Location.

The ECU is a dual channel computer housed in an aluminium chassis, which is secured on the right hand side of the fan inlet case.

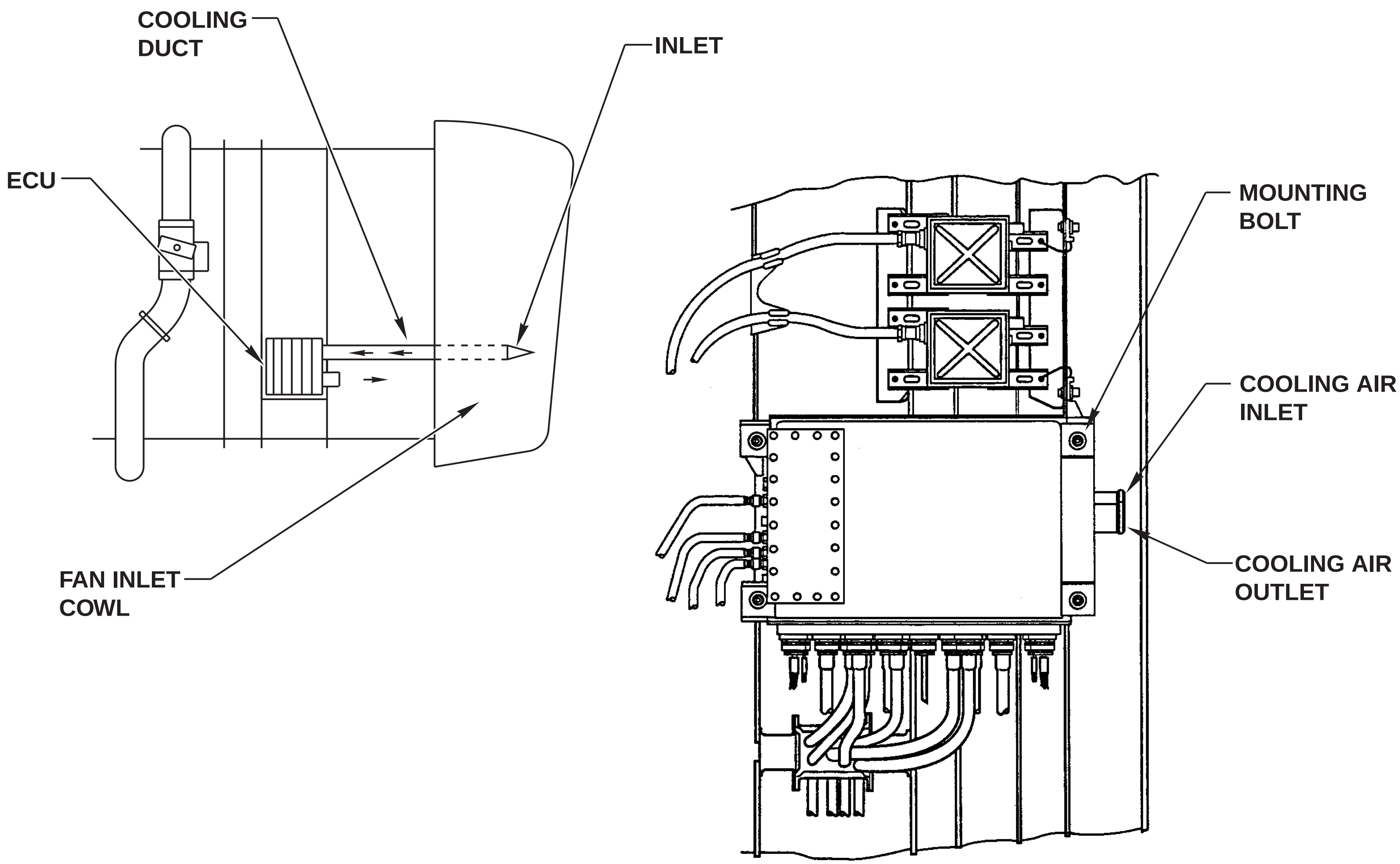
Four mounting bolts, with shock absorbers, provide isolation from shocks and vibrations.

Two metal straps ensure ground connection.

ECU Cooling System.

To operate correctly, the ECU requires cooling to maintain internal temperatures within acceptable limits.

Ambient air is picked up by an air scoop, located on the right hand side of the fan inlet cowl. This cooling air is routed up to the ECU internal chamber, around channel A and B compartments, and then exits through an outlet port in the fan compartment.



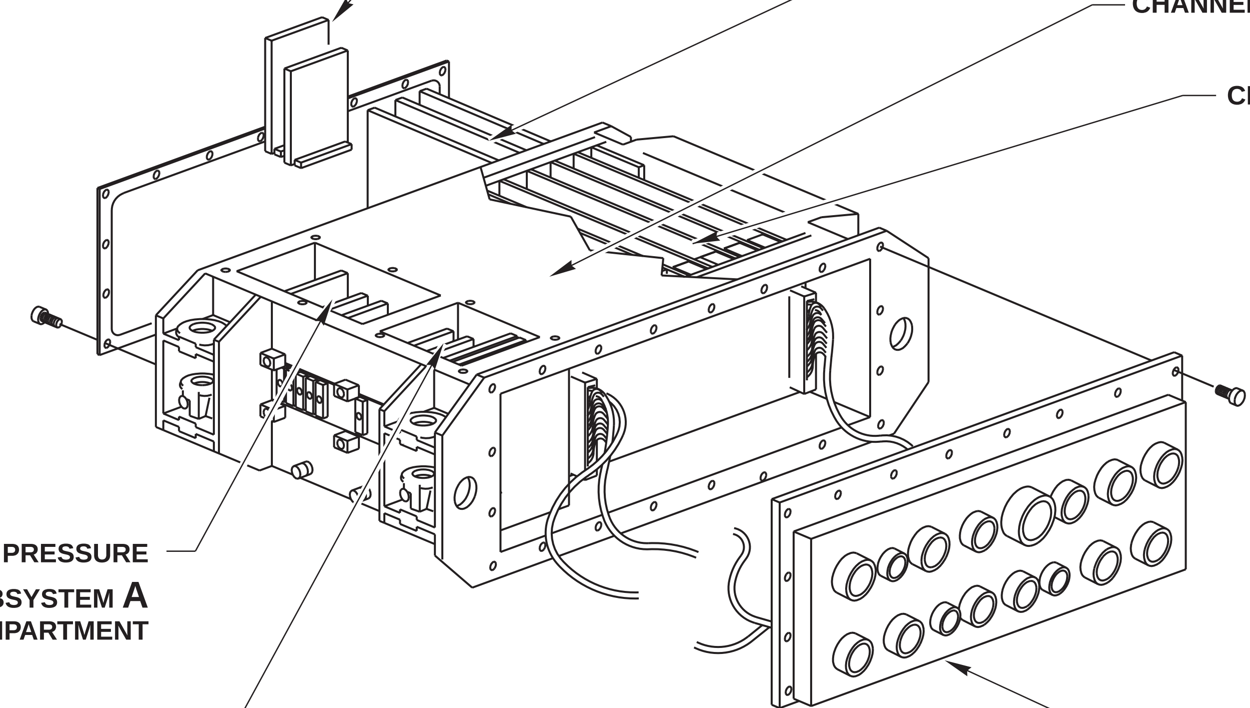
CTC-045-007-00

ELECTRONIC CONTROL UNIT

ECU architecture.

The ECU has three compartments :

- The main compartment houses channel A and channel B circuit boards and a physical partition separates them. The motherboard, accessed through the front panel, accomodates :
  - Electrical connectors.
  - Ignition relays.
  - Hardwired lightning protection assemblies.
- Two pressure subsystem compartments house pressure transducers. One subsystem is dedicated to channel A, the other to channel B.



CTC-045-008-00

ECU COMPARTMENTS

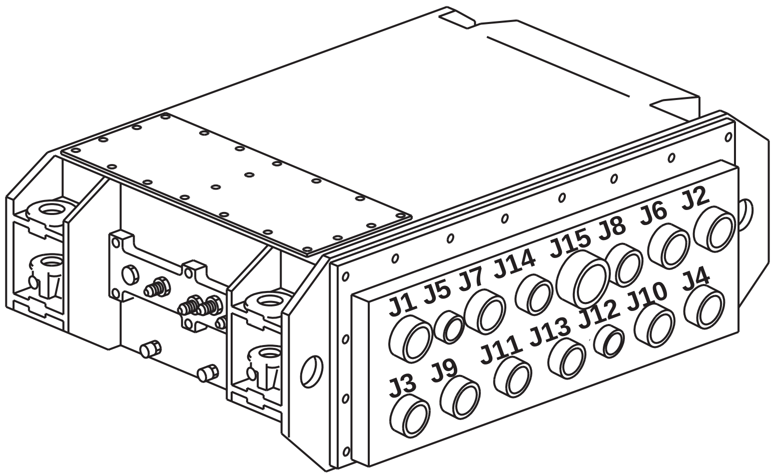
Front Panel Electrical Connectors.

There are 15 threaded electrical connectors located on the front panel.

Each connector features a unique key pattern which only accepts the correct corresponding cable plug.

The connectors are identified through numbers from J1 to J15 marked on the panel.

All engine input and command output signals are routed to and from channels A and B, through separate cables and connectors.



CHANNEL A CONNECTOR (ODD)	CHANNEL B CONNECTOR (EVEN)	FUNCTION
J1	J2	A/C POWER (28V) AND IGNITER POWER (115V)
J3	J4	A/C INPUT/OUTPUT AND TLA
J5	J6	THRUST REVERSER
J7	J8	SOLENOIDS, TORQUE MOTORS, RESOLVERS, N2
J9	J10	ALTERNATOR, SAV, N1 AND T12
J11	J12	LVDT'S, RVDT'S, T25, BSV POSITION SWITCH
SHARED	J14	ENGINE IDENTIFICATION PLUG
J13	SHARED	WF METER, THERMOCOUPLES
J15	SHARED	TEST INTERFACE

CTC-045-009-00

ELECTRICAL CONNECTORS

Engine Rating / Identification Plug.

The engine rating/identification plug provides the ECU with engine configuration information for proper engine operation.

It is plugged into connector J14 and attached to the fan case by a metal strap. It remains with the engine even after ECU replacement.

The ECU stores schedules, in its Non-Volatile Memory (NVM), for all available engine configurations.
During initialization, it reads the plug by looking for voltages on certain pins. Depending on the location and voltage present at specific pins, the ECU will select a specific schedule.

In the case of a missing, or invalid ID plug, the ECU uses the value stored in the NVM for the previous plug configuration.

Coding Circuit.

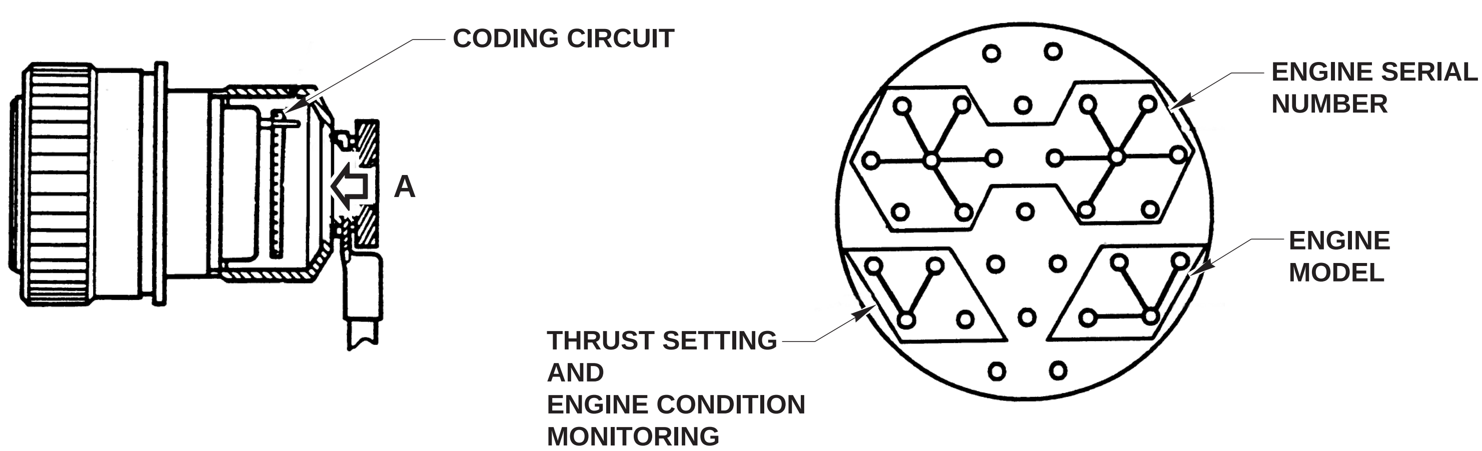
The plug includes a coding circuit, soldered to the plug connector pins.

Fuse links :

The coding circuit is equipped with fuse links which either ensure, or prohibit connections between the different plug connector pins. They provide the ECU with thrust information at power up.
They are made by metallization of an area between two contacts of the coding circuit.
Closed by design, these links can only be opened by burning them out, thus their reconfiguration is not possible.

PMUX (engine condition monitoring) **:**
An optional monitoring kit is available upon customer request and comprises: PS13, P25 and T5.

VIEW A
ADDITIONAL BOOST PMUX (FUSE LINKS)



IDENTIFICATION PLUG

CTC-045-010-00

Certified thrust ratings :

Specific contacts within the identification plug enable various thrust ratings, which are :

- 5A4 : 22,000 lbs for A319 (EGT = 890°C)
- 5A4/F: 22,000 lbs for A319 (EGT = 915°C).
- 5A5 : 23,500 lbs for A319 (EGT = 890°C).
- 5A5/F: 23,500 lbs for A319 (EGT = 915°C) .

- 5A1 : 25,000 lbs for A320 (EGT = 890°C).
- 5A1/F: 25,000 lbs for A320 (EGT = 915°C).
- 5A3 : 26,500 lbs for A320 (EGT = 915°C).

CFM56-5A FOR AIRBUS APPLICATIONS

CTC-045-011-00

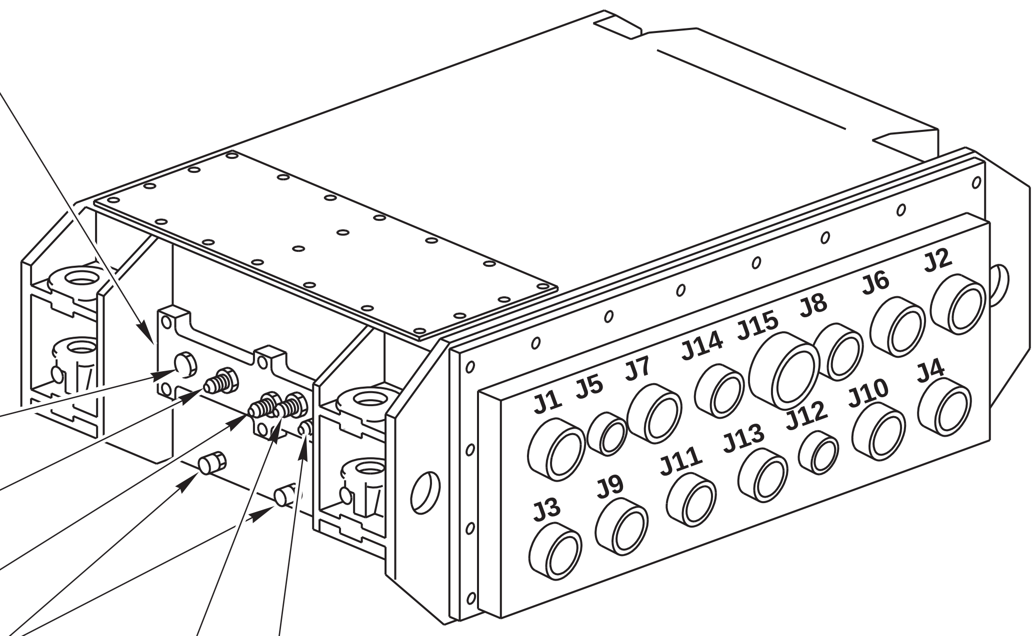
Pressure Sub-system.

Five pneumatic pressure signals are supplied to the ECU pressure sub-system.

Transducers inside the pressure sub-system convert these pneumatic signals into electrical signals.

The three pressures used for engine control (P0, PS12, PS3) are supplied to both channels.

The two optional monitoring pressures are supplied to a single channel :
- PS13 is dedicated to channel A
- P25 is dedicated to channel B



PRESSURE SUB SYSTEM

CTC-045-012-00

Pressure sub-system interfaces.

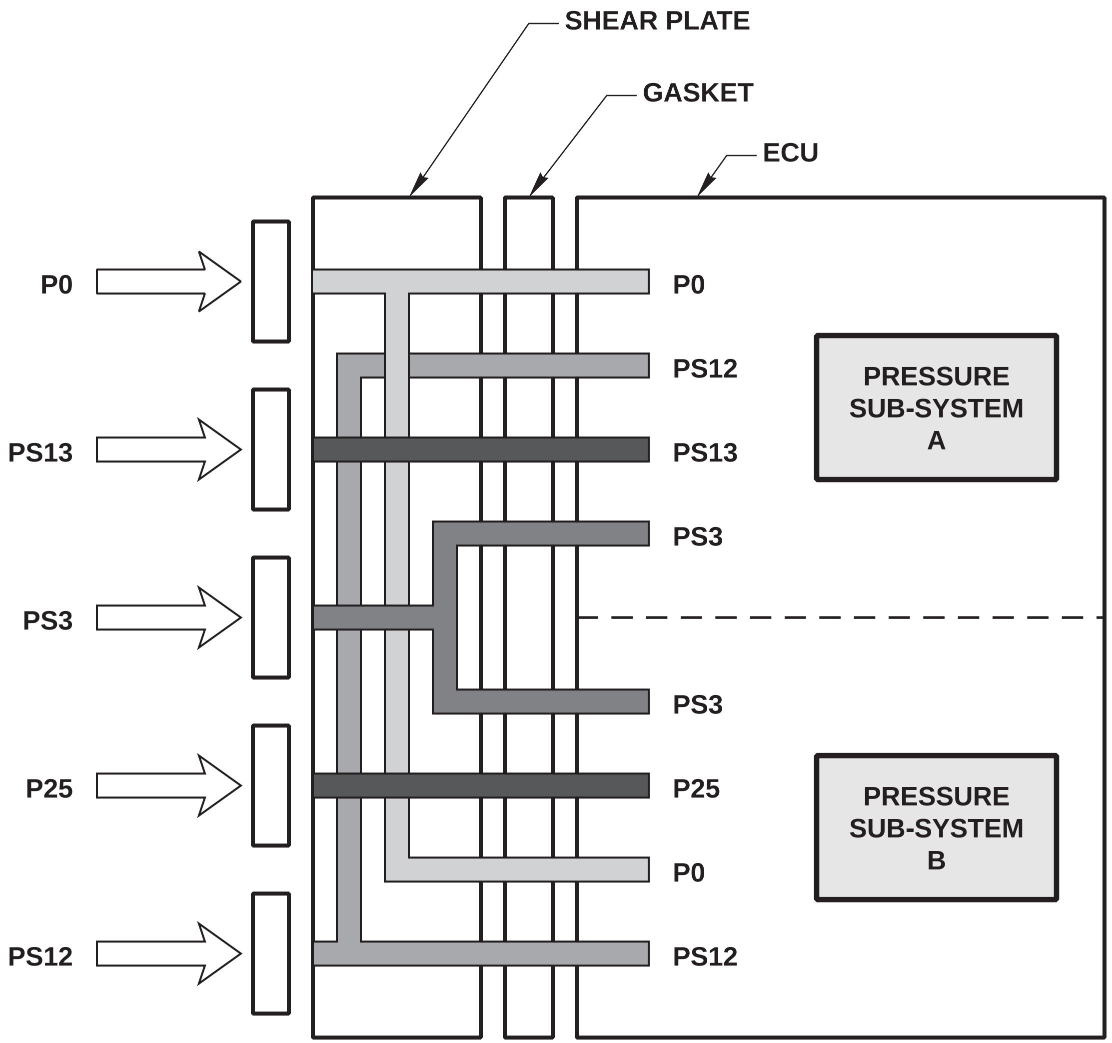
The shear plate serves as an interface between the pneumatic lines and the ECU pressure sub-system.

The three control pressures are divided into channel A and channel B signals by passages inside the shear plate, which is bolted on the ECU chassis.

Individual pressure lines are attached to connectors on the shear plate. The last few inches of the pressure lines are flexible to facilitate ECU removal and installation.

The shear plate is never removed during line maintenance tasks.

When the optional monitoring kit (PMUX) is not required, P25 and PS13 ports are blanked off, and the two dedicated transducers are not installed in the ECU.



SHEAR PLATE

CTC-045-013-00

ELECTRONIC CONTROL UNIT

ECU power supply.

The ECU is provided with redundant power sources to ensure an uninterrupted and failsafe power supply.

A logic circuit within the ECU, automatically selects the correct power source in the event of a failure.

The power sources are the aircraft 28 VDC normal and emergency busses.

The two aircraft power sources are routed through the EIU and connected to the ECU.
- -The A/C normal bus is hardwired to channel B.
- -The A/C emergency bus is hardwired to channel A.

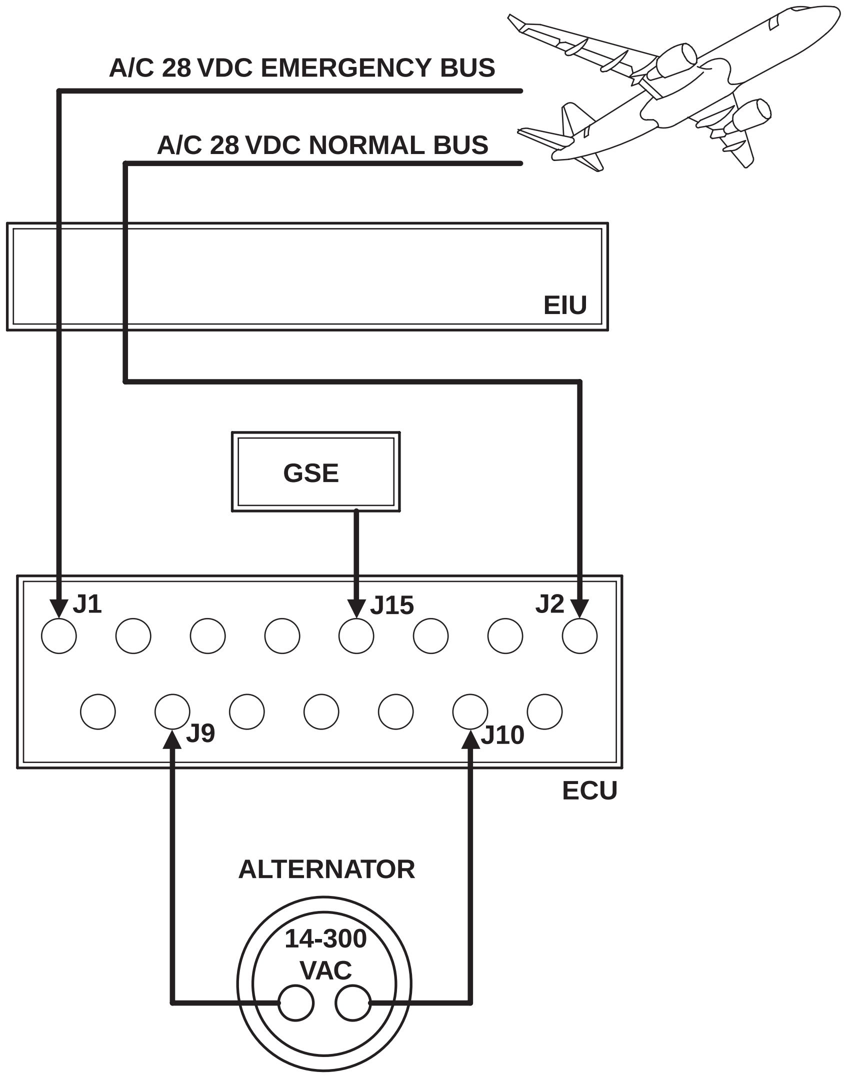
Control Alternator.

The control alternator provides two separate power sources from two independent windings.

One is hardwired to channel A, the other to channel B.

The alternator is capable of supplying the necessary power above an engine speed of approximately 10% N2.

ECU test equipment provides 28 VDC power to the ECU during bench testing and it is connected to connector J15.



ECU POWER SUPPLY

CTC-045-014-00

ECU Power Supply Logic.

Power supply when N2 < 12%.
Each channel is supplied by the A/C 28 VDC, through the EIU. This enables:

- Automatic ground checks of the ECU before engine running.
- Engine starting.
- Supply of power to the ECU until the engine speed reaches 12% N2.

Power supply when N2 > 15% :

- Above 15% N2, the ECU logic automatically switches off the A/C power source, through the EIU power down function.

Note : In case of total alternator failure, the ECU will receive, as a back-up, the 28 VDC power from the A/C network. If the failure only affects the active channel, the ECU switches engine control to the other channel.
The ENGine FIRE pushbutton cuts off the A/C 28 VDC.

Auto Power Down.

The ECU is automatically powered down on the ground, through the EIU, five minutes after engine shutdown. This allows printing of the post-flight report.

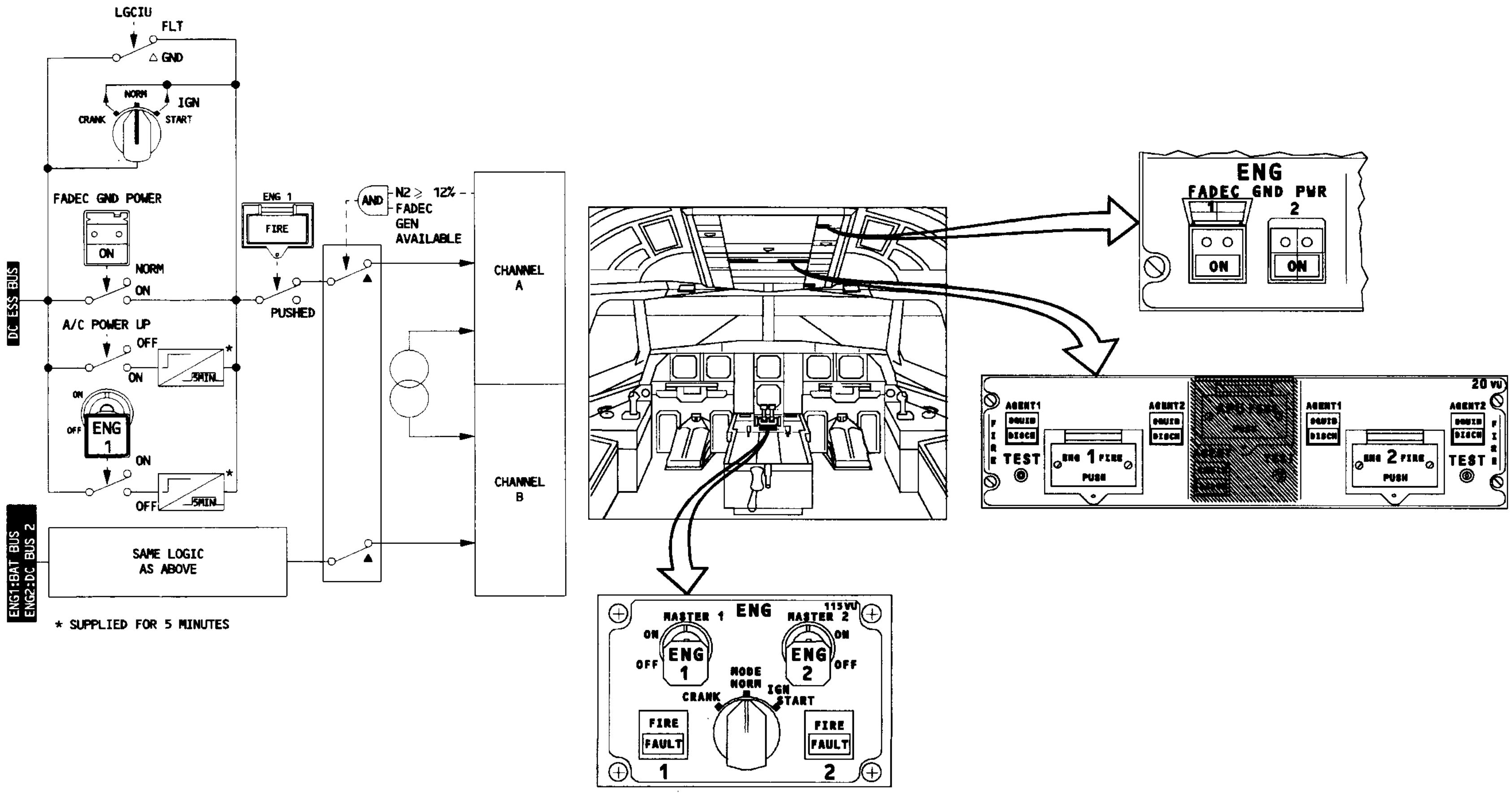
The ECU is also powered down, on the ground, five minutes after A/C power up, unless MCDU menus are used.

Fadec Ground Power Panel.

For maintenance purposes, the engine FADEC ground power panel enables FADEC supply to be restored on the ground, with engine shut down.
When the corresponding ENGine FADEC GND POWER pushbutton is pressed “ON”, the ECU is supplied.

Caution : In this case, there is no automatic power down function. As long as the pushbutton is pressed “ON”, the ECU is supplied. ECU overtemperature may occur after a while.

Note : Both engines ECU’s are re-powered as soon as IGN/START is selected with the rotary selector.
With master lever selected ON, the corresponding ECU is supplied.



ECU POWER SUPPLY LOGIC

CTC-045-015-00

ECU Control Alternator.

The control alternator supplies electrical power directly to the ECU and is installed on the front face of the Accessory GearBox (AGB).

It is located between the Integrated Drive Generator (IDG) and the hydraulic pump and consists of :

- A stator housing, secured on the attachment pad by means of three bolts.
- Two electrical connectors, one for each ECU channel.
- A rotor, secured on the AGB gearshaft by a nut.

This control alternator is a “wet” type alternator, lubricated with AGB engine oil.

Functional Description.

The control alternator consists of a rotor and stator enclosing two sets of windings.

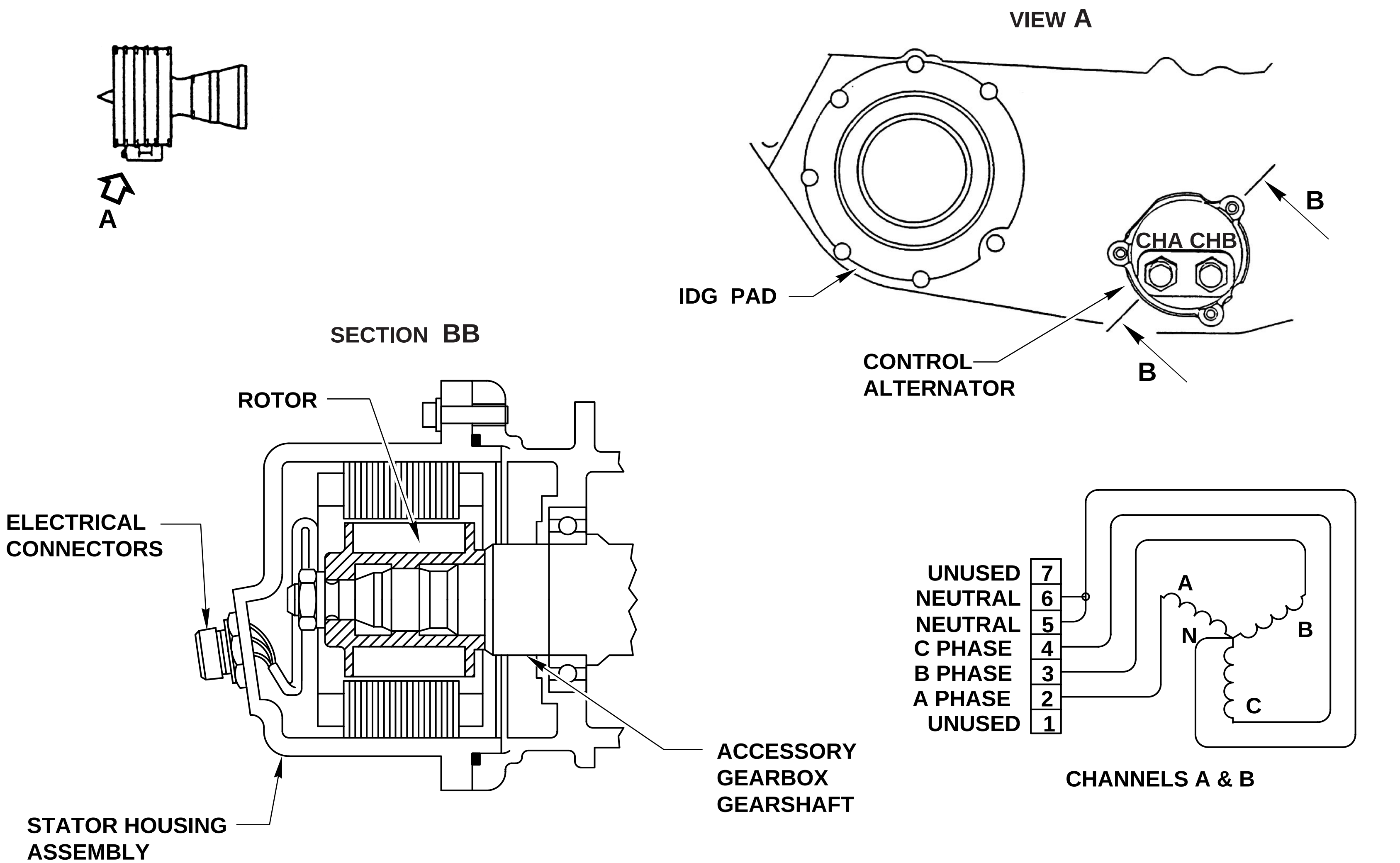
The rotor contains permanent magnets, and is secured on a stub shaft extending from the drive pad of the AGB. It is seated in position through 3 flats and a securing nut.

The windings are integrated with the housing structure, and surround the rotor when the housing is mated to the drive pad mounting boss.

Each set of windings supplies a three-phase power signal to each ECU connector on the forward face of the housing.

Each power signal is rated between 14.2 and 311 VAC depending on core speed and load conditions.

The alternator continues to meet all electrical power requirements at core speed above 45%, even if one phase in either set, or one phase in both sets of windings fails.



ECU CONTROL ALTERNATOR

CTC-045-016-00

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ENGINE SENSORS

Aerodynamic stations.

The ECU requires information on the engine gas path and operational parameters in order to control the engine during all flight phases.

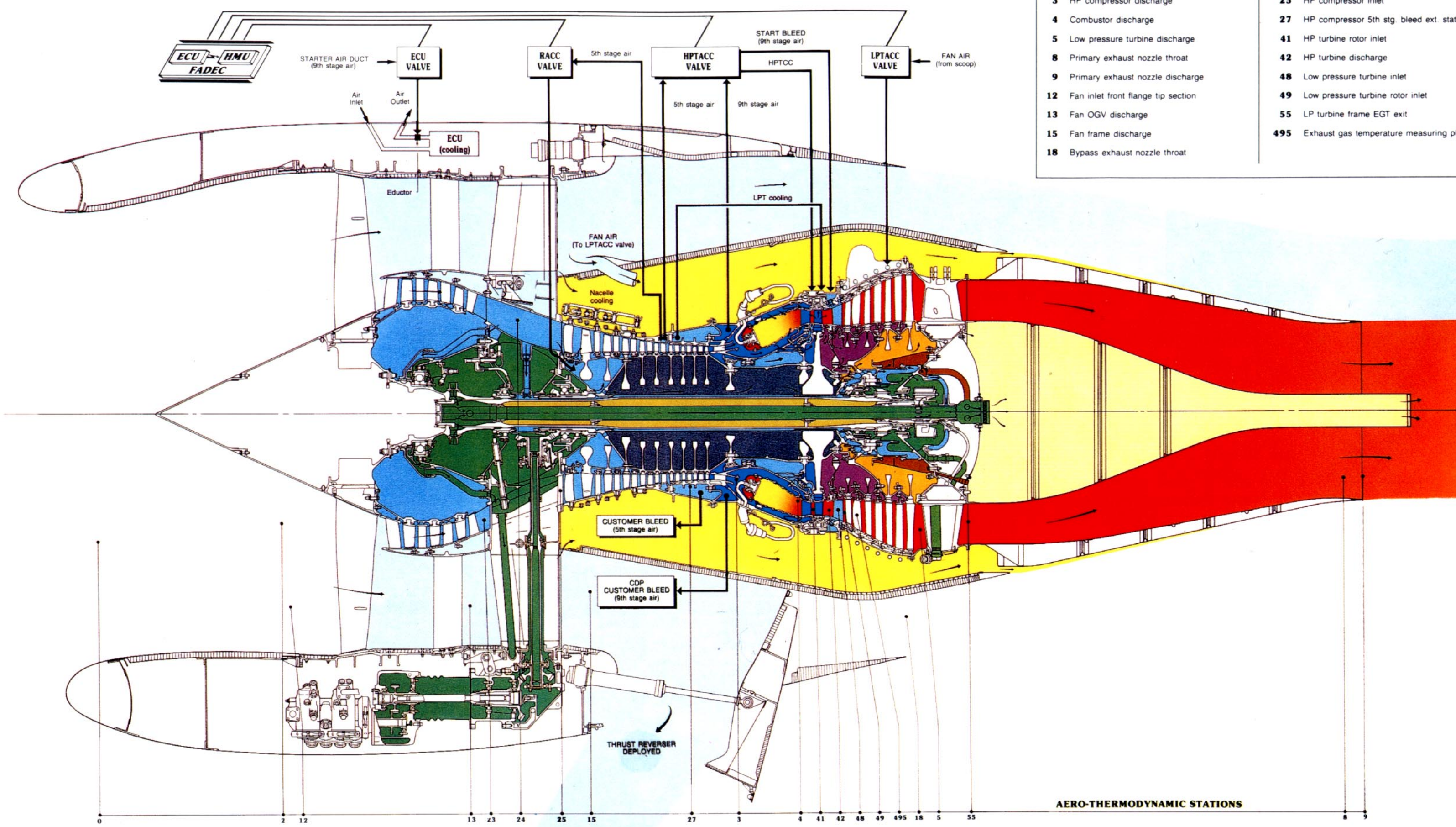
Sensors are installed at aerodynamic stations and various engine locations, to measure engine parameters and provide them to the ECU subsystems.

Sensors located at aerodynamic stations have the same number as the station. e.g. T25.

Sensors placed at other engine locations have a particular name. e.g. T case sensor.

ENGINE STATION IDENTIFICATION

0	Free stream ambient conditions	23	Booster discharge
2	Fan inlet front frame hub section	24	Booster variable bleed valve discharge
3	HP compressor discharge	25	HP compressor inlet
4	Combustor discharge	27	HP compressor 5th stg. bleed ext. station
5	Low pressure turbine discharge	41	HP turbine rotor inlet
8	Primary exhaust nozzle throat	42	HP turbine discharge
9	Primary exhaust nozzle discharge	48	Low pressure turbine inlet
12	Fan inlet front flange tip section	49	Low pressure turbine rotor inlet
13	Fan OGV discharge	55	LP turbine frame EGT exit
15	Fan frame discharge	495	Exhaust gas temperature measuring plane
18	Bypass exhaust nozzle throat		



ENGINE SENSORS

CTC-045-017-00

Speed sensors.

LP rotating system speed, N1.
HP rotating system speed, N2.

Resistive Thermal Device (RTD sensors).

Fan inlet temperature, T12.
High Pressure Compressor inlet temperature, T25.

Thermocouples.

Compressor discharge temperature, T3.
Exhaust Gas Temperature, EGT or T49.5.
LPT discharge temperature, T5 (optional monitoring kit).
HPT shroud support temperature, T Case.
Engine Oil Temperature, TEO.

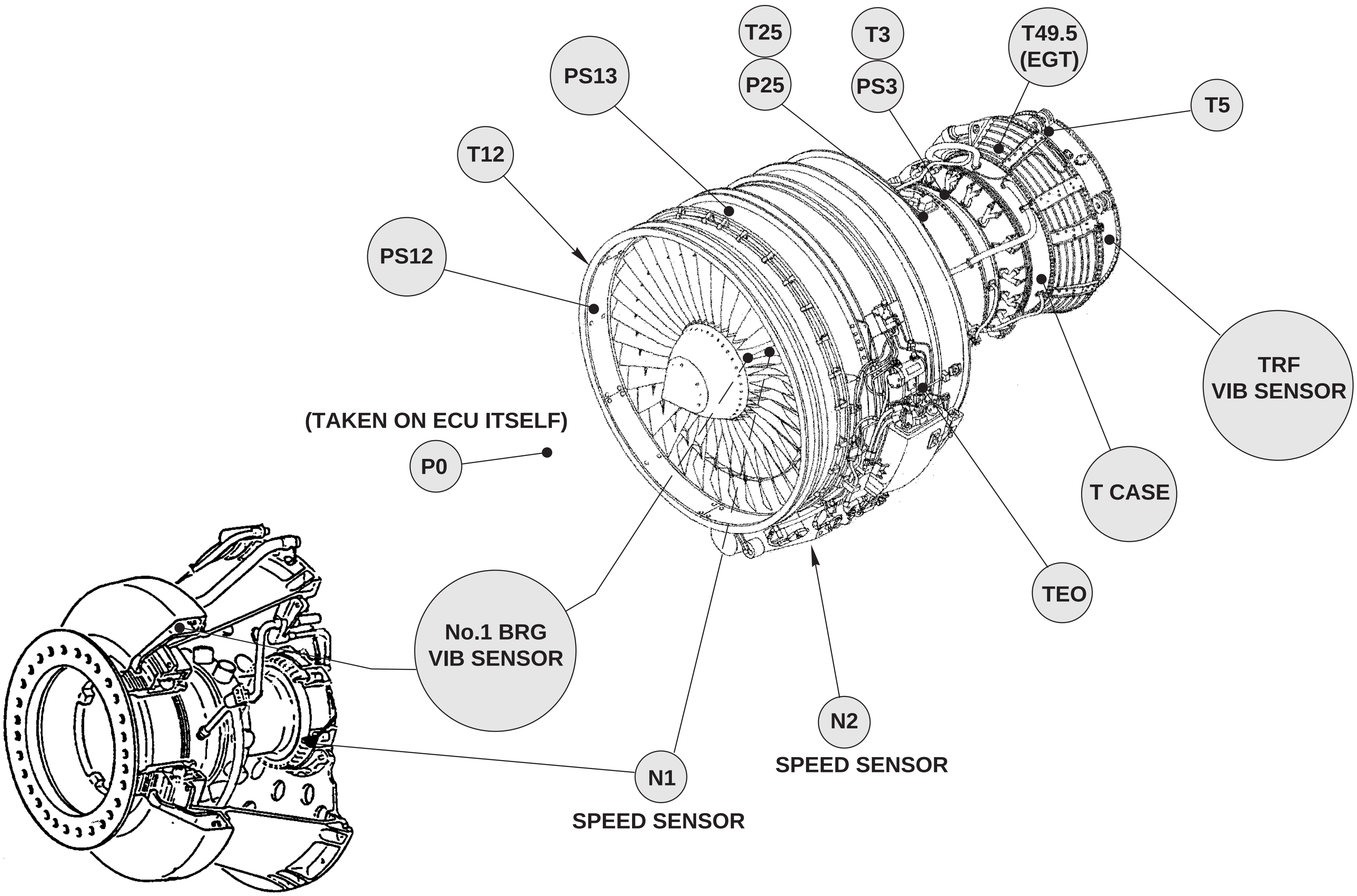
Pressures.

Ambient static pressure, P0.
HPC discharge static pressure, PS3 or CDP.
Engine inlet static pressure, PS12.
Fan discharge static pressure, PS13 (optional).
HPC inlet total pressure, P25 (optional).

The pressures are measured through transducers located in the ECU.

Vibration sensors.

There are two vibration sensors, which are installed on the engine and connected to the Engine Vibration Monitoring Unit (EVMU).



ENGINE SENSORS

CTC-045-018-00

Speed sensor design.

The speed sensors provide the ECU channels A and B with signals that are representative of the rotational speeds, N1 and N2.

On each sensor, a third connector allows signals to be sent to the EVMU for vibration analysis, in conjunction with data from the vibration sensors.

Both N1 and N2 speed sensors operate on the same principle.

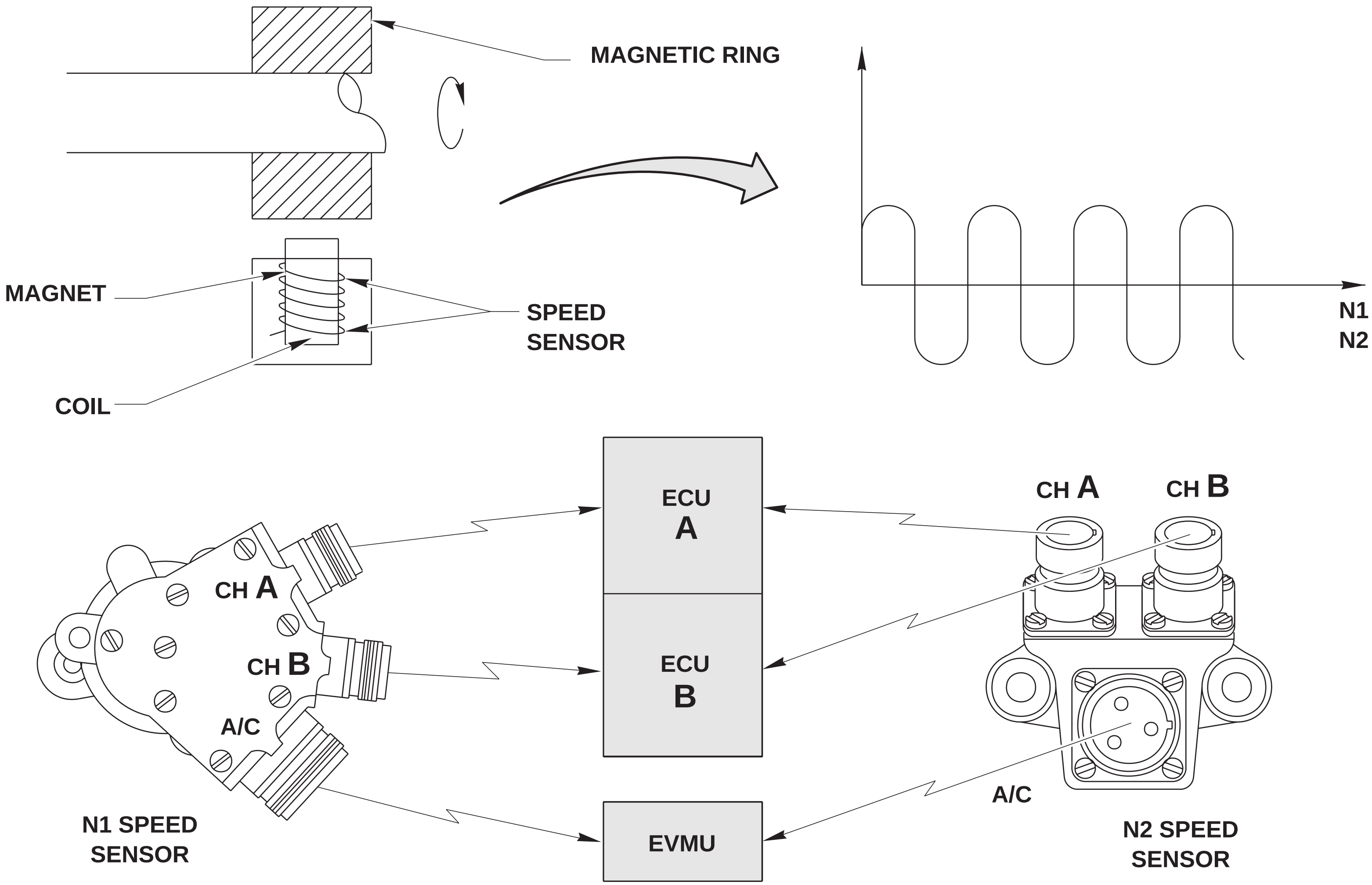
They are induction type tachometers, which provide electrical output signals.

These outputs are Alternating Current (AC) signals, and the frequency is directly proportional to the rotational speed of the dedicated rotor.

The sensing element is an electrical winding with a core made up of a permanent magnet. Both sensors feature three independent sensing elements insulated from each other, thus there is one output signal per connector.

The passage of a sensor tooth ring modifies the magnetic field around the core of the winding and causes a magnetic flux variation in the coil.
Each tooth induces a pulse into the coil, and therefore, the number of pulses is proportional to the sensor ring speed.

Note : N1 sensor ring features 30 teeth.
N2 sensor ring features 71 teeth.



SPEED SENSOR DESIGN

CTC-045-019-00

N1 speed sensor.

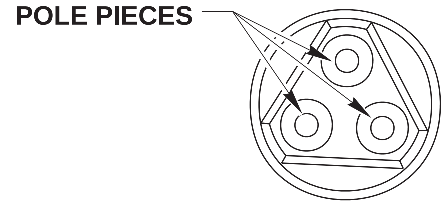
The N1 speed sensor is mounted through the 5 o'clock fan frame strut.The sensor body has a flange to attach the complete sensor to the fan frame and once secured on the engine with 2 bolts, only the body and the receptacle are visible.

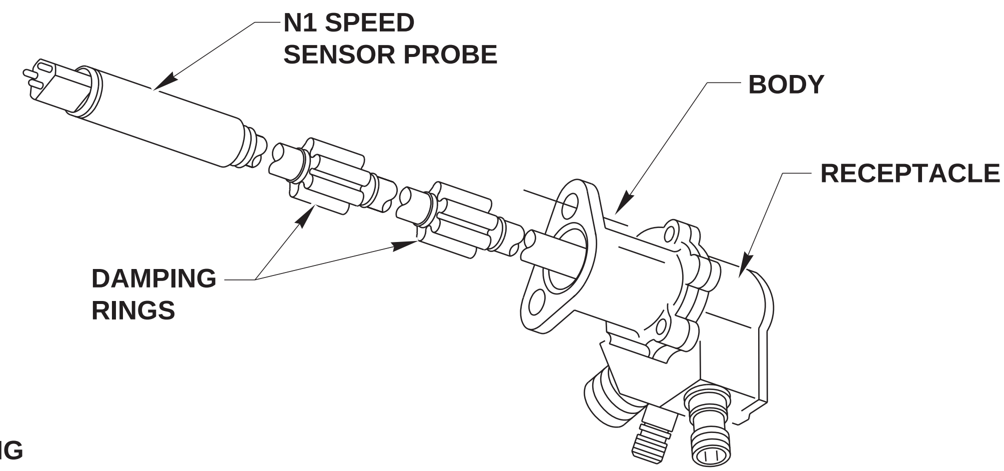
The receptacle has three electrical connectors.
Two connectors provide the ECU with output signals.
The third is connected to the EVMU.

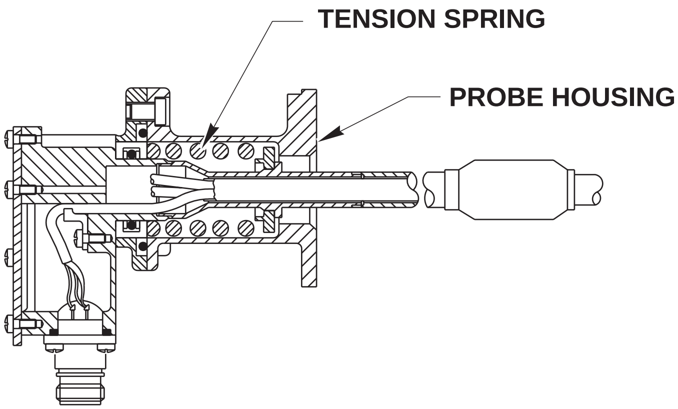
The N1 sensor ring has one tooth which is thicker than the others and this generates a stronger pulse in the sensor and is used as a phase reference in engine vibration analysis.

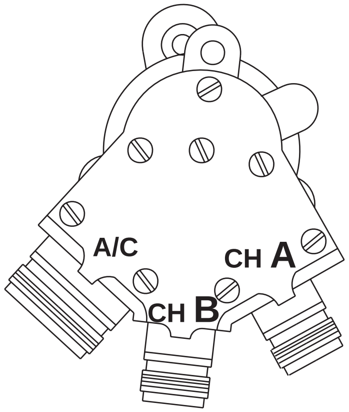
Internally, a spring keeps correct installation of the sensor probe, regardless of any dimensional changes due to thermal effects.

Externally, there are two damping rings to isolate the probe from vibration.









CTC-045-020-00

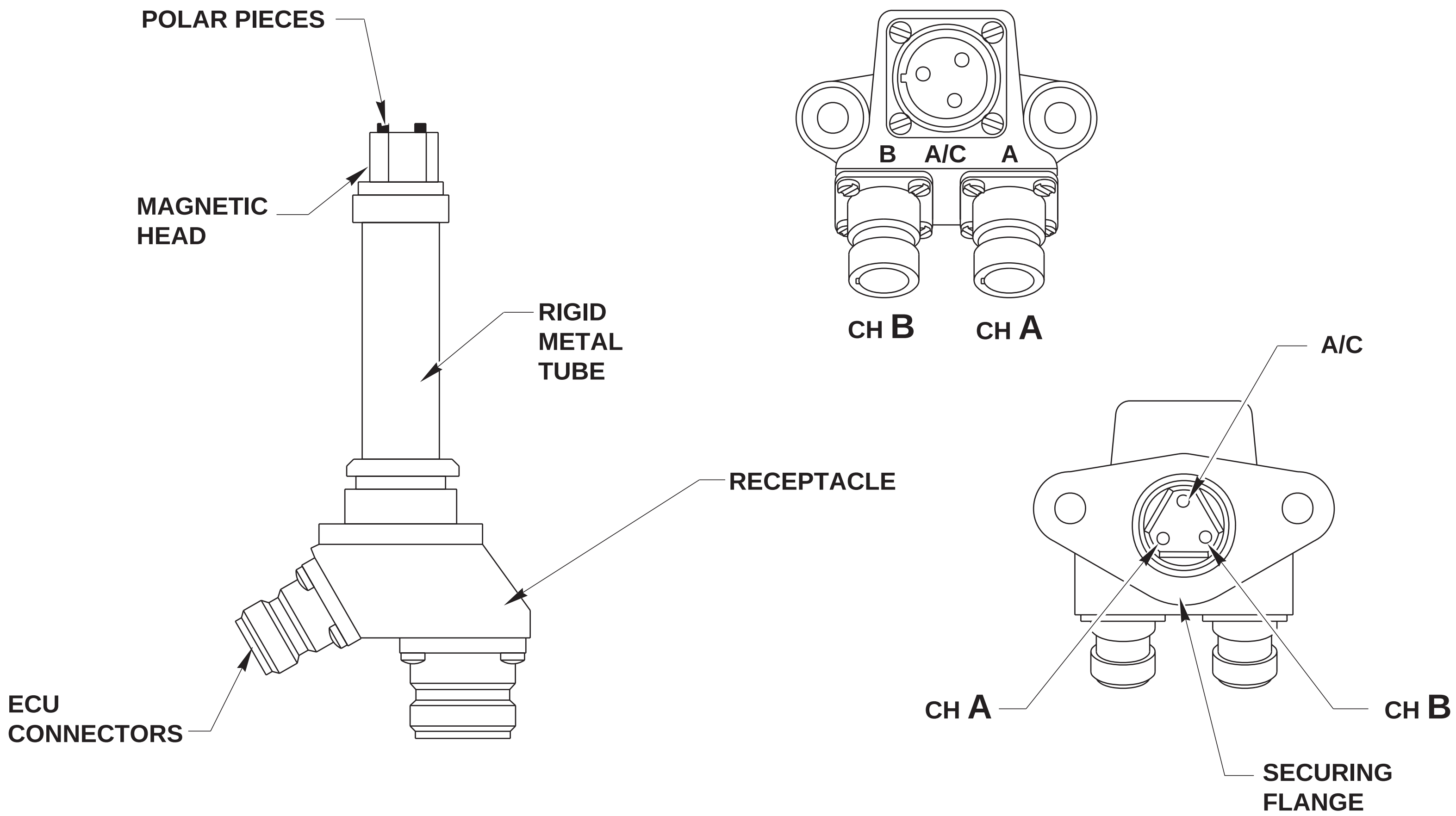
N1 SPEED SENSOR

N2 speed sensor.

The N2 speed sensor is installed on the rear face of the AGB at 6 o'clock and secured with 2 bolts.

The housing has three connectors :

- ECU channel A.
- ECU channel B.
- EVMU.



CTC-045-021-00

N2 SPEED SENSOR

RTD type sensors.

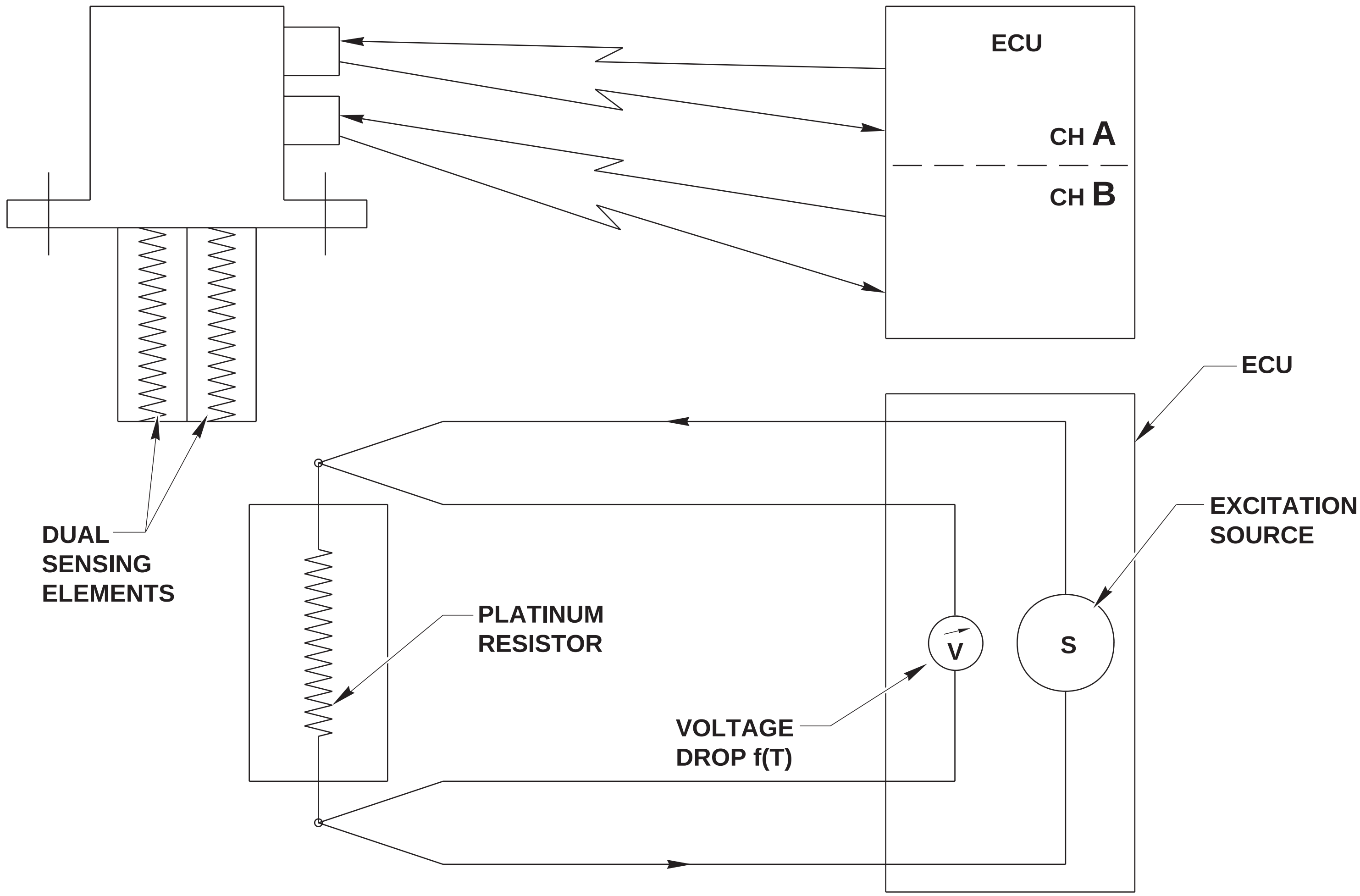
Resistive Thermal Devices (RTD) are installed on the engine at aerodynamic stations 12 and 25.

They operate in the same manner. The ECU determines the air temperature by monitoring the electrical resistance value of the sensing element.

The sensing element is located in the probe housing, which is inserted in the airstream and is made of a ceramic core wrapped with a platinum wire.
As the airflow heats the element, the electrical resistance of the element varies. If the air temperature increases, the resistance of the element increases and vice versa.

The ECU determines the resistance by sending an electrical excitation signal through the element and measuring the voltage drop that results.

A unique voltage drop is developed for every possible air temperature within the operational range of the sensor.



CTC-045-022-00

RESISTIVE THERMAL DEVICE

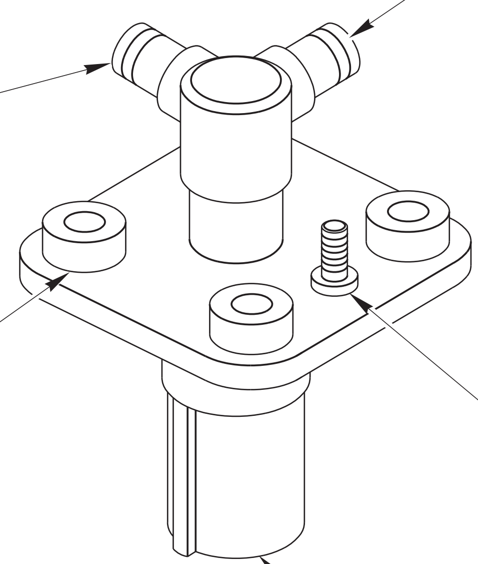
T12 sensor.

The T12 temperature sensor measures the fan inlet temperature and is installed in the fan inlet cowl, at the 1 o'clock position.

The portion that protrudes into the airflow encloses two identical sensing elements.

One sensing element is dedicated to the ECU channel A, the other to channel B.

The sensor is secured on the fan inlet case with four bolts and a stud ensures correct ground connection.



T12 SENSOR

CTC-045-023-00

T 25 sensor.

The T25 temperature sensor measures the High Pressure Compressor inlet temperature, and is installed in the fan frame mid-box structure, at approximately the 5 o'clock position.

The sensor is composed of :

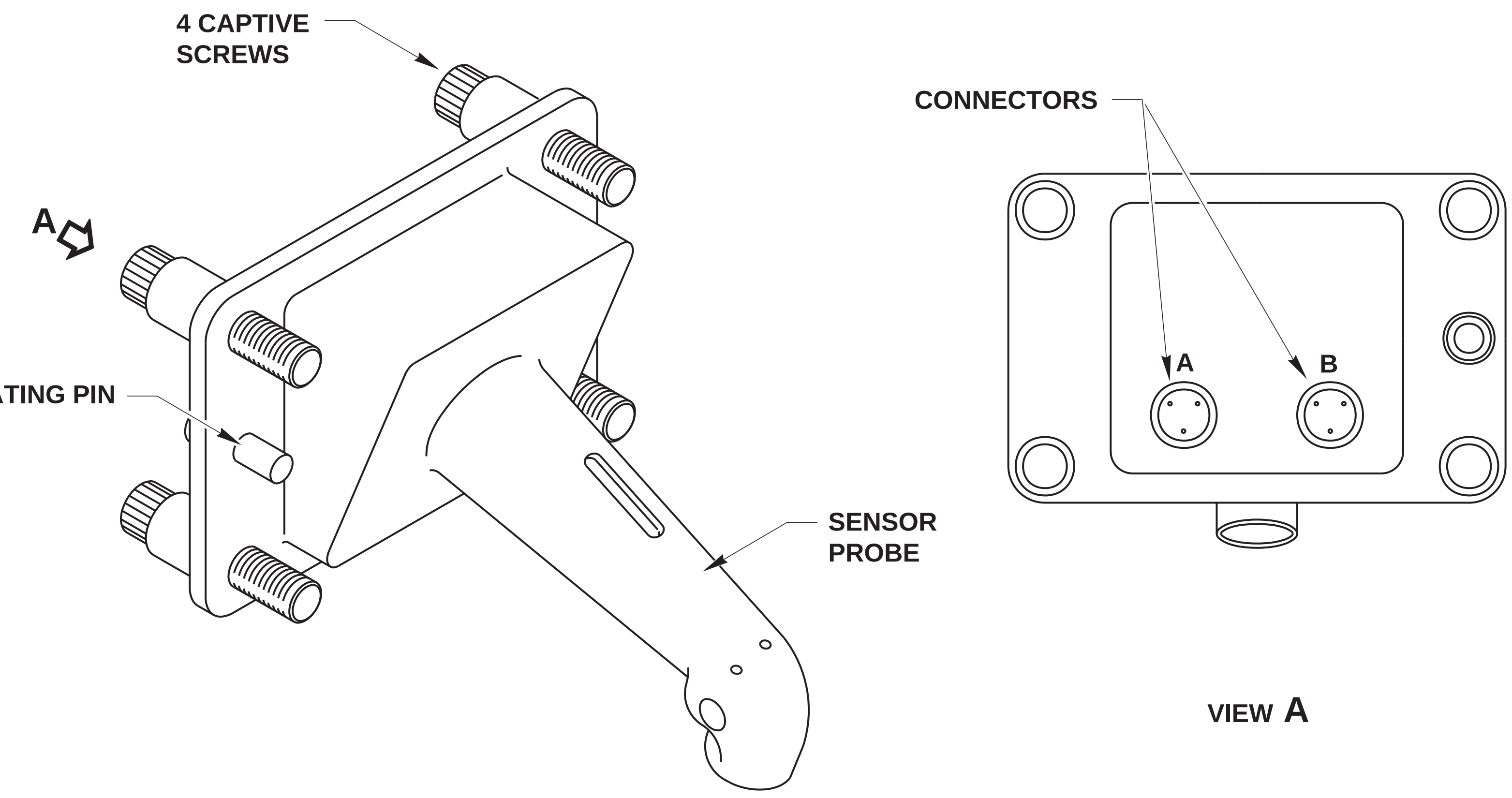
- a probe, which encloses two sensing elements protruding into the airflow.

- a mounting flange, with four captive screws and a locating pin.

- two electrical connectors, one per sensing element.

- two holes are drilled, opposite the probe airflow inlet, to let dust out.

The locating pin on the mounting flange prevents the sensor from being mis-installed.



T25 SENSOR

CTC-045-024-00

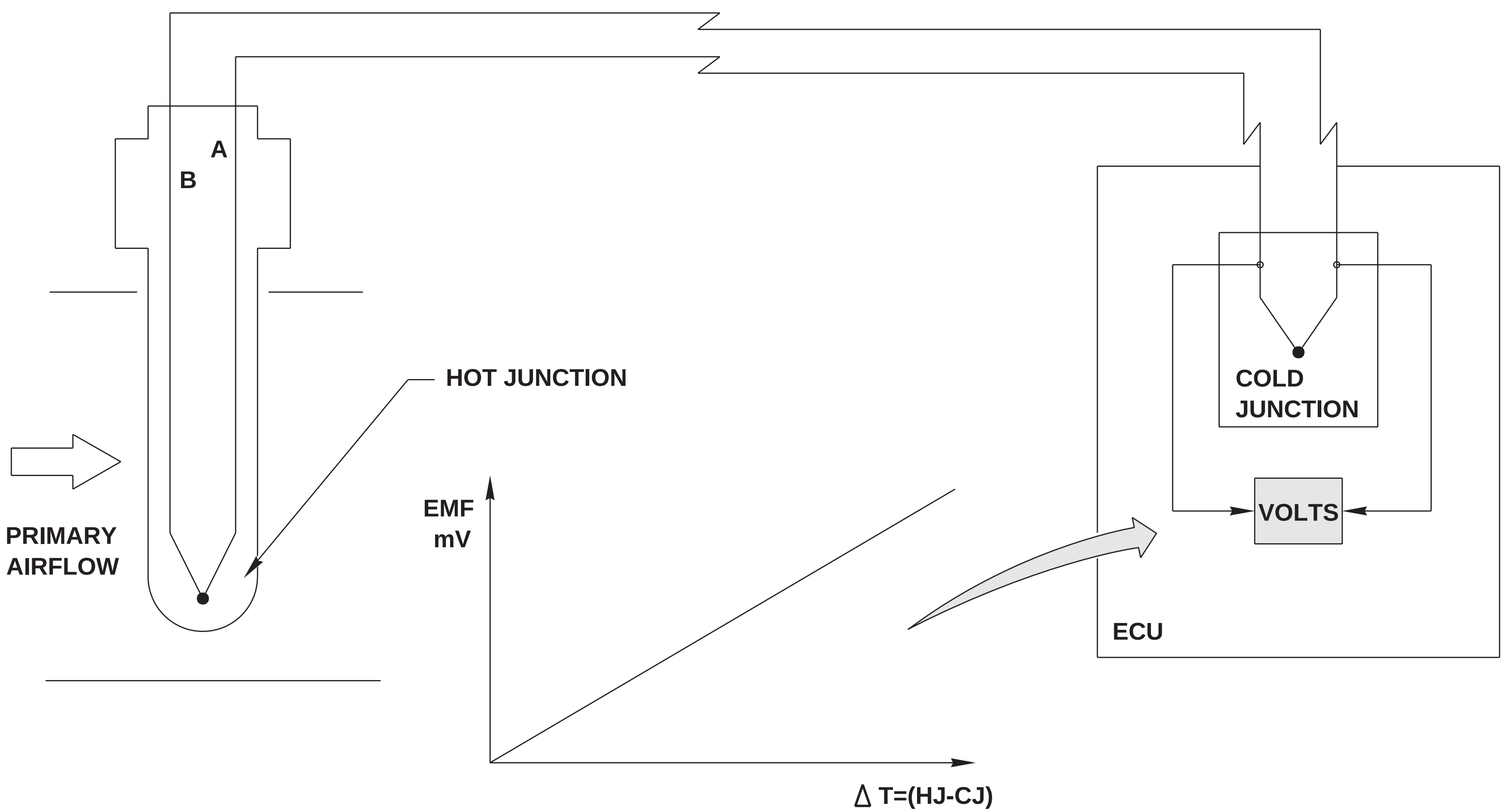
Thermocouple type sensors.

Thermocouple sensors are designed to convert high temperatures into signals compatible with the ECU .

Thermocouple operation is based on the following principle :

- Two dissimilar metals, chromel (+) and alumel (-), connected to a complete circuit, generate an electromotive force, proportional to the difference of temperature between a known reference (cold junction) and a sensing junction at a temperature to be measured.

The sensing junction is incorporated into the sensor and the cold junction is installed on the ECU mother board.



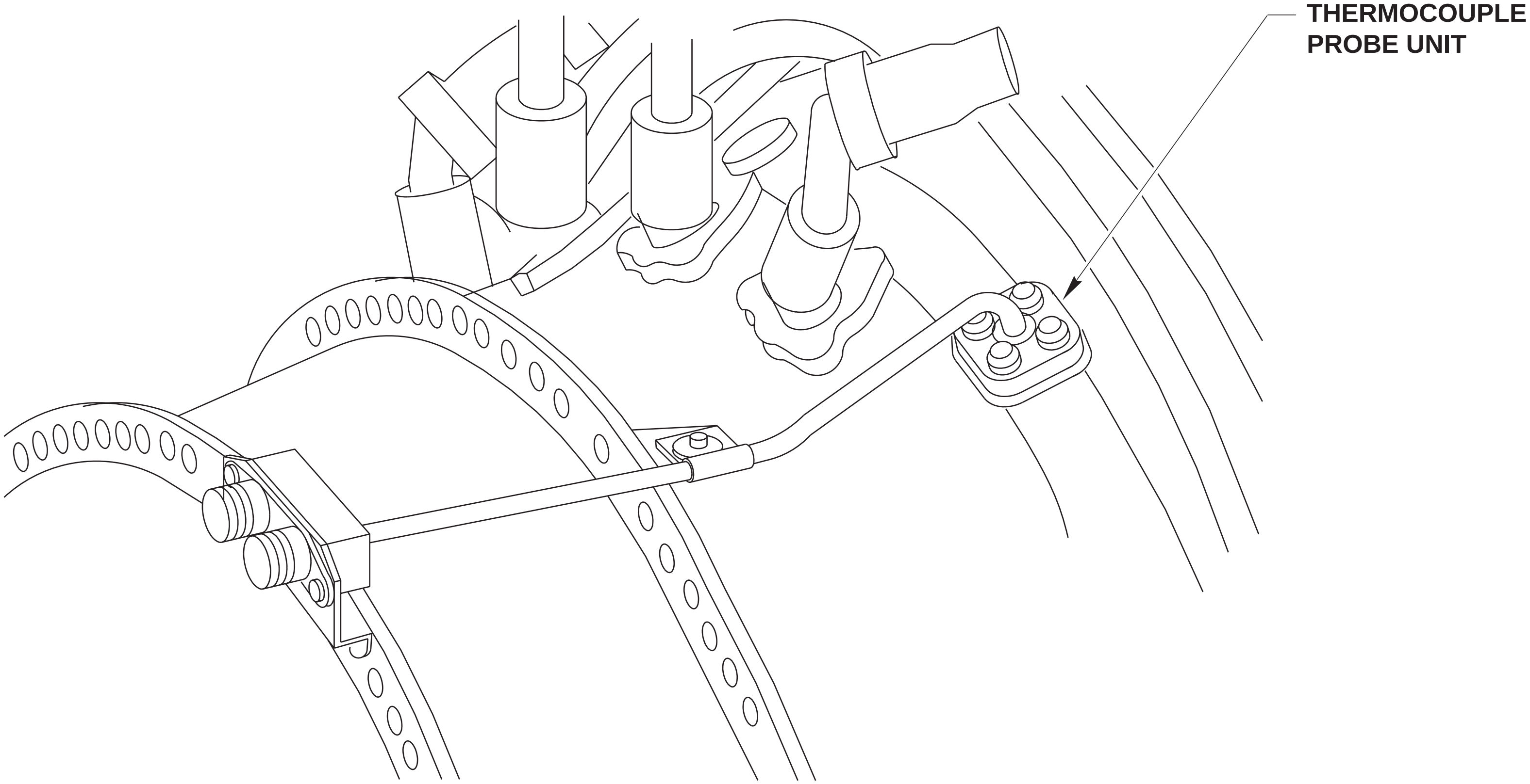
THERMOCOUPLE PRINCIPLE

Compressor discharge temperature T3.

The T3 temperature sensor is installed at the 12 o'clock position on the combustion case, just behind the fuel nozzles.

Two probes, enclosed in the same housing, sense the air temperature at the HPC outlet.

The signals from both probes are directed through a rigid lead to a connector box, which accomodates two connectors, one per ECU channel.



CTC-045-026-00

T3 TEMPERATURE SENSOR

Exhaust Gas Temperature.

The Exhaust Gas Temperature (EGT) sensing system is located at aerodynamic station 49.5.

This EGT value is used to monitor the engine's condition.

The system includes nine probes, secured on the Low Pressure Turbine (LPT) case and the sensing elements are immersed in the LPT nozzle stage 2.

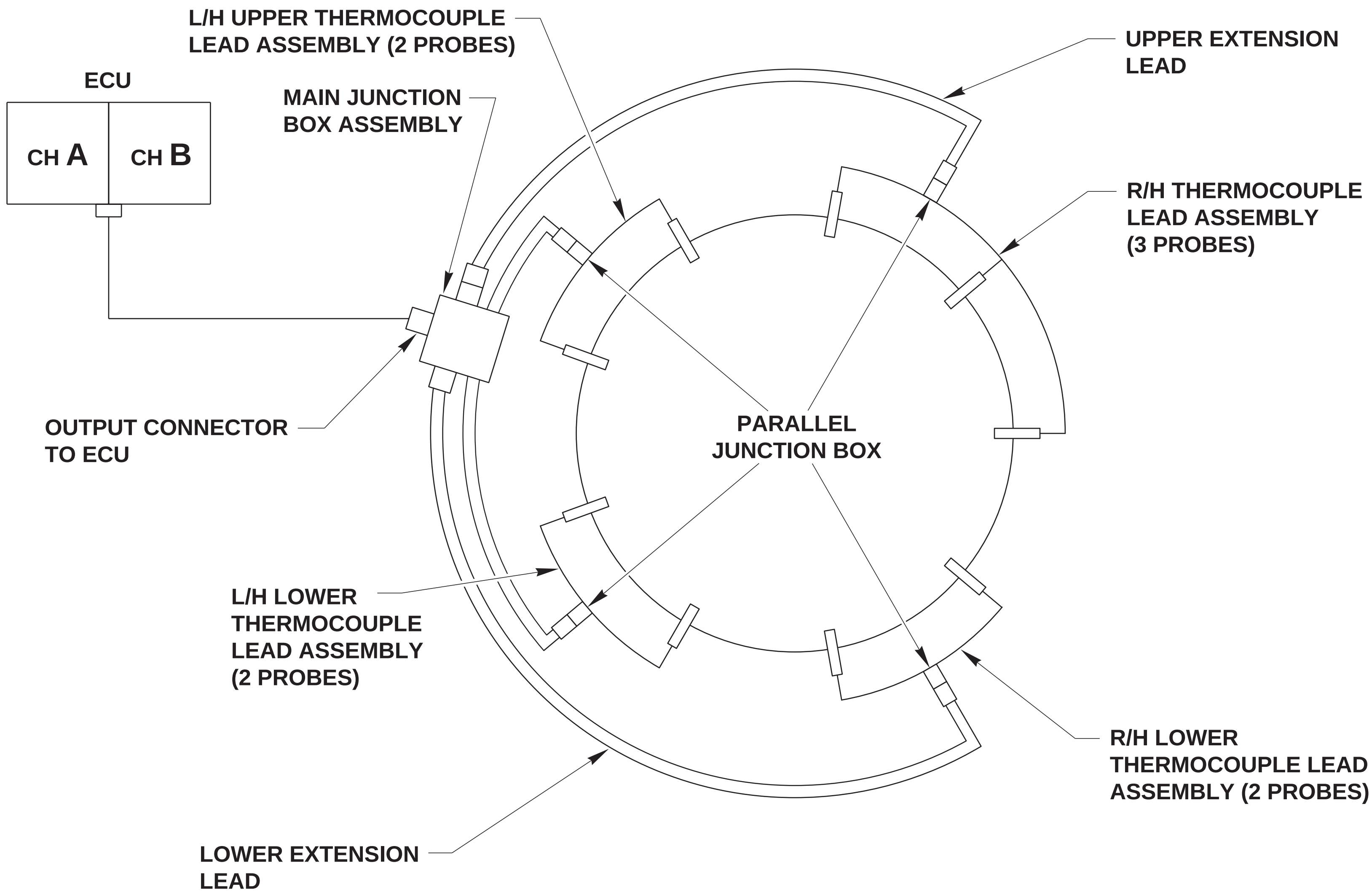
Each thermocouple produces an electrical output signal proportional to the temperature. They are connected together through a wiring harness.

The EGT wiring harness consists of :

- three thermocouple lead assemblies with two probes in each. Each thermocouple carries 2 measurements to a parallel junction box.

- one thermocouple lead assembly with three probes. This assembly carries 3 measurements to a parallel junction box.

- one main junction box assembly where all the thermocouple lead assemblies are connected. The main junction box accomodates one connector to carry the nine output signals to the ECU, where they are averaged.



CTC-045-027-00

EXHAUST GAS TEMPERATURE

LPT discharge temperature T5.

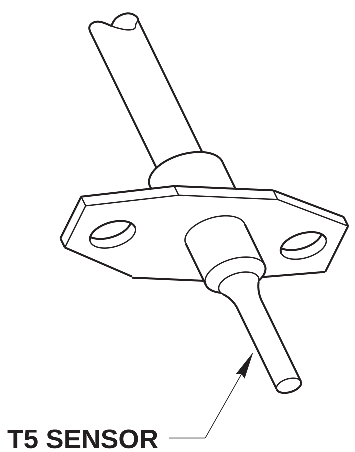
The T5 temperature sensor is located at the 4 o'clock position, on the turbine rear frame .

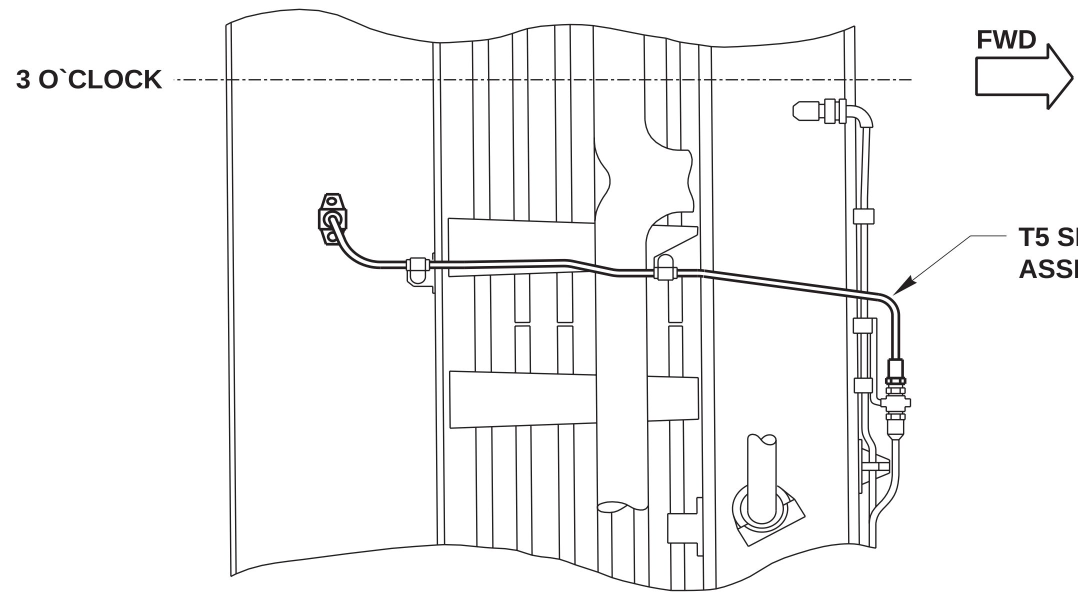
This sensor is part of the optional monitoring kit, available upon customer request.

It consists of a metal body, which has two thermocouple probes and a flange for attachment to the engine.

A rigid lead carries the signal from the probe to a main junction box with a connector that allows connection with a harness.

The two thermocouples are parallel-wired in the box and a single signal is sent to the ECU channel A.





CTC-045-028-00

T5 TEMPERATURE SENSOR

T case.

The T case sensor measures the High Pressure Turbine (HPT) shroud support temperature.

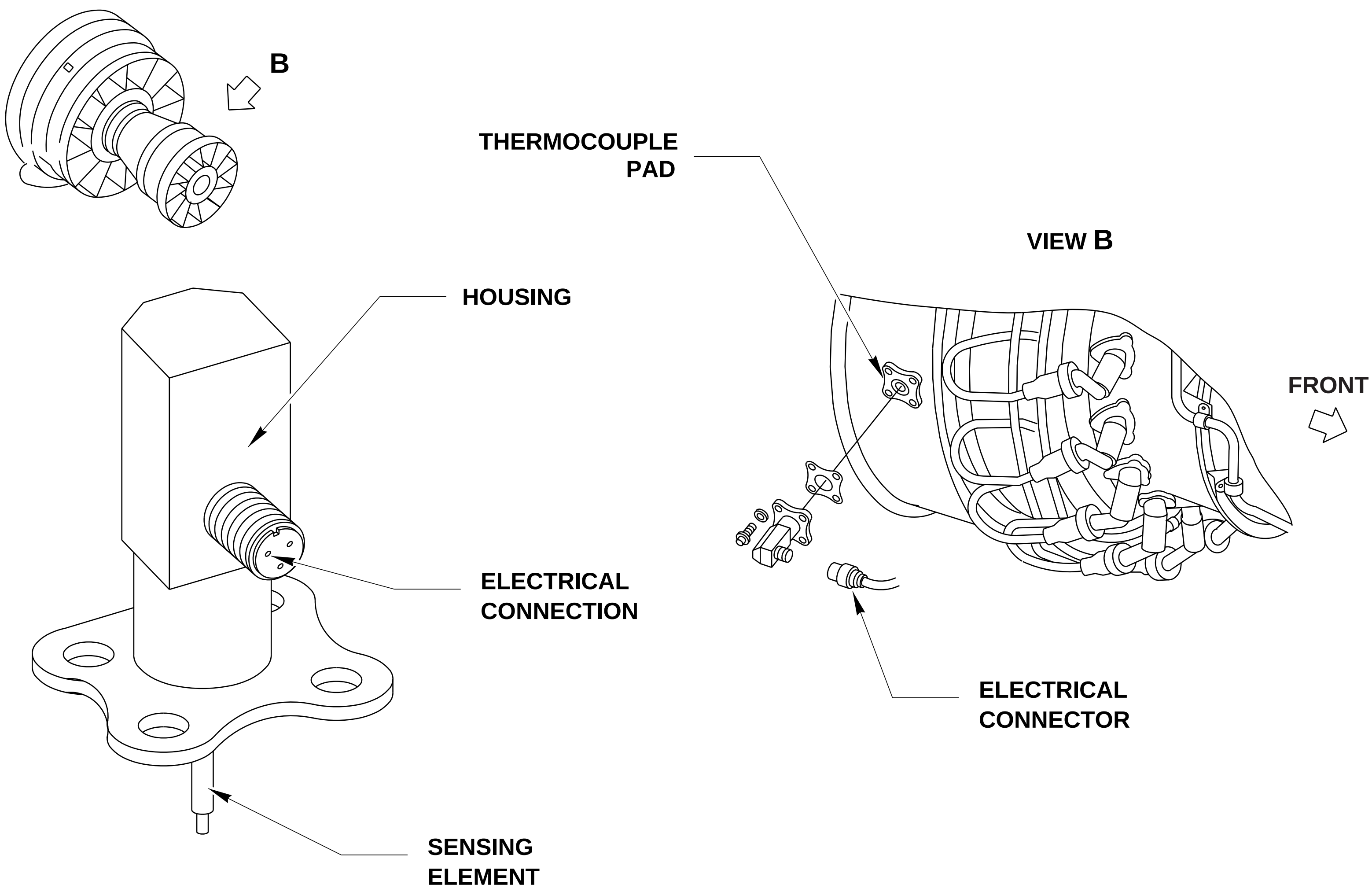
The temperature value is used by the ECU in the HPT Clearance Control system logic.

The sensor is installed on the combustion case at the 3 o’clock position, and consists of :

- a housing, which provides a mounting flange and an electrical connector.

- a sensing element, fitted inside the housing and in contact with the shroud support.

Note : The probe is spring-loaded to ensure permanent contact with the shroud support.



T CASE SENSOR

CTC-045-029-00

Engine oil temperature.

The engine is equipped with 2 oil temperature sensors.

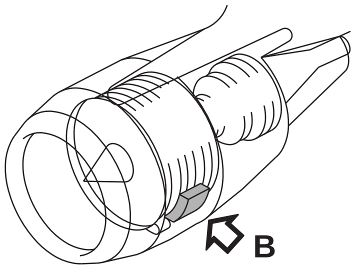
One of the sensors, the TEO sensor, provides a temperature value used for the Integrated Drive Generator (IDG) oil cooling system and the FRV.

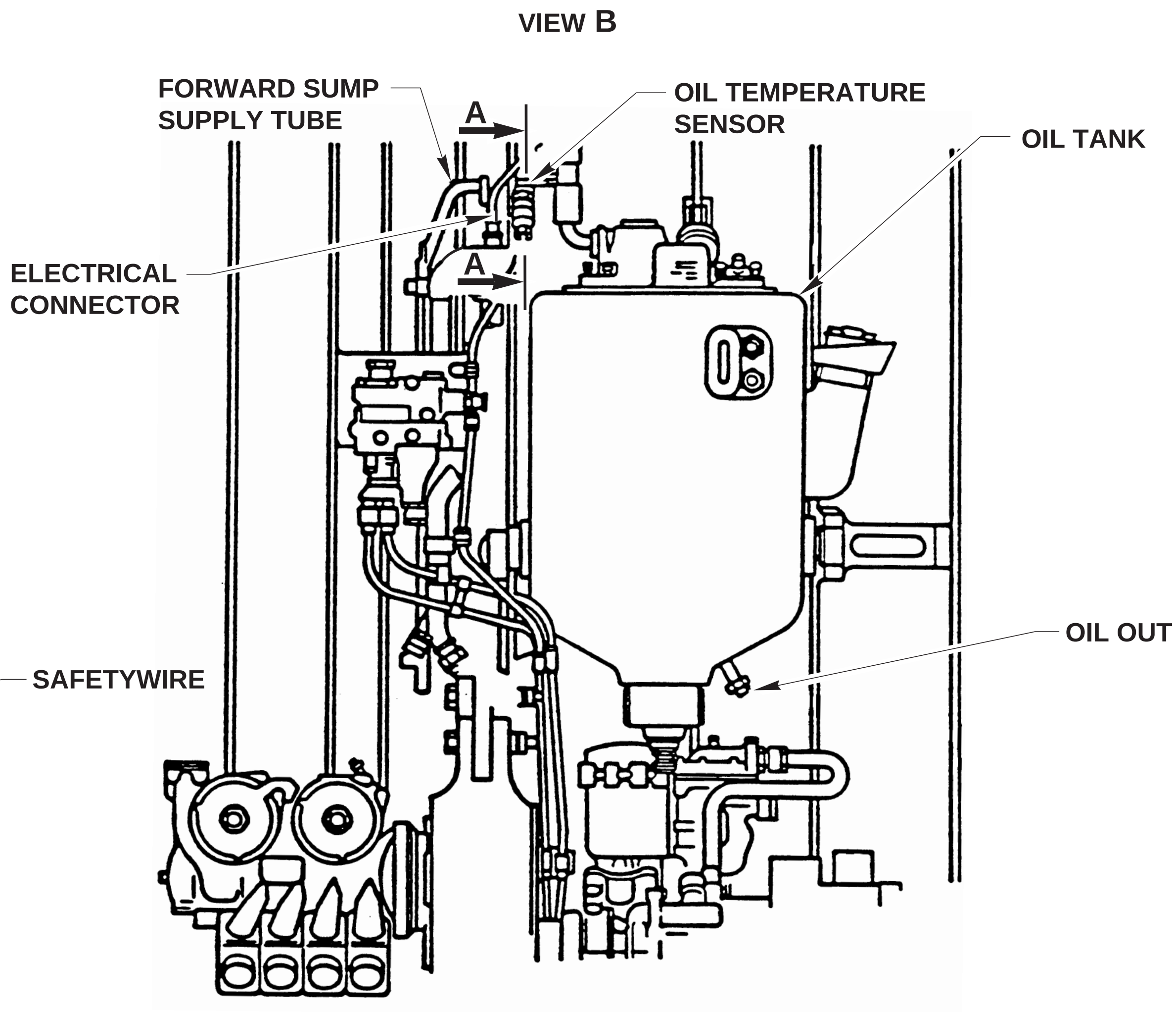
The TEO sensor is installed on the oil supply line to the forward sump, at the 9 o'clock position, above the oil tank.

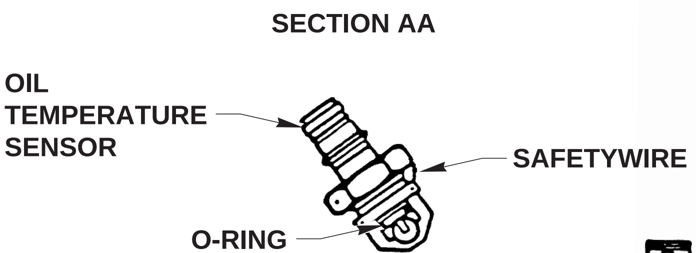
It has a captive nut in order to secure it to the supply line.

The TEO provides two identical electrical outputs proportional to the supply oil temperature. A single electrical connector routes the outputs to the ECU.

The second sensor is installed on the lube unit, and is described in the oil system section.







TEO SENSOR

CTC-045-030-00

Pressure signals.

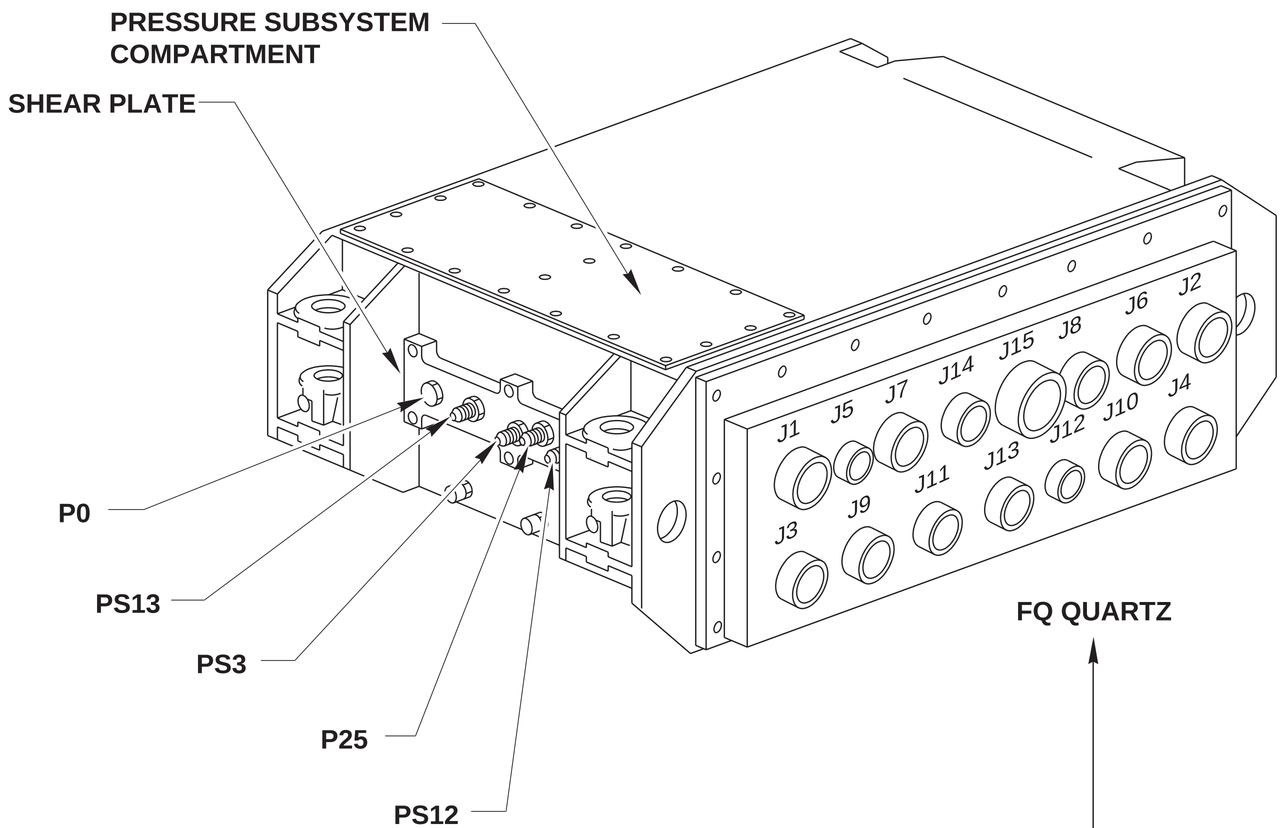
Various pressures, picked-up at specific aerodynamic stations, provide the ECU with information for engine control, or monitoring.

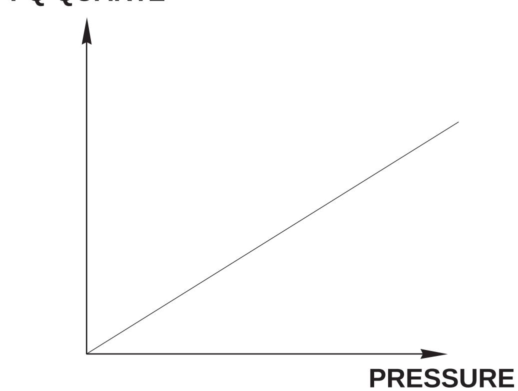
Air pressures are sent to the shear plate of the ECU by pressure lines, which are drained at their lowest part by weep holes.

The shear plate routes the pressures to the channel A and B transducers, which compute the actual pressures.

The transducers are quartz capacitive types and the vibration frequency of the quartz element varies with the stress induced into the element by the air pressure.

The computation of this frequency with temperature compensation, determines the corrected pressure value.





PRESSURE SIGNAL CONNECTIONS

CTC-045-031-00

Ambient static pressure P0.

This value is used by the ECU, in case of lost signals from the Air Data Computer (ADC).

The P0 air pressure is measured through a vent plug, installed on the ECU shear plate.

HPC discharge pressure PS3.

The PS3 static pressure pick-up is located on the combustion case, at the 9 o'clock position, between two fuel nozzles.

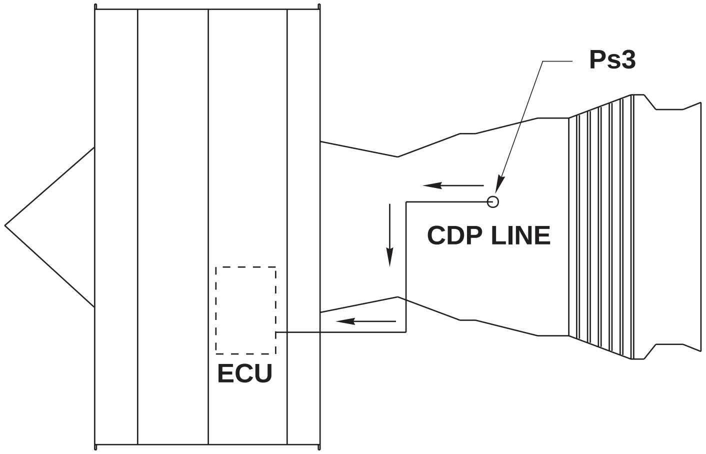
The lower part of the line is drained through a weep hole.

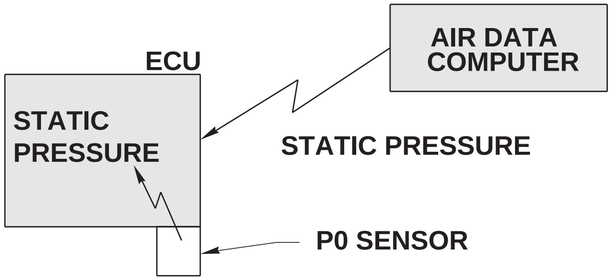
Engine inlet static pressure PS12.

Three static pressure ports are mounted on the forward section of the fan inlet case, at the 12, 4 and 8 o'clock positions.

A pneumatic line runs around the upper portion of the fan inlet case, collecting and averaging the pressures.

The lower part of the line is drained through a weep hole.





PRESSURE PICK-UPS

CTC-045-032-00

Fan discharge static pressure PS13.

PS13 is part of the optional monitoring kit, available upon customer request.

If the kit is not required, the PS13 port is blanked off on the ECU shear plate.

The PS13 pick-up is located at the 1.30 clock position, downstream from the fan Outlet Guide Vanes (OGV).

This signal is processed by channel A only.

The lower part of the line is drained through a weep hole.

HPC inlet total pressure P25.

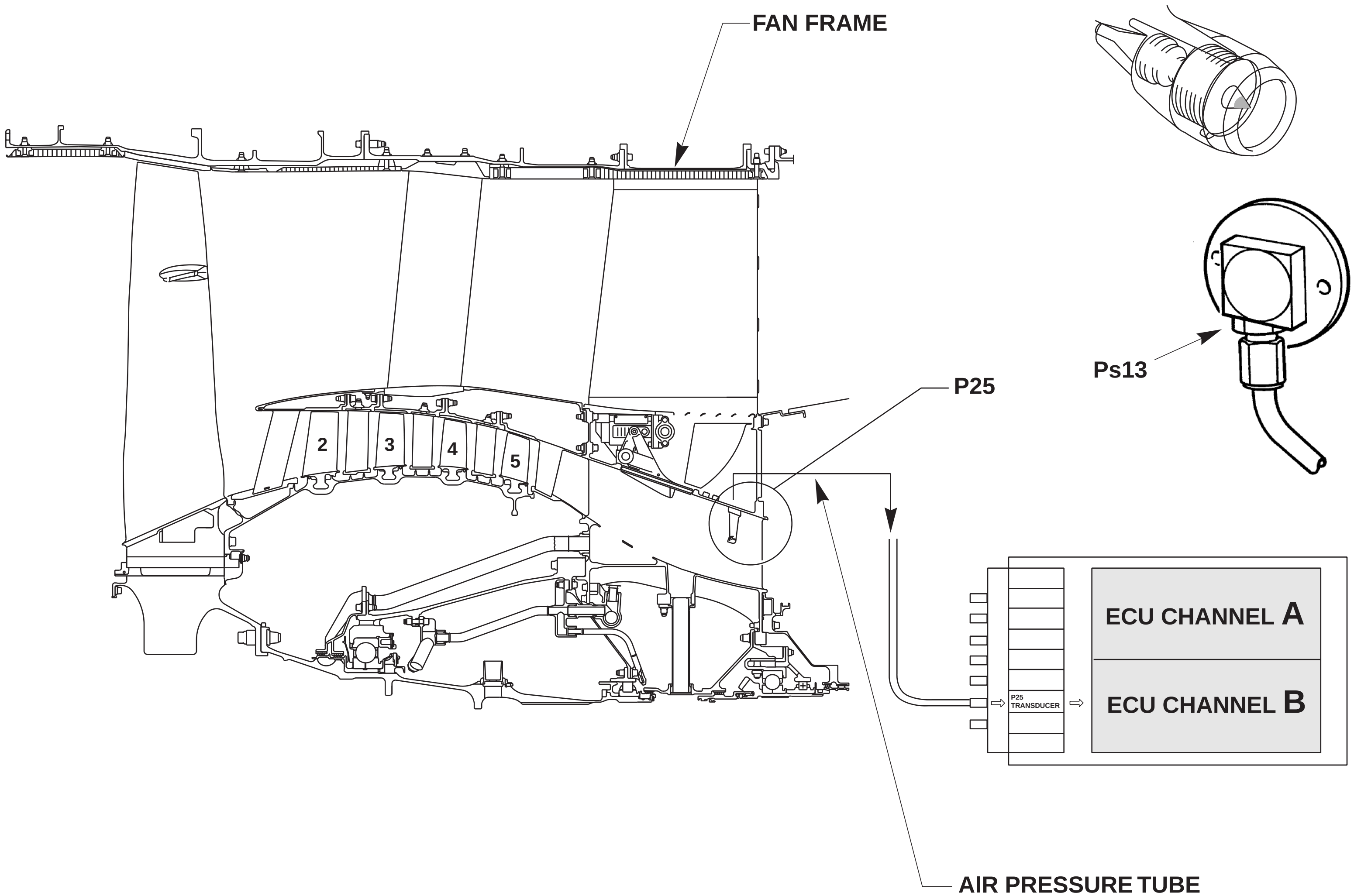
P25 is part of the optional monitoring kit, available upon customer request.

If the kit is not required, the P25 port is blanked off on the ECU shear plate.

The P25 probe is installed in the fan frame mid-box structure, at the 6 o'clock position.

The pressure line exits the fan frame on its rear wall through a nipple.

The signal is processed by channel B only.



Ps13 AND P25 SENSORS

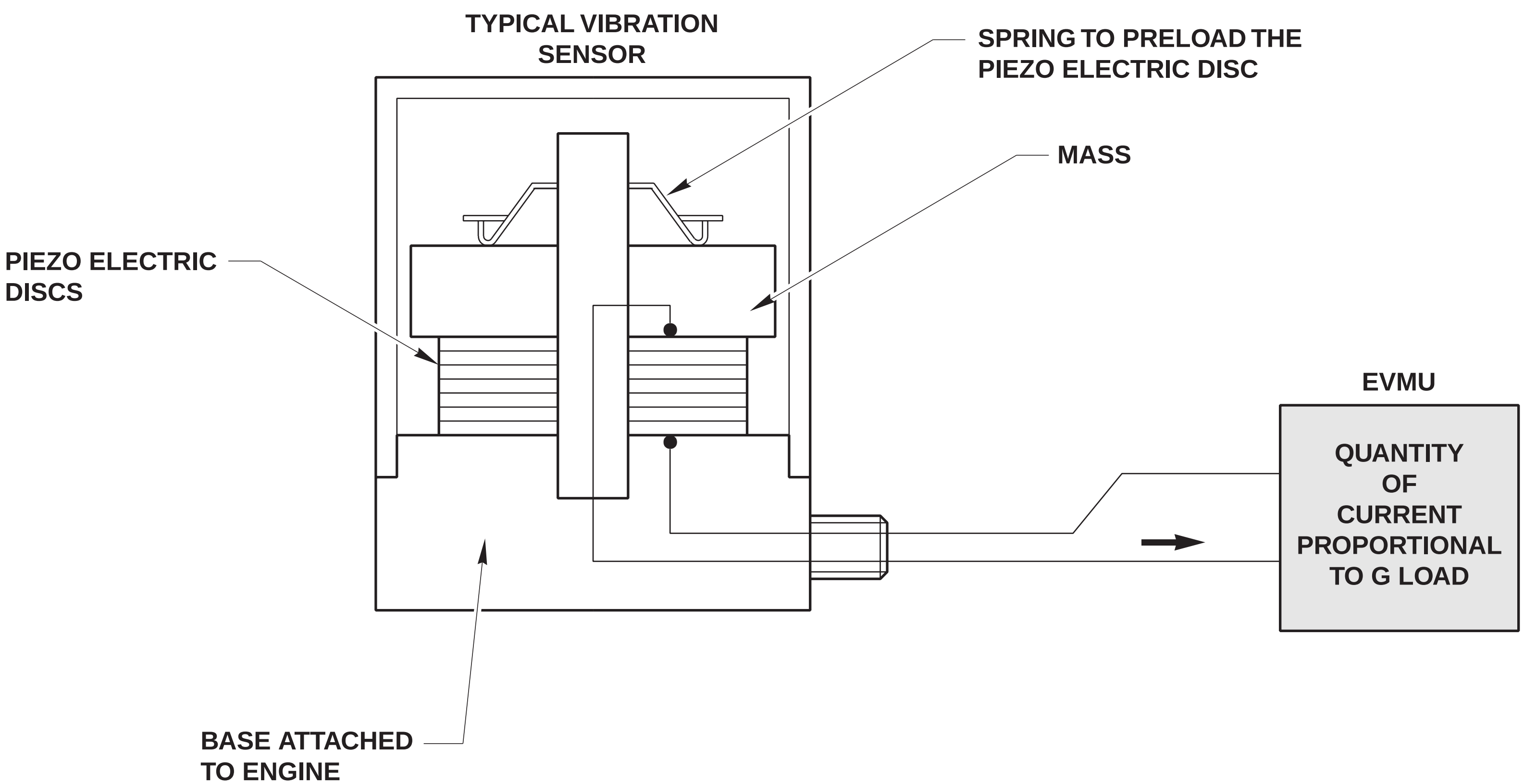
CTC-045-033-00

Vibration sensors.

The engine is equipped with two accelerometers, which are able to sense and measure vertical displacement.

Both sensors are piezo-electric type, which have a stack of piezo-electric discs that are placed between a mass and a base.

When the accelerometer is subjected to a vibration, the mass exerts a variable force on the discs. This generates a potential difference directly proportional to the acceleration in a certain frequency range.



CTC-045-034-00

VIBRATION SENSORS

#1 bearing vibration sensor assembly

The assembly is made up of a vibration sensor, which is secured at the 9 o'clock position on the #1 bearing support front flange.

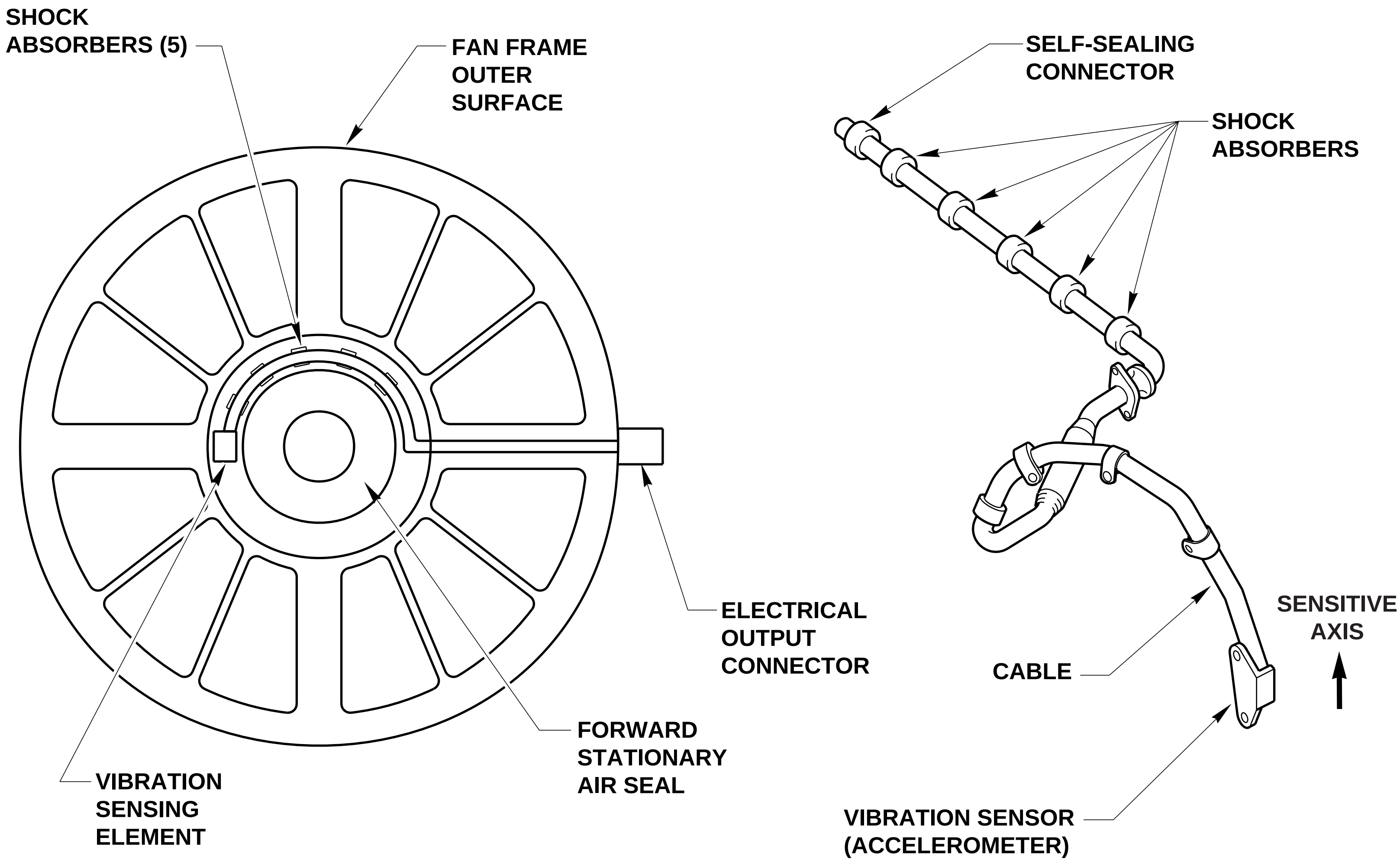
It is a 100 pC/g piezo-electric sensor.

A semi-rigid cable, routed in the engine fan frame, links the vibration sensor to an electrical output connector, located at the 3 o'clock position on the fan frame outer barrel.

The cable is protected by the installation of shock absorbers which damp out any parasite vibration.

The #1 bearing vibration sensor permanently monitors the engine vibration and due to its position, is more sensitive to fan and booster vibration. However, this sensor also reads N2 and LPT vibrations.

The data is used to perform fan trim balance. This sensor is not a Line Replaceable Unit (LRU). In case of failure, the TRF sensor must be selected, through the CFDS in maintenance mode, in order to continue engine vibration monitoring.



CTC-045-035-00

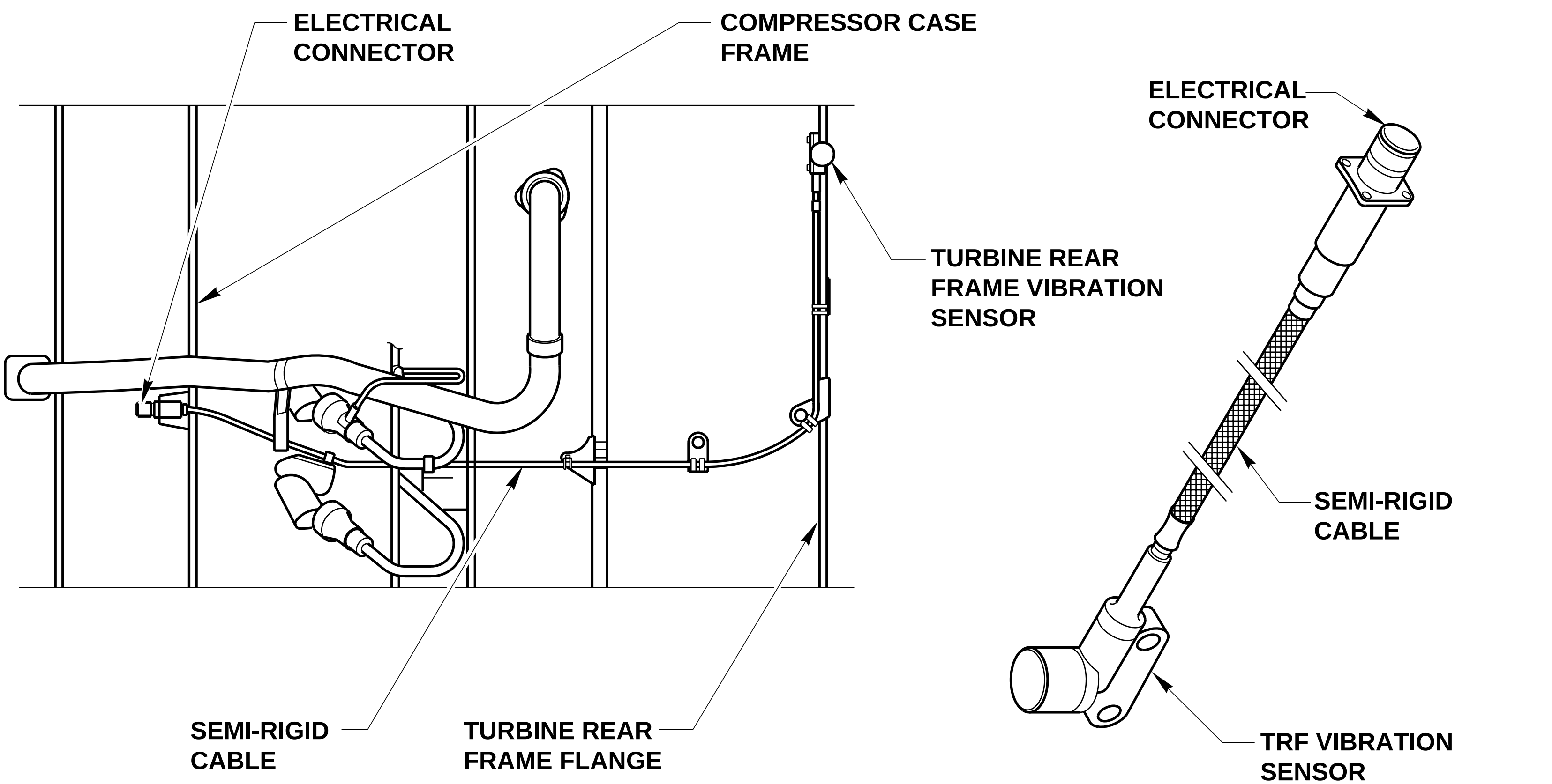
No 1 BEARING VIBRATION SENSOR

TRF vibration sensor.

The TRF vibration sensor is secured at the 12 o'clock position on the turbine rear frame.

It is a 50 pC/g piezo-electric sensor.
.
A semi-rigid cable is routed from the vibration sensor to an electrical connector, which is secured on a bracket on the core engine at the 10 o'clock position.

The TRF vibration sensor monitors the vertical acceleration of the rotors and sends the analogue signals to the EVMU for vibration analysis processing.



CTC-045-036-00

TURBINE REAR FRAME VIBRATION SENSOR

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ENGINE WIRING HARNESSES

ENGINE WIRING HARNESSES

The electrical harnesses ensure the connections between the various electrical, electronic and electro-mechanical components, mounted on the engine.

All the harnesses converge to the 6 o'clock junction box, which provides an interface between the two types.

They are all screened against high frequency electrical interferences, and each individual cable within a harness is screened against low frequency electrical interferences.

They are also constructed with fireproof materials and sealed to avoid any fluid penetration.

Two types of harnesses are used, depending on where they are installed on the engine.

Core engine section.

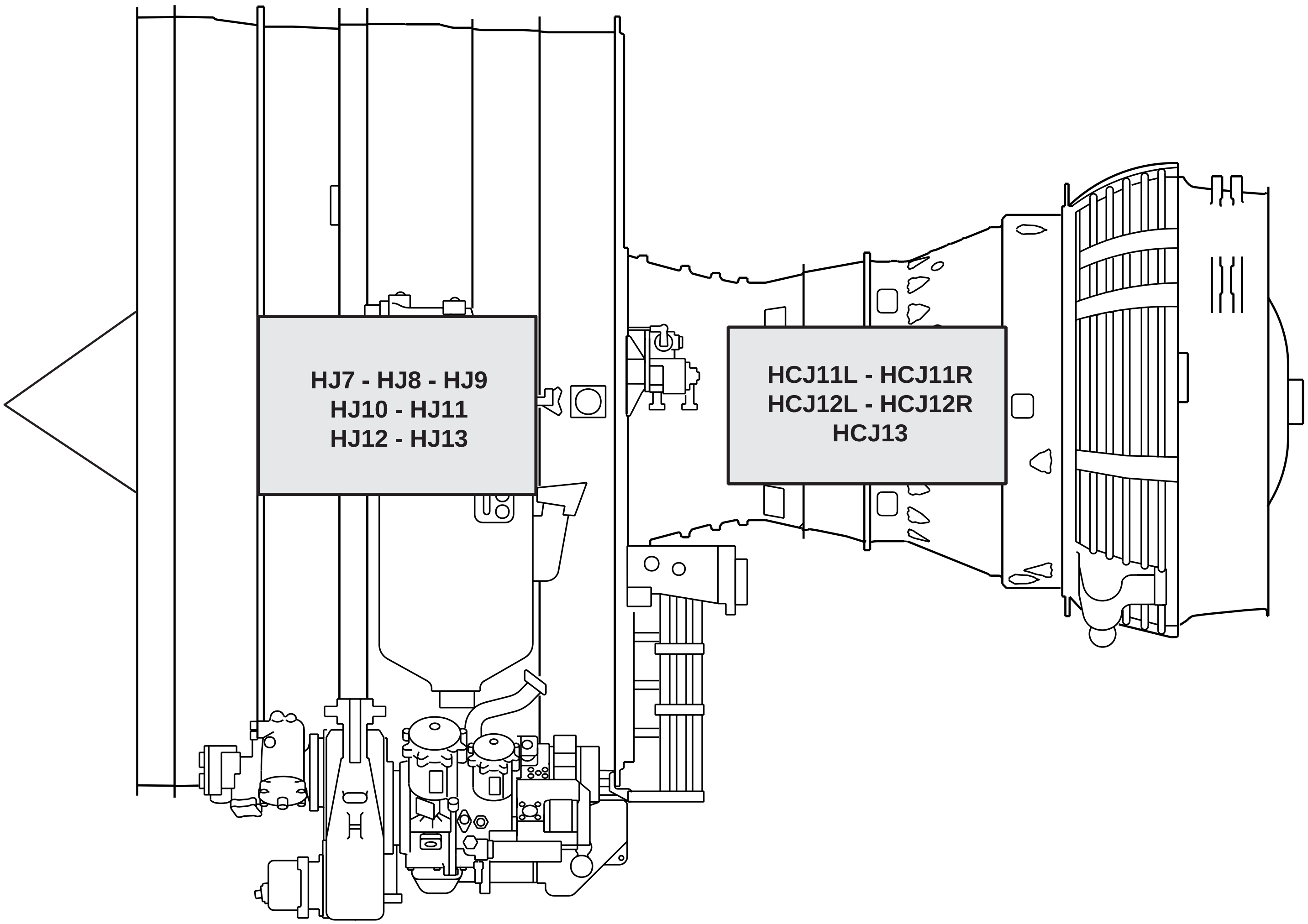
Harnesses routed along the core engine section have a special design that can withstand high temperatures.

Hot section harnesses are designated :
- HCJ11L, HCJ11R, HCJ12L, HCJ12R, HCJ13

Fan section.

Harnesses that run on the fan inlet case and the fan frame, have a more conventional design.

Cold section harnesses are designated :
- HJ7, HJ8, HJ9, HJ10, HJ11, HJ12, HJ13.



CTC-045-037-00

ENGINE ELECTRICAL HARNESSES

High temperature wiring harnesses

The high temperature wiring harness consists of screened and sealed cables, with several cores.

The cores are enclosed in a convoluted teflon conduit, for isolation and protection against shielding braid rubbing.

High frequency shielding is provided by a stainless steel braid.

The steel braid is surrounded by a polyamide braid, which is coated with Viton for protection against the barbs of the steel braid.

The polyamide braid is not used when the harness runs close to a very hot part of the engine (e.g. Combustion chamber).

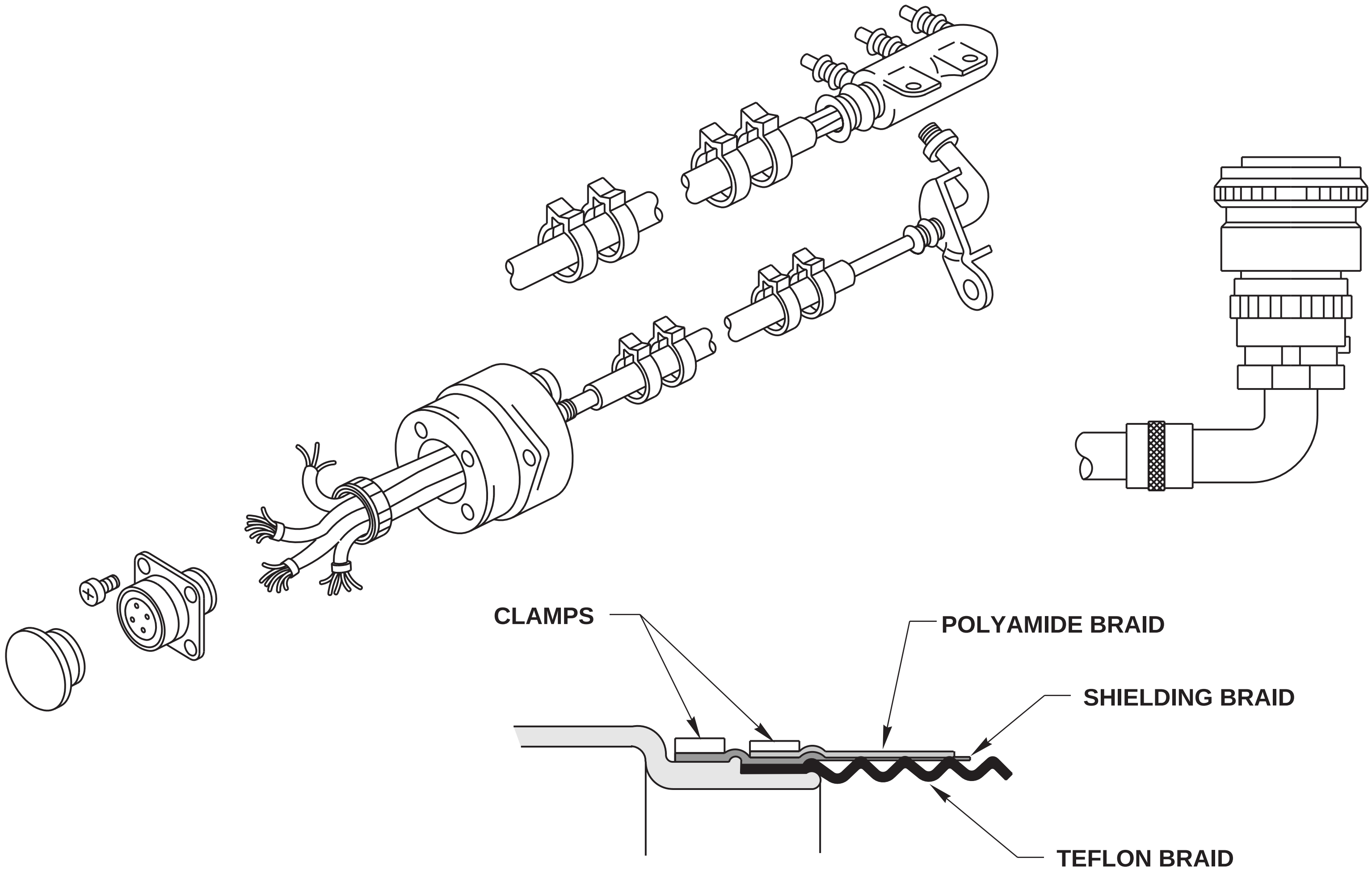
On these harnesses, the connector adaptor has two clamping lands.

The external polyamide braid and the teflon conduit are clamped on the first land and the stainless steel shielding braid is clamped on the second.

The connector adaptor is bolted on the electrical plug, and sealing is achieved by the teflon conduit clamping.

The harnesses on hot parts are connected through a junction box.

High temperature wiring harness connectors have their identification etched on them.



CTC-045-038-00

HOT SECTION HARNESSES

Fan section wiring harnesses.

The low temperature wiring harness consists of screened and sealed cables with several cores.

The cores are enclosed in a polyamide braid for isolation and protection against shielding braid rubbing.

High frequency shielding is provided by a tinned copper braid surrounded by a heat-shrink sleeve. This sleeve protects the copper braid and ensures wire sealing.

In the engine fan section, stainless steel, fluid-proof connectors are used.

There are two types of connectors, depending on the number of wires the harness contains.

If there is a single wire, the high frequency shielding braid is clamped directly on the connector adaptor.

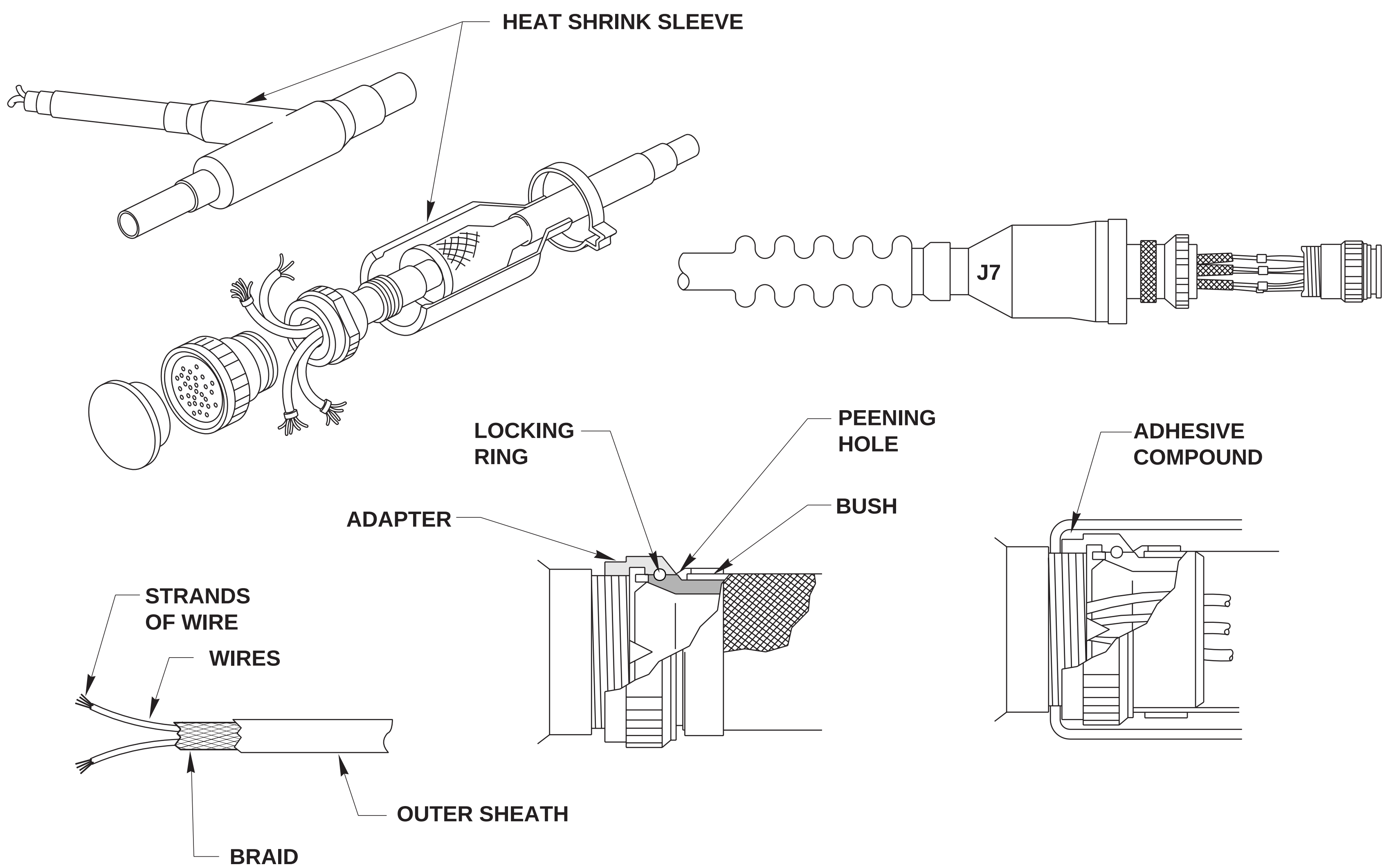
If there are several wires, the high frequency shielding braids are first crimped together with a main high frequency braid and then, clamped on the connector adaptor.

The adaptor is bolted on the electrical plug, and the junction is protected by a heat-shrink sleeve, glued and clamped on the connector adaptor.

A filling port allows the injection of a sealing compound inside the connector sleeve.

The junctions between the harnesses are protected with heat-shrink sleeves.

The connectors are identified by ring-sleeves that have the connection printed on them.



CTC-045-039-00

FAN SECTION HARNESSES

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STARTING SYSTEM

Starting function.

The FADEC is able to control engine starting, cranking and ignition, using aircraft control data.

Starting can be performed either in Manual Mode, or Automatic Mode.

For this purpose, the ECU is able to command :

- opening and closing of the Starter Air Valve (SAV),
- positioning of the Fuel Metering Valve (FMV),
- energizing of the igniters.

It also detects abnormal operation and delivers specific messages.

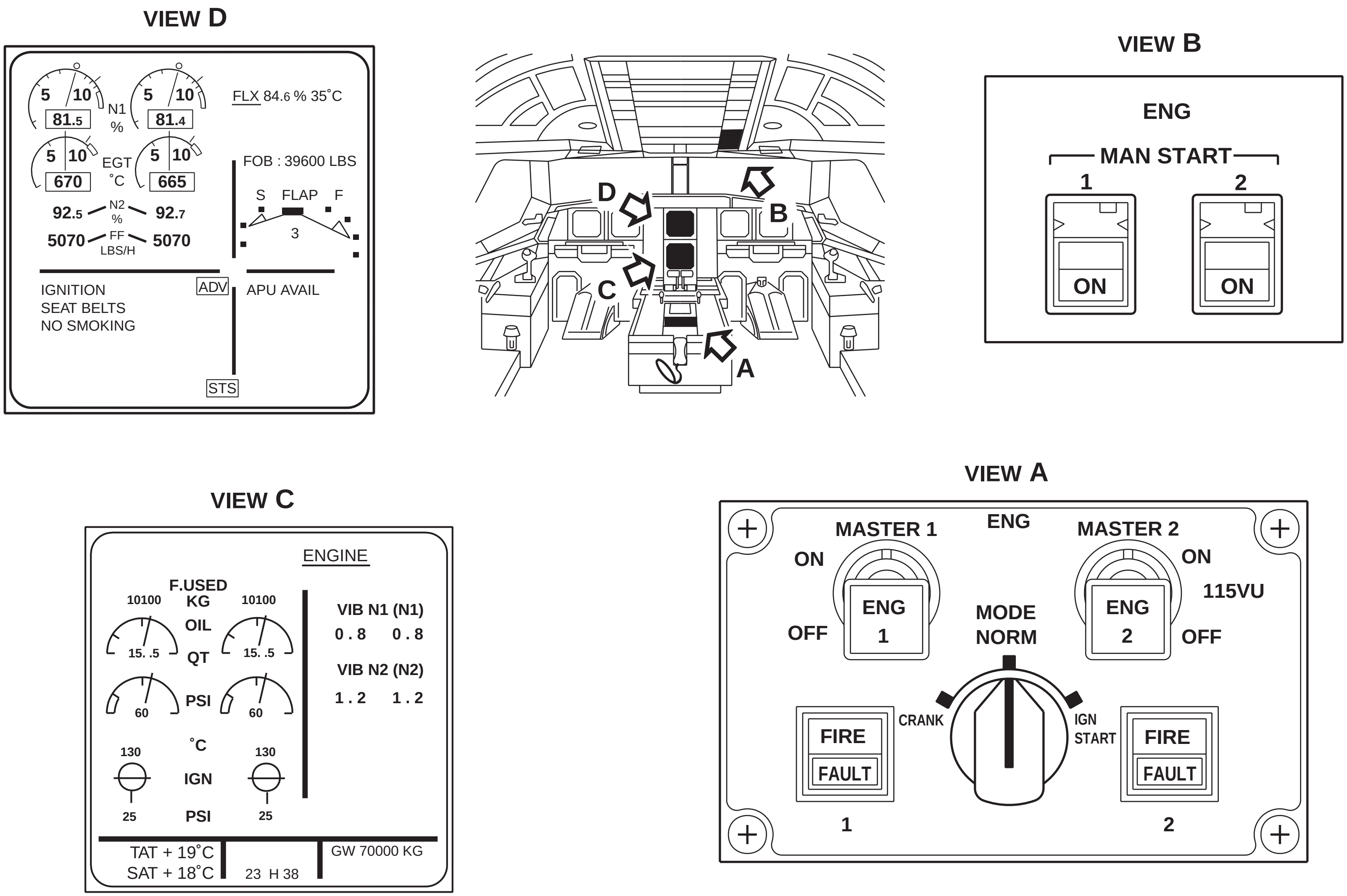
Engine panels.

Starting is initiated from the following cockpit control panels :

- The engine control panel on the central pedestal, which has a single Rotary Mode Selector for both engines and two Master Levers, one for each engine.

- The engine Man Start panel on the overhead panel, which has two switches, one for each engine.

- The Engine Warning Display (EWD) and the System Display (SD) on the upper and lower ECAM's, where starting data and messages are displayed .



ENGINE PANELS

There are two starting procedures which correspond to two starting laws in the ECU logic :

1. -The automatic starting process, under the full authority of the FADEC system.
2. -The manual starting process, with limited authority of the FADEC system.

1) Automatic start.

During an automatic start, the ECU includes engine protection and provides limits for N1, N2 and EGT, with the necessary indications in the cockpit.

The automatic starting procedure is :

- Rotate mode selector to IGN/START.

Both ECU's are powered up.

- Switch the MASTER LEVER to 'ON'.

The SAV opens and :

- at 16% N2 speed, one igniter is energized.
- at 22% N2 speed, fuel is delivered to the combustor.
- at 50% N2 speed, the SAV is closed and the igniter de-energized.

In case of no ignition, the engines are dry motored and a second starting procedure initiated on both igniters.

2) Manual start.

During a manual start, the ECU provides limited engine protection and limitation on EGT only.

The manual starting procedure is :

- Rotate mode selector to IGN/START.

Both ECU's are powered up.

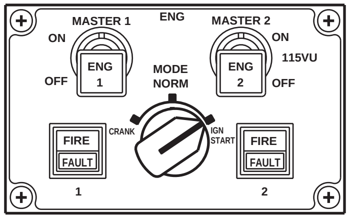
- Press the MAN/START push button.

The SAV opens and :

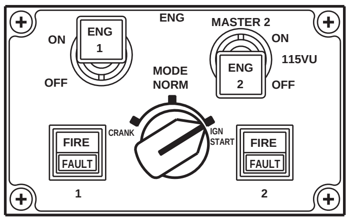
- when N2 speed > 20%, switch the MASTER LEVER to 'ON'.
- the two igniters are energized and fuel is delivered to the combustor.
- at 50% N2 speed, the SAV is closed and the igniters automatically de-energized.

When the engines are started (manual, or automatic), the mode selector must be switched back to the NORMAL position.

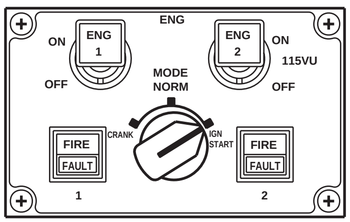
AUTOMATIC START



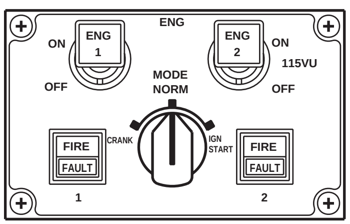
(1) IGN/START ON MODE SELECTOR



(2) MASTER LEVER SWITCHED "ON"
- STARTER VALVE OPENS
- 16% N2 : IGNITION "ON"
- 22% N2 : FUEL "ON"
- 50% N2 : S.A.V. CLOSES IGNITION "OFF"

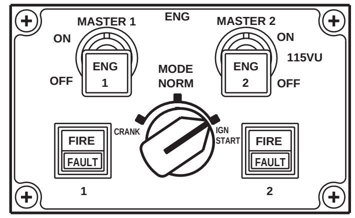


(3) START THE SECOND ENGINE MASTER LEVER SWITCHED "ON"

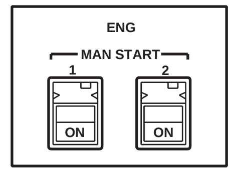


(4) MODE SELECTOR BACK TO NORMAL WHEN ENGINES STABILIZED AT IDLE

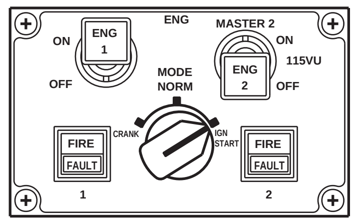
MANUAL START



(1) IGN/START ON MODE SELECTOR

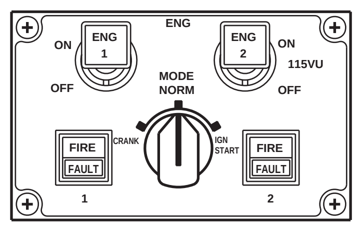


(2) MAN START PUSHBUTTON "ON" TO OPEN STARTER VALVE



(3) WHEN N2 > 20% MASTER LEVER "ON"
- IGNITION "ON"
- FUEL "ON"
- 50% N2 : S.A.V. CLOSES IGNITION "OFF"

(4) START THE SECOND ENGINE



(5) MODE SELECTOR BACK TO NORMAL WHEN ENGINES STABILIZED AT IDLE

STARTING SYSTEM

CTC-045-041-00

STARTING SYSTEM

The starting system provides torque to accelerate the engine to a speed such that it can light off and continue to run unassisted.

The starting system is located underneath the right hand side engine cowlings, and consists of :

- one pneumatic starter.
- one Starter Air Valve (SAV).
- two air ducts.

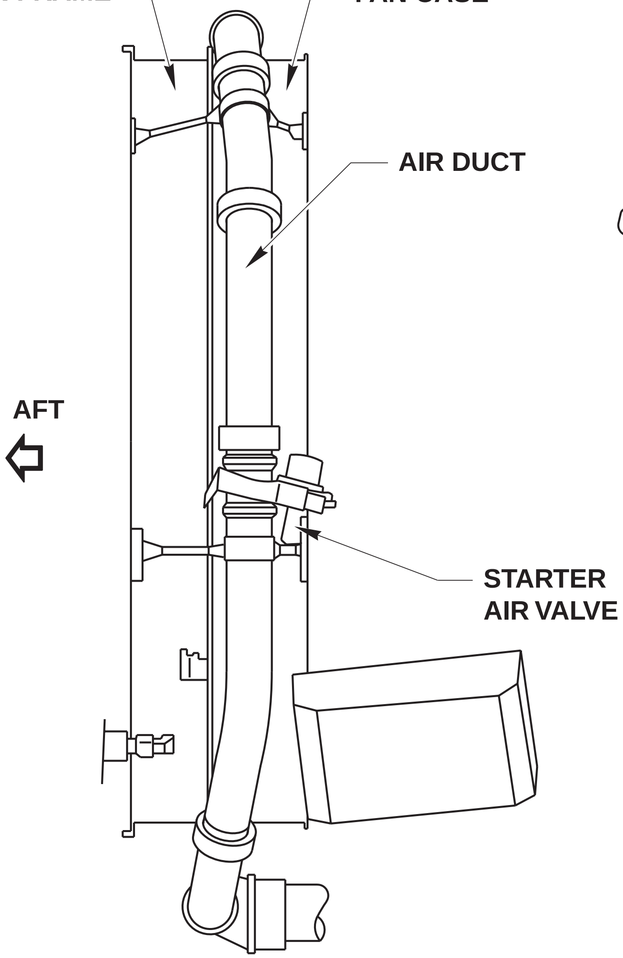
Starting operation.

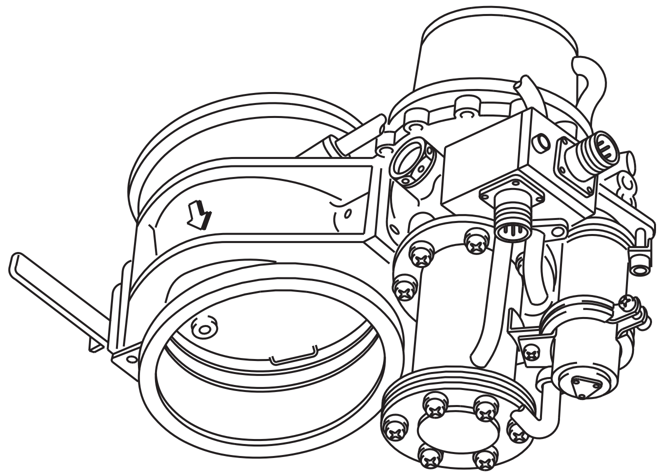
When the starter air valve is energized, it opens and air pressure is delivered to the pneumatic starter.

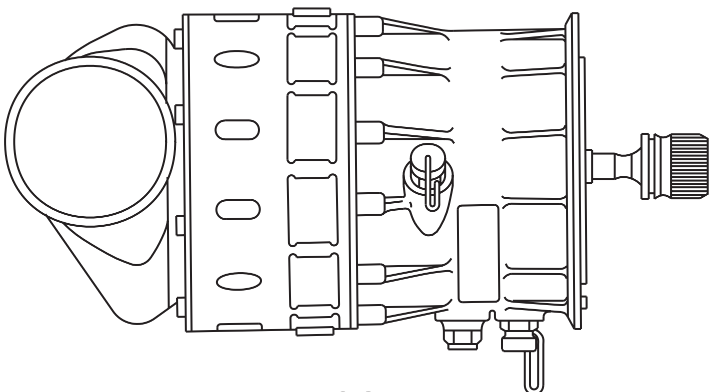
The pneumatic starter provides the necessary torque to drive the HP rotor, through the AGB, TGB and IGB.

The necessary air pressure for the starter comes from :

- the APU.
- the other engine, through the cross bleed system.
- a ground power unit (25 to 55 psi).







STARTING SYSTEM

CTC-045-042-00

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PNEUMATIC STARTER

PNEUMATIC STARTER

The pneumatic starter is connected to an air starter duct and converts the pressurized airflow from the aircraft air system into a high torque rotary movement.

This movement is transmitted to the engine High Pressure (HP) rotor, through the accessory drive system.

An internal centrifugal clutch automatically disconnects the starter from the engine shaft.

The pneumatic starter is secured on the aft right hand side of the AGB.

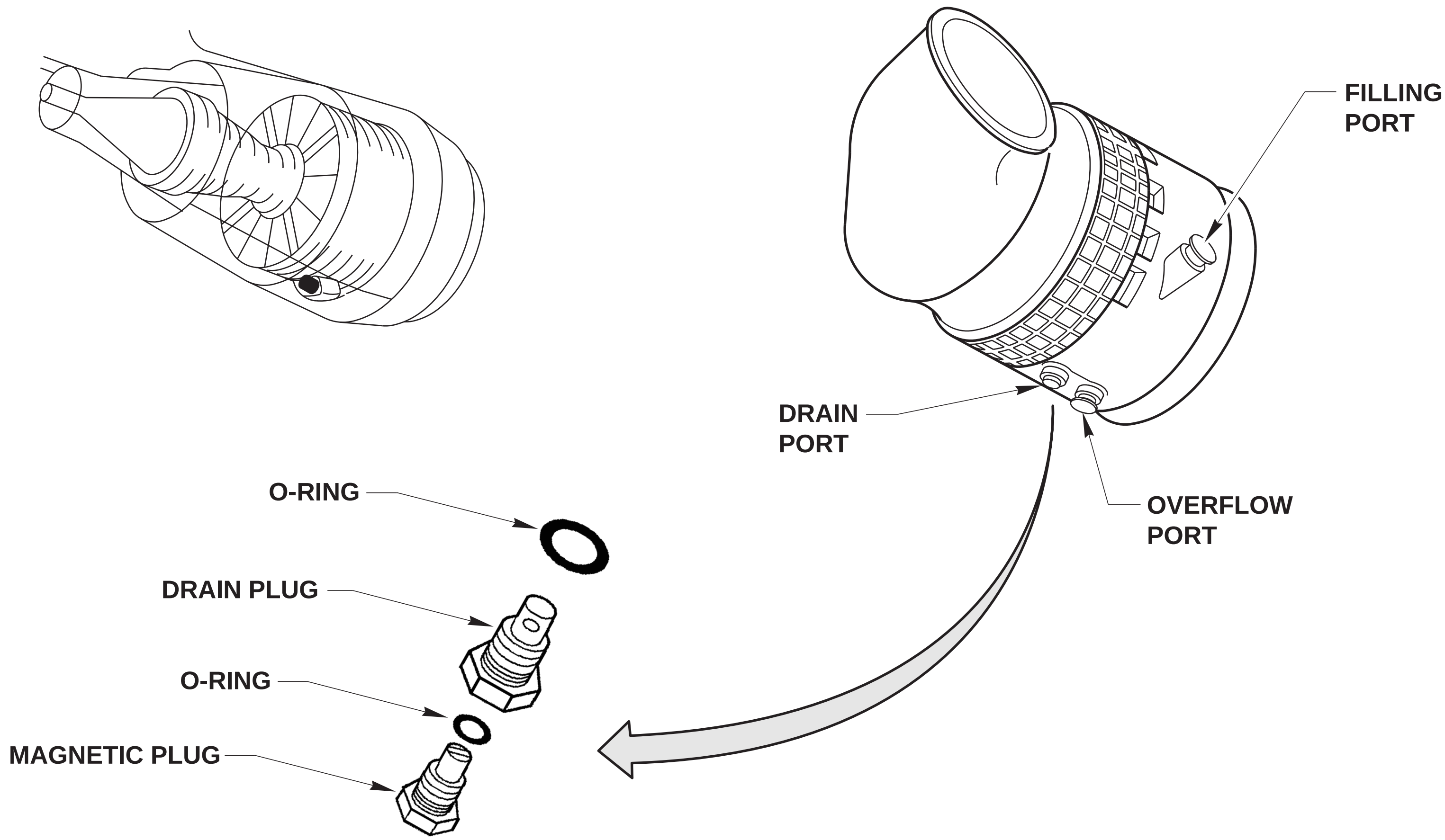
The pneumatic starter works with engine oil and has three ports :

- a filling port
- an overflow port
- a drain port.

The drain port features a plug made in two parts :

- an inner part, which is a magnetic plug used to trap any magnetic particles contaminating the oil.

- an outer part, which is the drain plug, receives the magnetic plug. This part has a check valve to prevent any oil spillage when the magnetic plug is removed for maintenance checks.



CTC-045-043-00

PNEUMATIC STARTER

PNEUMATIC STARTER

The pneumatic starter has an air inlet and a stator housing assembly, which contains the following main elements :

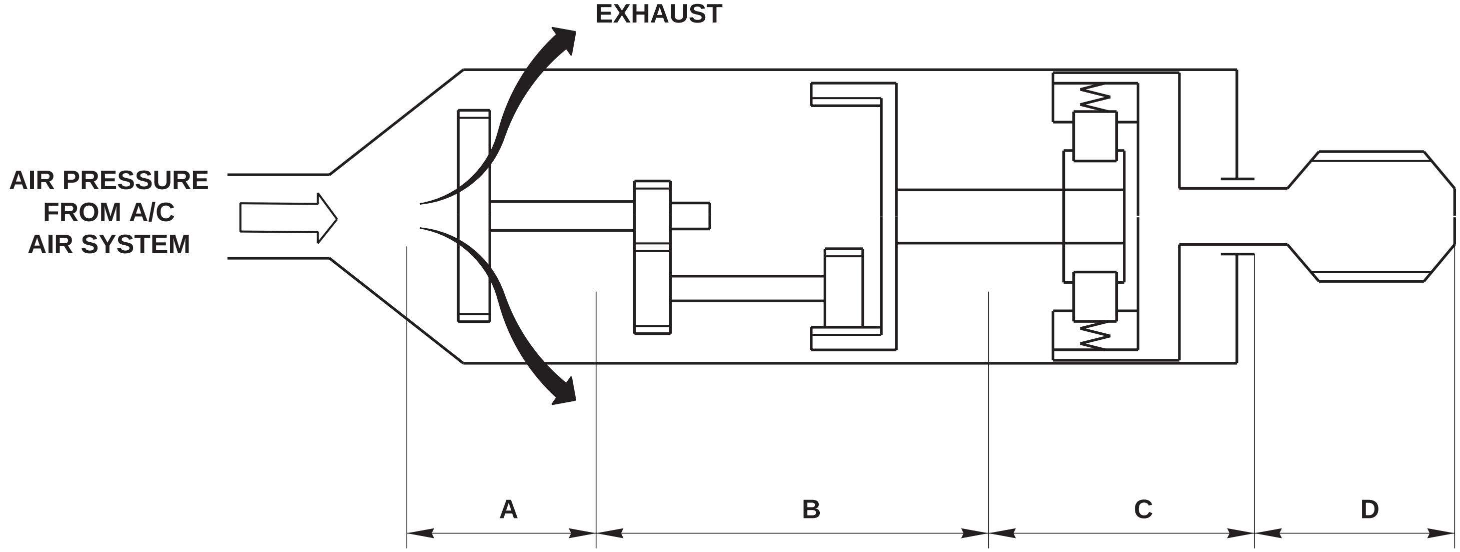
- a turbine wheel stator and rotor.
- a gear set.
- a clutch assembly.
- an output shaft.

Pressurized air enters the air starter and reaches the turbine section, which transforms the air's kinetic energy into mechanical power.

This high speed power output is transformed into low speed and high torque motion, through a reduction gear set.

A clutch system, installed between the gear set and the output shaft, ensures transmission of the turbine wheel power to the output shaft during engine starting, and disconnection when the output shaft speed reaches 50% of N2.

A = TURBINE
B = REDUCTION GEAR SET
C = CLUTCH
D = OUTPUT SHAFT



CTC-045-044-00

AIR STARTER OPERATION

PNEUMATIC STARTER

The inlet air plenum ducts the flow of compressed air to a stator, which then directs the airflow onto the blades of a turbine wheel.

The resulting rotation produces high speed and low torque.

The turbine exhaust air is discharged through an exhaust housing and screen.

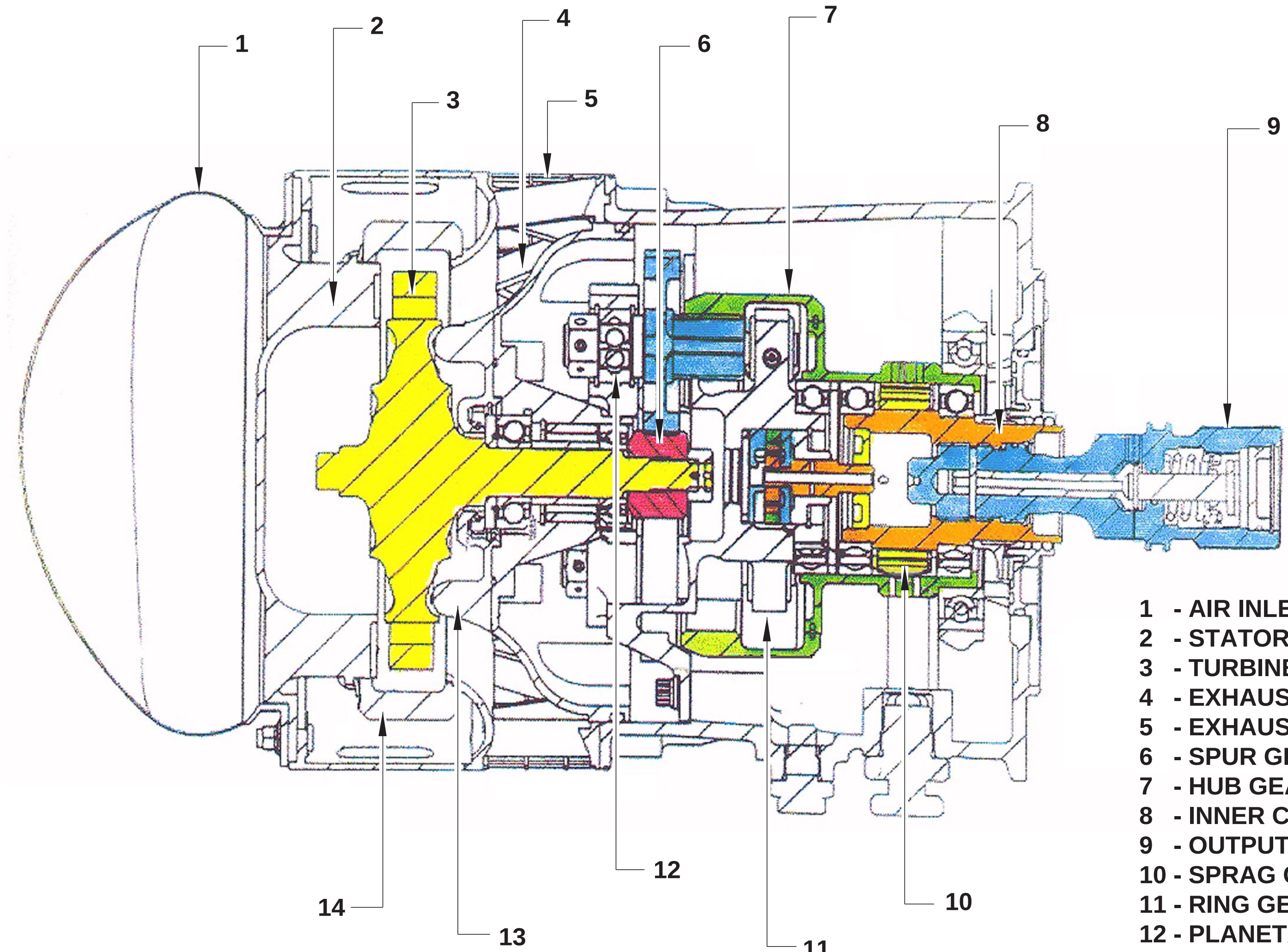
A spur gear drives three matched planetary gears, which drive a hub gear and a ring gear. The planetary gears, sprag clutch and components provide reduced speed and increased torque rotation to the inner clutch race and output shaft assembly.

The clutch consists of an inner race overrunning sprag clutch. During starter overrunning operation (50% N2), the inner race rotates while the sprags retain a fixed angular position with respect to the outer race. The outer race comes to rest following the start cycle. The sprags are lightly preloaded to allow for re-engagement with minimum backlash.

The sprag clutch provides positive engagement with the engine up to cutout speed (50% N2) and overruns during engine operation. This allows the planetary gears, hub gear, ring gear and stator to stop rotation. The starter may be re-engaged at any speed from zero to cutout.

The rotating assembly incorporates a cutter ring, which has 12 tungsten carbide cutter pins. In case of bearing failure, the turbine wheel moves axially, comes into contact with the cutter ring and then stops rotating.

A containment ring provides retention of any rotating part within the starter housing.



1 - AIR INLET PLENUM
2 - STATOR
3 - TURBINE WHEEL
4 - EXHAUST HOUSING ASSY
5 - EXHAUST SCREEN
6 - SPUR GEAR
7 - HUB GEAR
8 - INNER CLUTCH RACE
9 - OUTPUT SHAFT ASSY
10 - SPRAG CLUTCH
11 - RING GEAR
12 - PLANETARY GEAR
13 - CONTAINMENT RING ASSY
14 - CONTAINMENT RING

CTC-045-045-00

AIR STARTER

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STARTER AIR VALVE

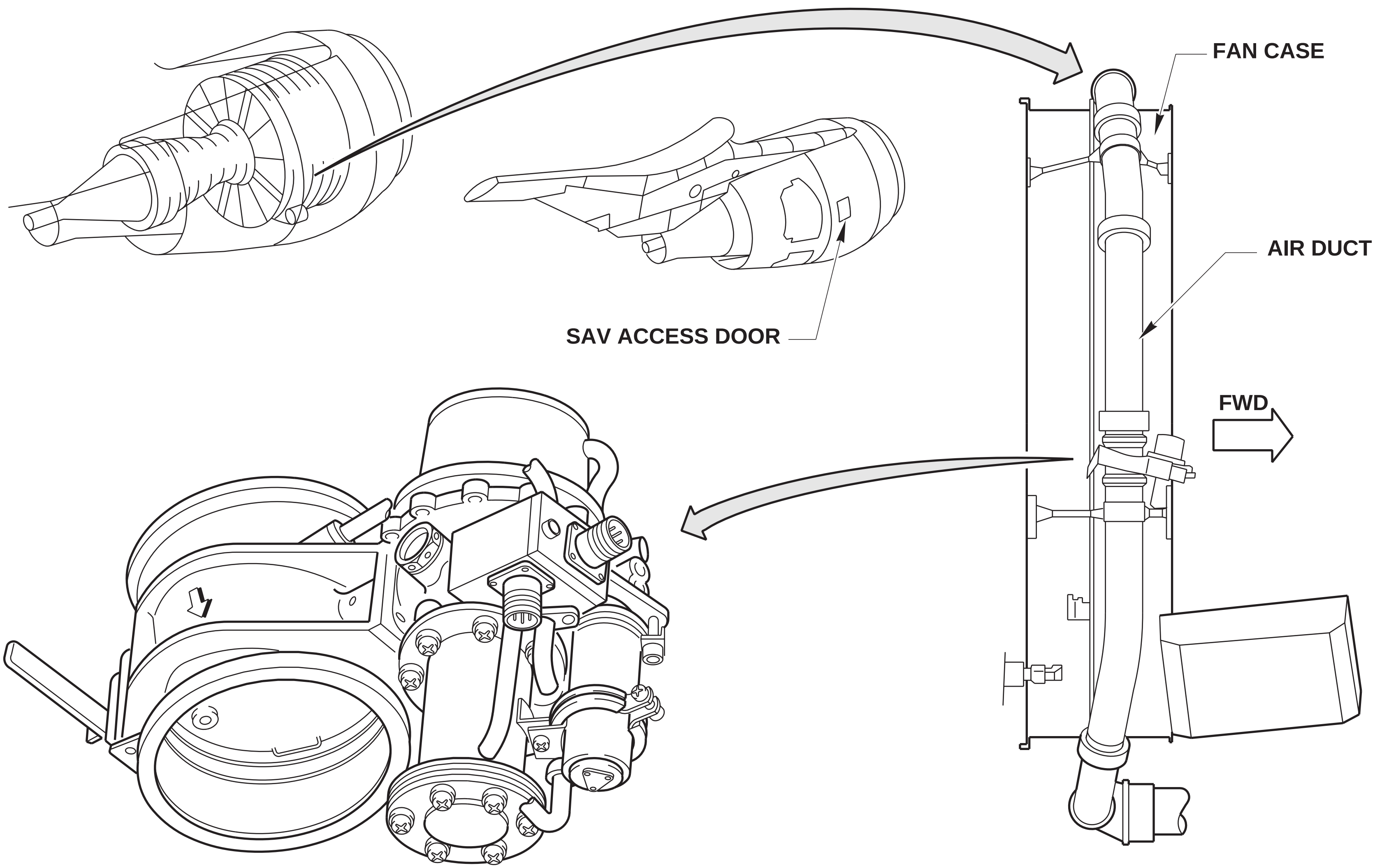
STARTER AIR VALVE

The Starter Air Valve (SAV) controls the pressurized air flow to the engine pneumatic starter.

The SAV is secured on the air starter duct, just below the 3 o’clock position and is accessible through an access door provided on the right hand side fan cowl.

The valve is connected to two air ducts. The upper duct (from the pylon to the valve), and the lower duct (from the valve to the air starter).

Two electrical connections transfer electrical signals to the ECU.



CTC-045-046-00

STARTER AIR VALVE LOCATION

STARTER AIR VALVE

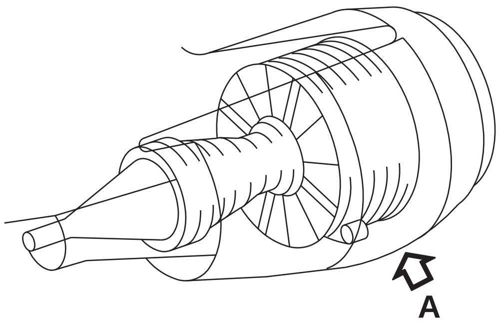
The SAV is normally closed.

An electrical signal, sent by the ECU, changes the valve status to the open position.

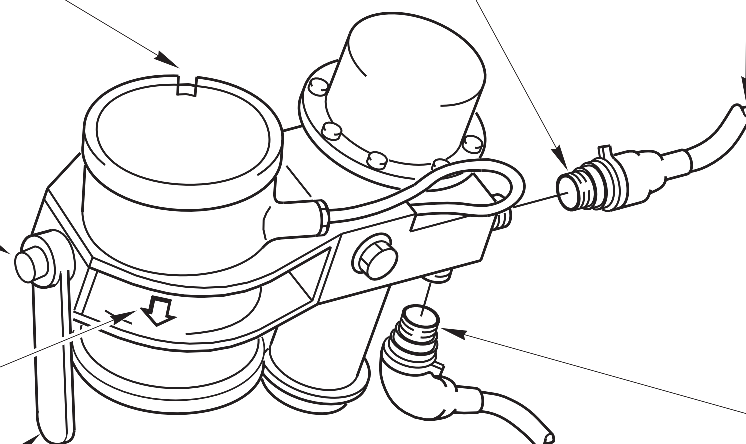
The valve can be manually operated in case of electrical command failure. The wrench button has to be pressed before moving the SAV handle and air pressure must be present, to avoid internal damage.

Gloves must be worn, to avoid injury from hot parts.

Position switches provide the valve status to the ECU.



SWITCHES CLOSED = VALVE NOT CLOSED
SWITCHES OPEN = VALVE CLOSED



STARTER AIR VALVE

CTC-045-047-00

STARTER AIR VALVE

The SAV has three main operations which are :

- Opening operation.
- Closing operation.
- Manual override operation.

Opening operation.

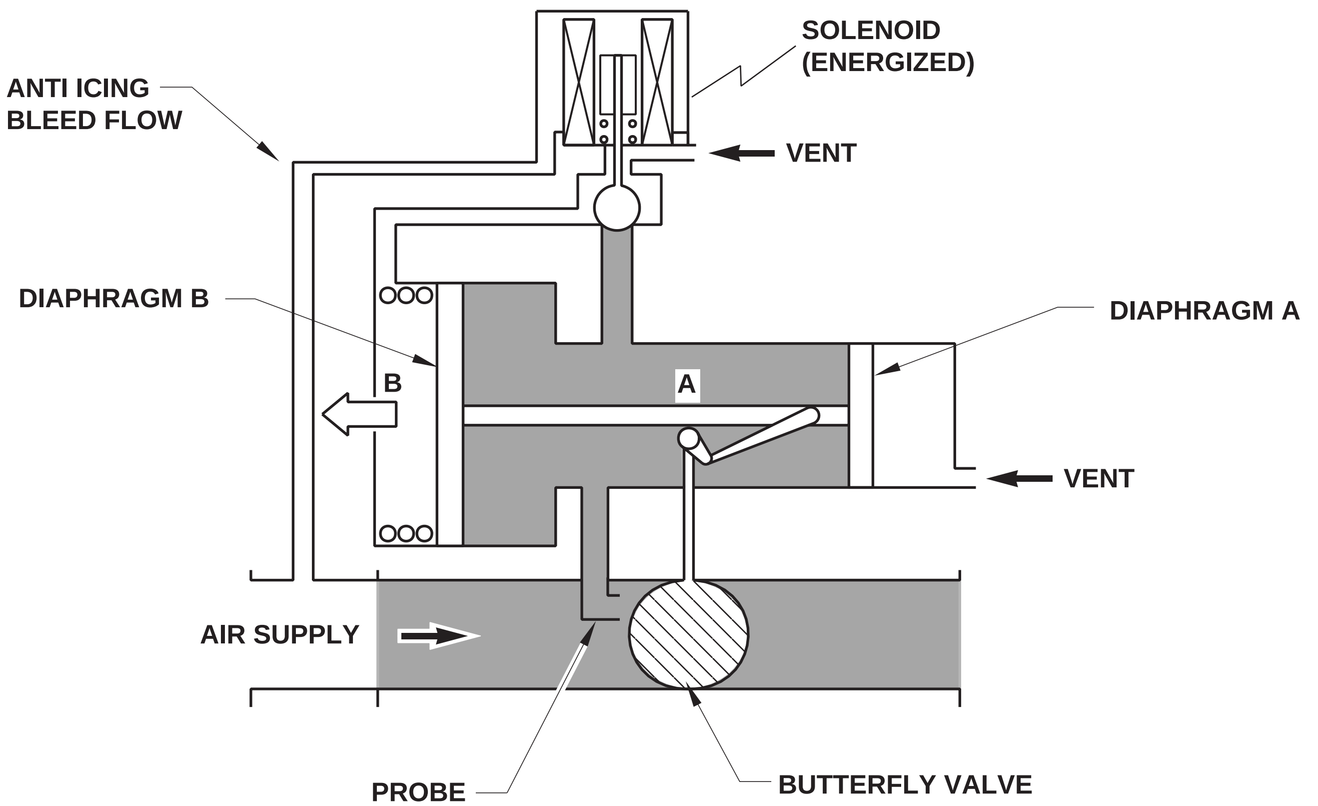
The valve is normally closed, and is opened by energizing either of the two solenoid coils.

Energization drives the solenoid ball down.

The pressure in chamber A is blocked by the solenoid ball, and the pressure in chamber B is vented to ambient, through an open rating orifice.

With chamber B vented, the pressure in chamber A applies greater force on diaphragm B.

The valve will actuate the butterfly to the open position, when the inlet pressure in chamber A is sufficient to overcome the force of the closing torsion spring.



CTC-045-048-00

STARTER AIR VALVE OPENING OPERATION

STARTER AIR VALVE

Closing operation.

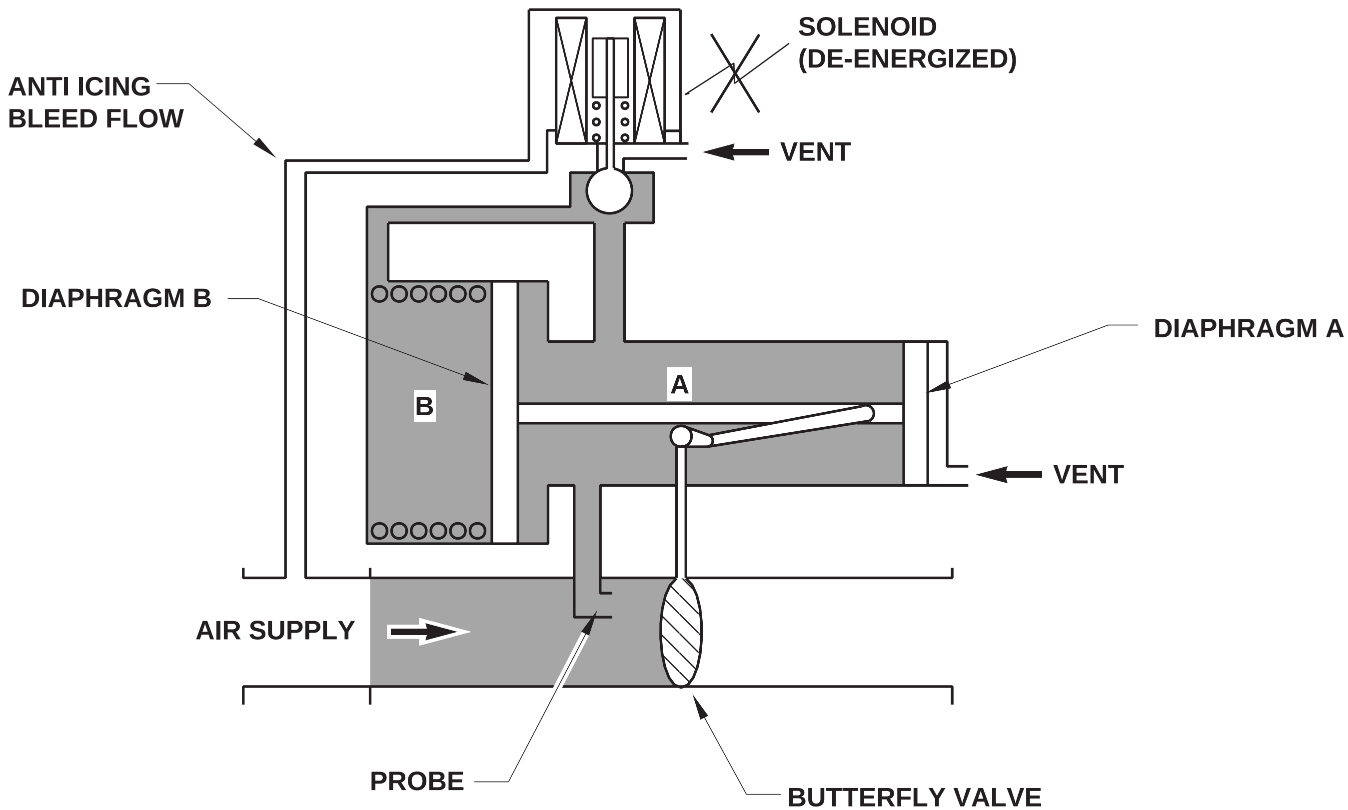
The butterfly valve remains closed when the solenoid is de-energized.

Inlet air pressure is routed through a downstream facing probe and regulating orifice to chamber A. The probe prevents contaminants entering the valve.

The pressure is then routed across the solenoid pilot valve, now in the open position, to chamber B.

Since the pressure on both sides of diaphragm B is equal, no force remains. The pressure in chamber A exerts a force on diaphragm A, and this force, combined with the force of the closing torsion spring, closes the butterfly valve.

To prevent the possibility of valve malfunction due to freezing of the solenoid pilot valve, the unit incorporates a small permanent pneumatic bleed flow to heat the solenoid control valve.



CTC-045-049-00

STARTER AIR VALVE CLOSING OPERATION

Manual override operation.

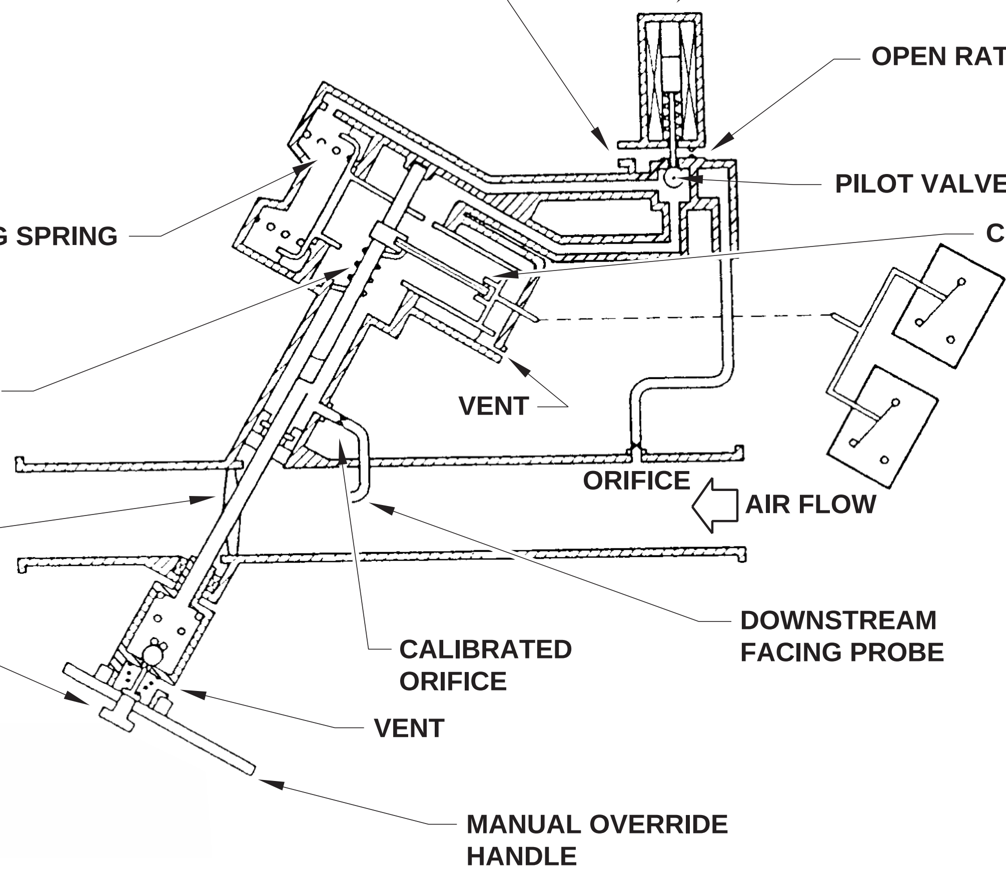
The valve is manually opened by first pushing the wrench button and then, rotating the manual override lever.

Pushing the wrench button vents chamber A and B past the manual override vent ball. Because the manual override vent is larger than the regulating orifice, the pressures in chambers A and B decrease to ambient pressure.

Since there is no longer any diaphragm force on the actuator, the handle can be rotated against the closing torsion spring to open the butterfly.

When the handle is released, the torsion spring turns the butterfly valve to the closed position, and the button is returned to the closed position by the action of the vent ball spring.

The override handle aligns with markings on the valve to provide an external indication of the butterfly valve position.



STARTER AIR VALVE MANUAL OVERRIDE

CTC-045-050-00

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IGNITION

IGNITION GENERAL

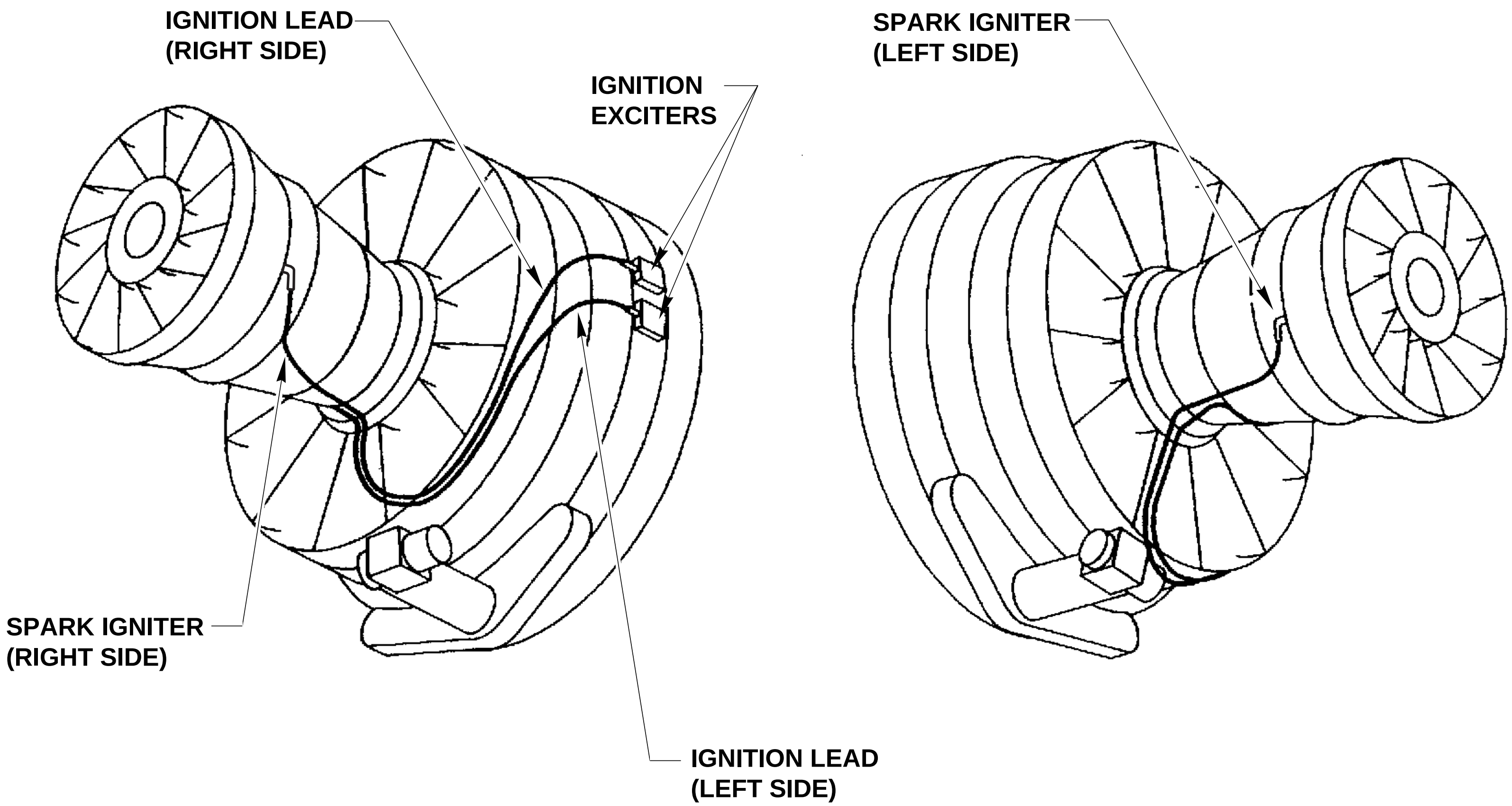
The purpose of the ignition system is to ignite the air/fuel mixture within the combustion chamber.

The engine is equipped with a dual ignition system, located on the right-hand side of the fan case and both sides of the cores.

The ignition system has two independent circuits consisting of :

- 2 high energy ignition exciters.
- 2 ignition lead assemblies.
- 2 spark igniters.

A current is supplied to the ignition exciters and transformed into high voltage pulses. These pulses are sent, through ignition leads, to the tip of the igniter plugs, producing sparks.



CTC-045-051-00

IGNITION GENERAL

IGNITION SYSTEM

Power Supply

The ignition system receives its electrical power from the aircraft.

115 VAC/400 Hz is provided to channels A and B of the ECU, through 2 separate power supplies:

- channel A from the A/C emergency bus.
- channel B from the A/C normal bus.

Each supply is dedicated to one input, one providing power for ignition exciter No 1, and the other for ignition exciter No 2.

The A/C power supply will be automatically disconnected by the Engine Interface Unit (EIU) if :

- the master lever is selected OFF.
- in case of fire emergency procedure.

The A/C ignition power supply is failsafed to ON in case of a failed EIU.

Each channel in the ECU is able to control both ignition exciters, by switching the appropriate 115 volts source through ignition relays.

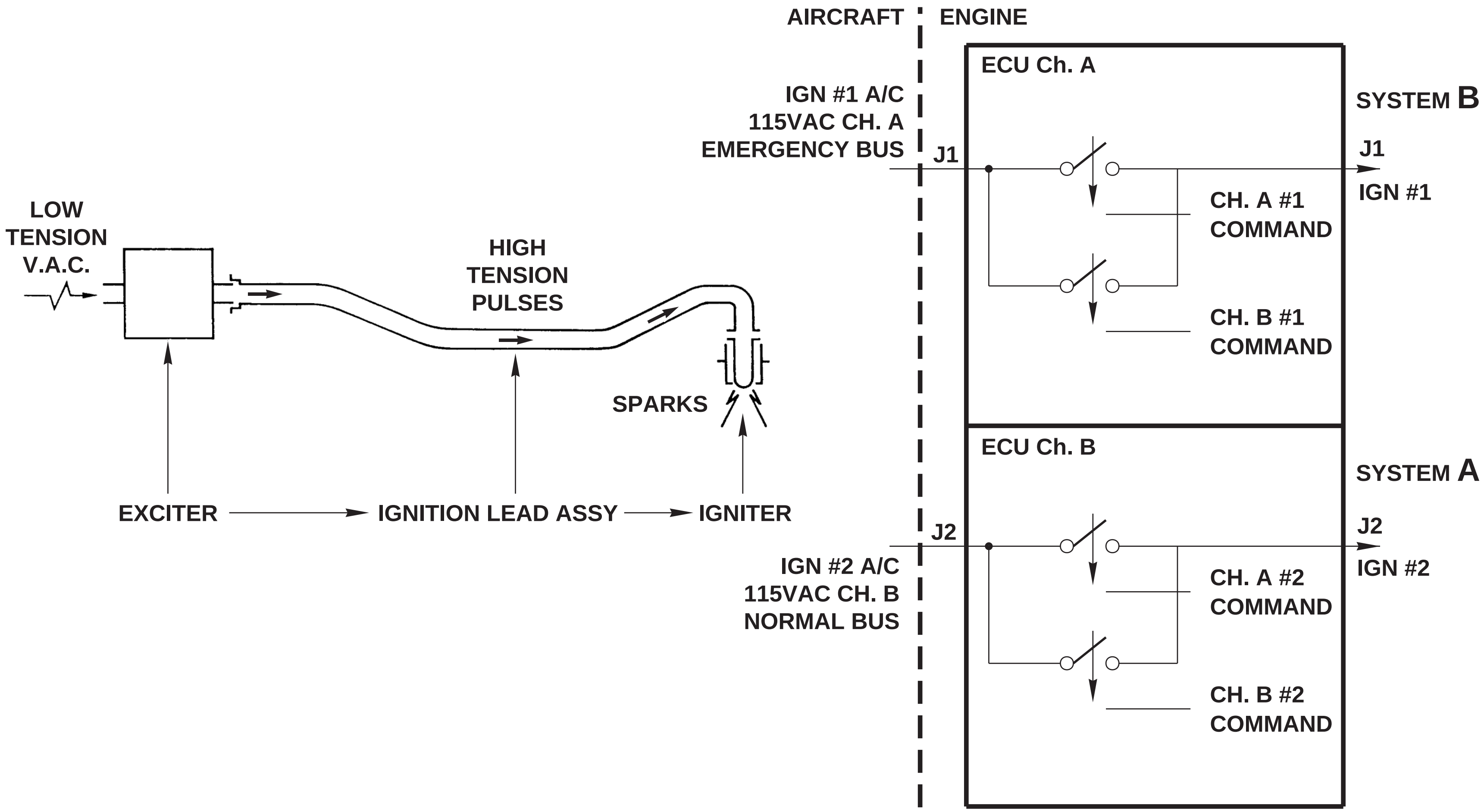
In normal automatic start, on the ground, switching occurs every other start (A-A-B-B-A-A etc…), assuming that N2 speed reaches 50%.

If the ground automatic start attempt fails, a second attempt is performed, energizing both igniters.

The two igniters are selected “ON” during :

- an automatic start in flight.
- manual start, either in flight or, on the ground.
- continuous ignition.

System B, located on the left hand side, is connected to the lower ignition box #1.
System A, located on the right hand side, is connected to the upper ignition box #2.



IGNITION SYSTEM

CTC-045-052-00

IGNITION BOXES

The ignition exciters, which are capacitor discharge type, use 115 VAC to produce high voltage pulses to energize the spark igniters .

The ignition exciters transform this low voltage input into repeated 20 KV high voltage output pulses.

The 2 ignition exciters are installed on the fan case, between the 3 and 4 o'clock positions.

A stainless steel protective housing, mounted on shock absorbers and grounded, encloses the electrical exciter components.

The housing is hermetically sealed, ensuring proper operation, whatever the environmental conditions.

The components are secured mechanically, or with silicon cement, for protection against engine vibration.

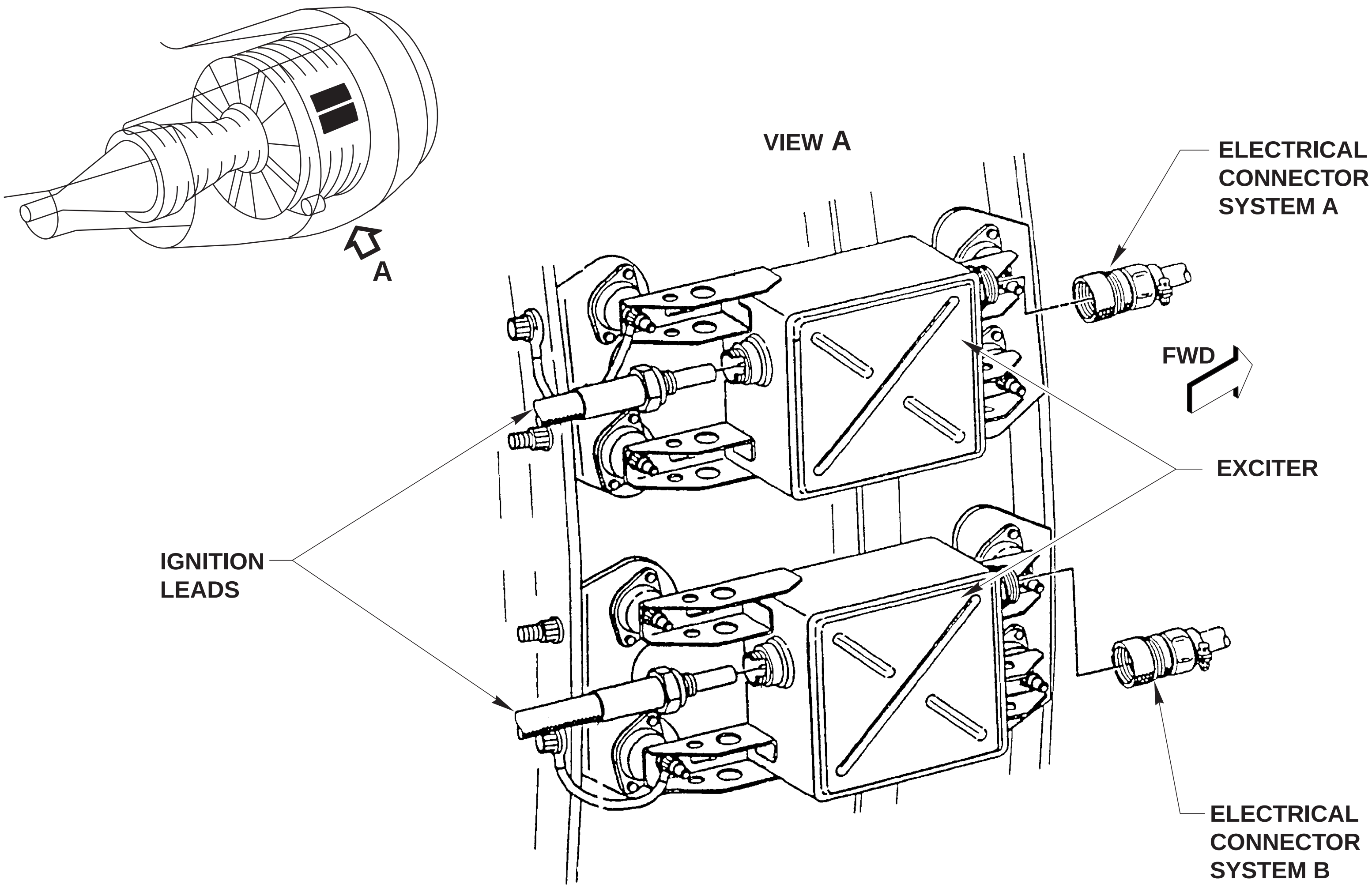
The ignition exciter electrical circuit consists of :

- an input circuit.
- a rectifier and storage circuit.
- a discharge circuit.

The A/C alternating input voltage is first rectified and then stored in capacitors.

In the discharge circuit, a spark gap is set to break down when the capacitors are charged, delivering a high voltage pulse at a regular rate.

Input voltage:	105-122 VAC	(115V nominal).
	380-420Hz	(400 Hz nominal).
Output voltage:	15-20KV	at the end of the ignition lead.



CTC-045-053-00

IGNITION BOXES LOCATION

IGNITION DISTRIBUTION SYSTEM

The purpose of the distribution system is to transmit the electrical energy delivered by the ignition exciters to produce sparks inside the combustion chamber.

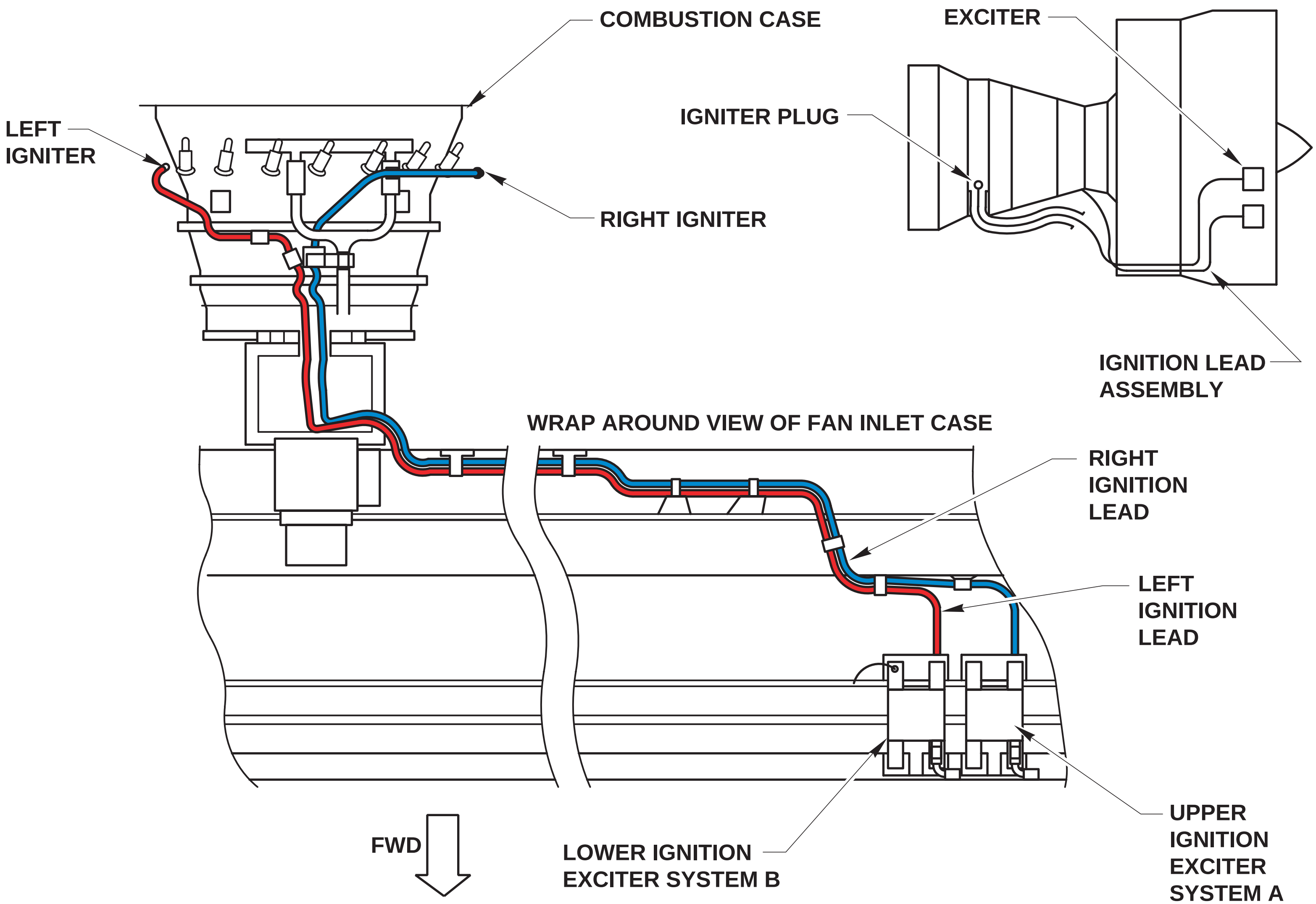
The main elements of distribution are :

- 2 ignition lead assemblies, from the exciters to the combustor case, at each spark igniter location.
- 2 spark igniters, located on the combustor case at 4 and 8 o'clock.

The two ignition lead assemblies are identical and interchangeable, and each connects one ignition exciter to one spark igniter.

A single coaxial electrical conductor carries the high tension electrical pulses to the igniter plug.

The portion of the lead assembly along the core, as well as the outer portion of the igniter, is cooled by booster discharge air.



IGNITION DISTRIBUTION SYSTEM LOCATION

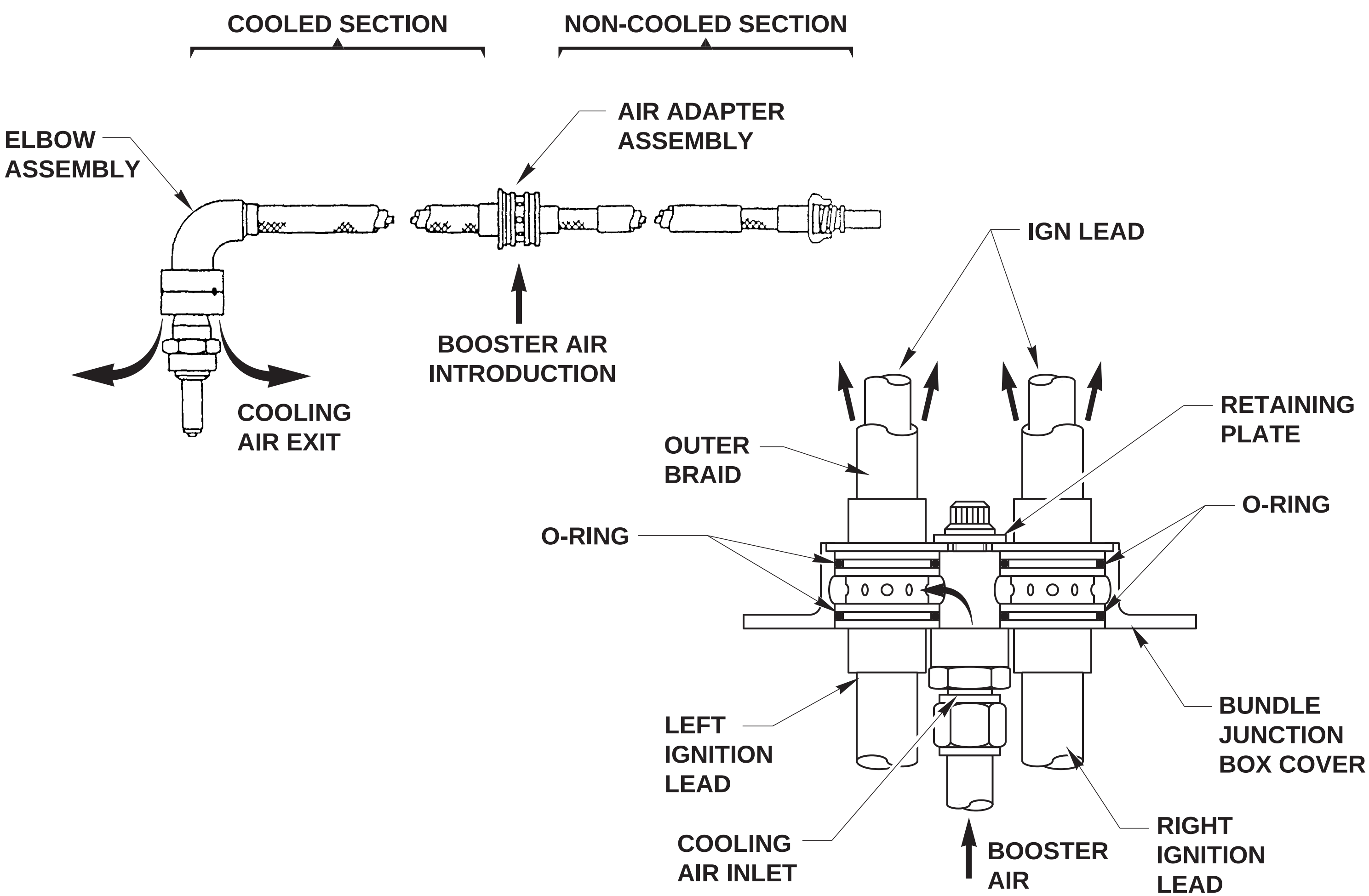
CTC-045-54-00

IGNITION DISTRIBUTION SYSTEM

The ignition lead assembly consists of an elbow, an air inlet adapter, an air outlet and terminals that are interconnected with a flexible conduit assembly.

The flexible conduit consists of an inner copper braid, a convoluted conduit, and a nickel outer braid.
Within this metal sleeve is a stranded, silicon-insulated wire.

Booster air is introduced at the air adapter assembly, into the cooled section of the conduit, and exits at the connection with the igniter.



IGNITION LEAD

CTC-045-055-00

IGNITION DISTRIBUTION SYSTEM

Igniter plug.

The igniter plug is a recessed gap igniter, which has :

- an input terminal contact,
- a shell seal.
- a retained insulator.
- an installation flange gasket.
- a spark gap.

The igniter plug operates in conjunction with the capacitor discharge-type ignition exciter.

An electrical potential is applied across the gap between the center electrode and the shell.

As the potential across the electrode and shell increases, a spark is emitted, igniting the fuel/air mixture.

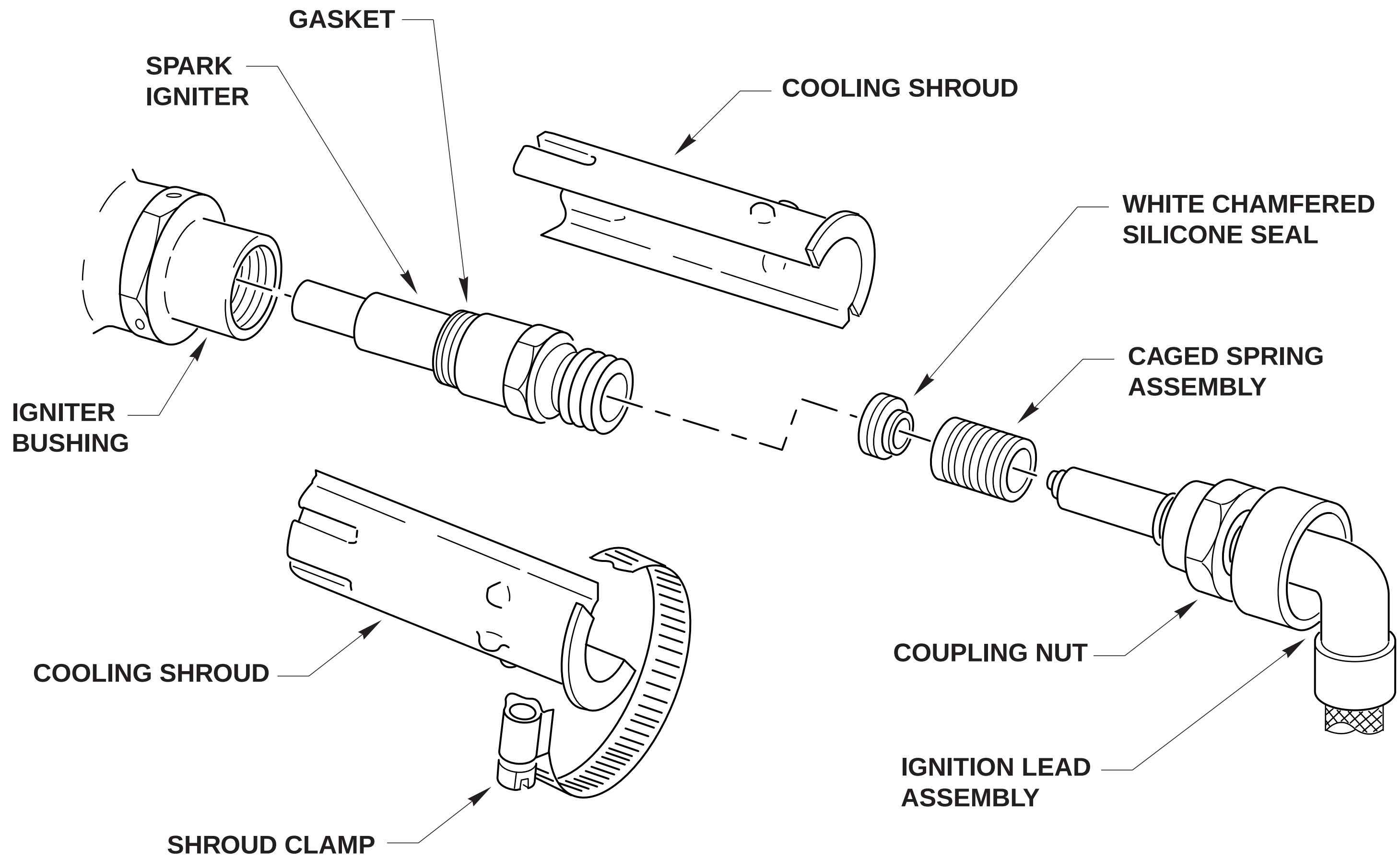
The connection between the igniter plug and the ignition lead is surrounded by a shroud, which ducts the ignition lead cooling air around the igniter plug.

The depth of the spark igniter is controlled by the igniter bushing and igniter plug gasket(s). Each gasket is 0.38mm in thickness.

Before installing the spark igniter, a small amount of graphite grease should be applied to the threads that connect with the igniter bushing in the combustion case boss.

Note : Do not apply grease or any lubricant to the threads of the connector on the ignition lead as this will cause damage to the igniter and lead.

If the igniter has been removed for maintenance or repair, the white chamfered silicone seal must be replaced.



IGNITER PLUG

CTC-045-056-00

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POWER MANAGEMENT & FUEL CONTROL

POWER MANAGEMENT

The power management function computes the fan speed (N1) necessary to achieve a desired thrust.

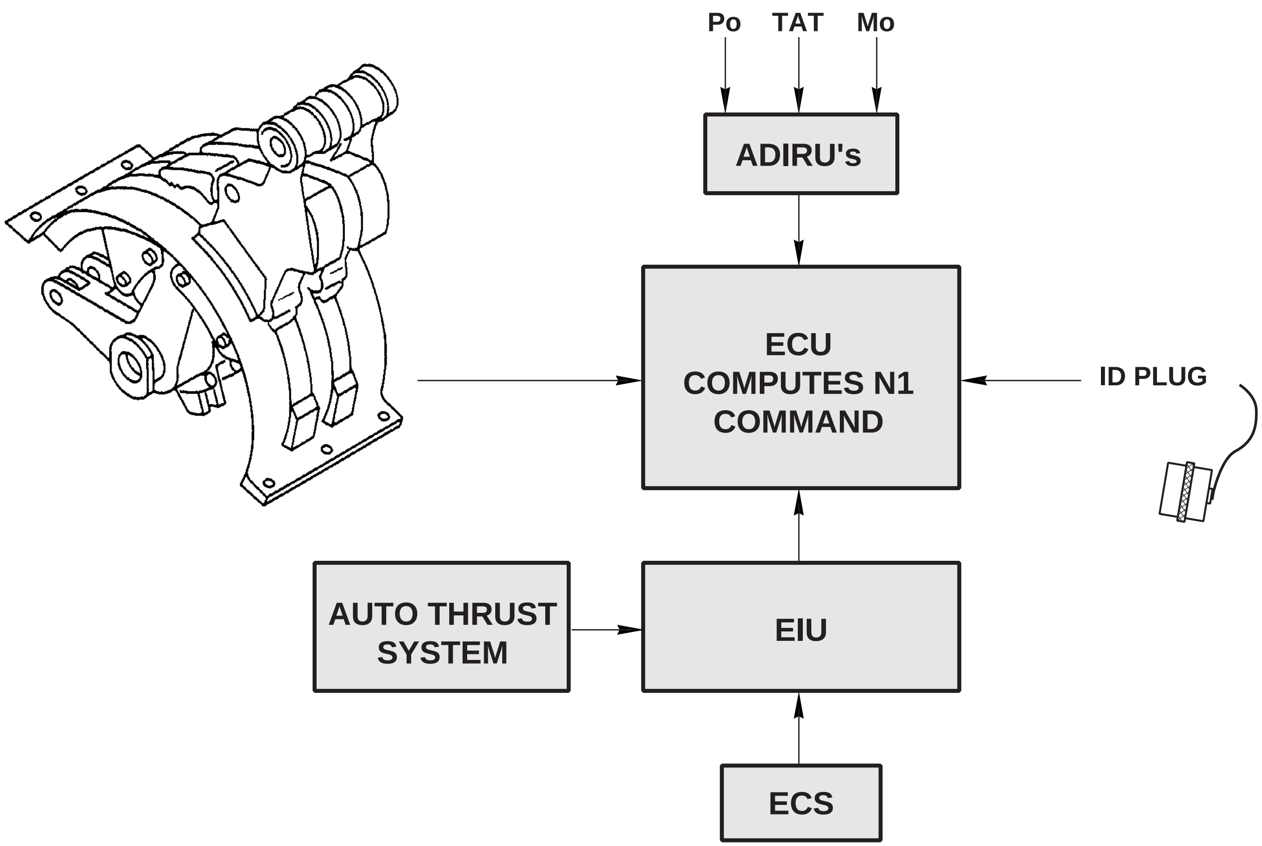
The FADEC manages power, according to two thrust modes :

- Manual mode, depending on the Thrust Lever Angle.

- Autothrust mode, according to the autothrust function generated by the autoflight system.

Power management uses N1 as the thrust setting parameter.

It is calculated for the appropriate engine ratings (coded in the identification plug) and based upon ambient conditions, Mach number (ADIRU's) and engine bleeds (ECS).



POWER MANAGEMENT

POWER MANAGEMENT

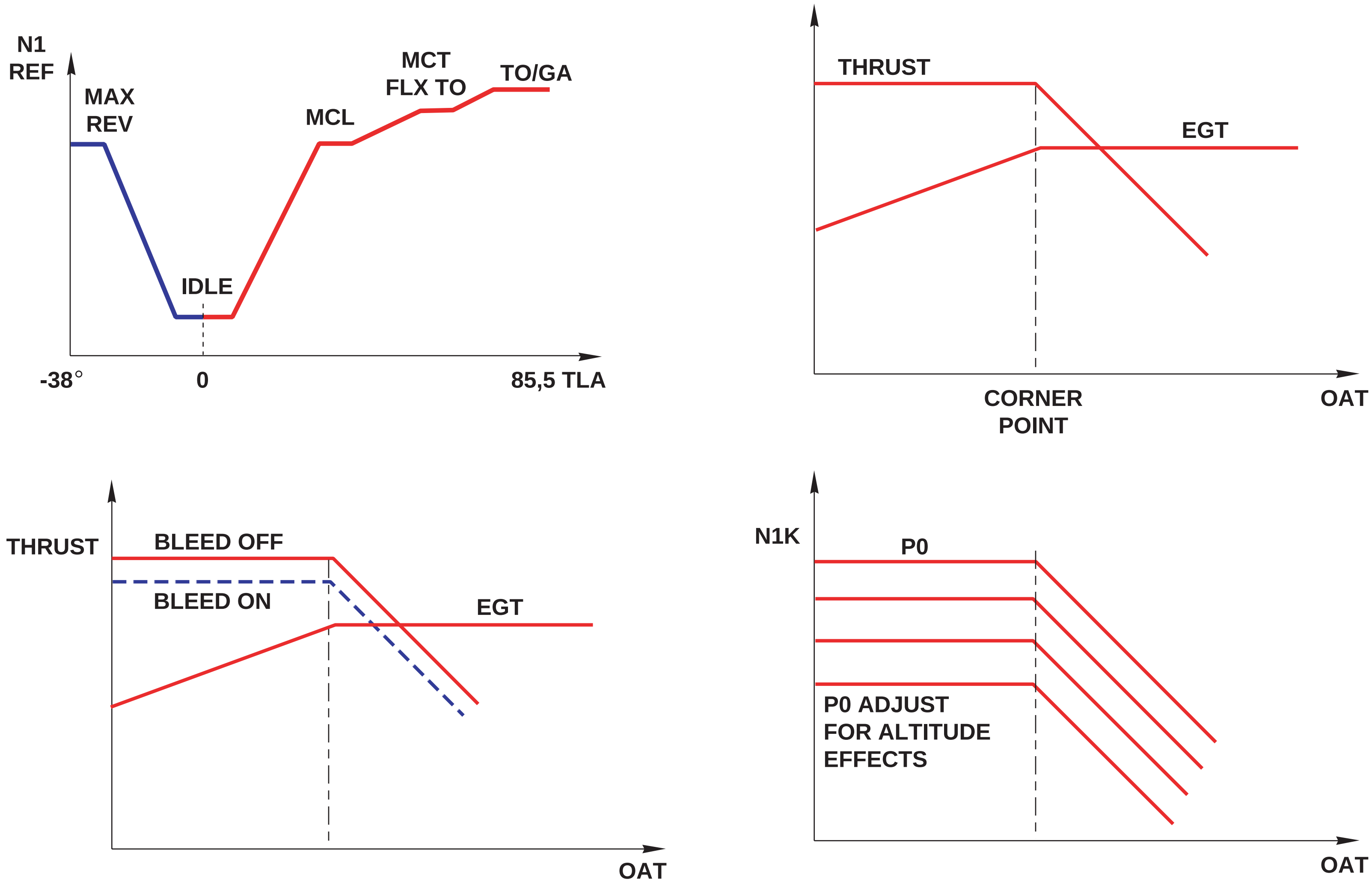
The different thrust levels are :

- Idle.
- Maximum Climb (MCL).
- Maximum Continuous (MCT).
- Flexible Take-off (FLX TO).
- Maximum Take-off or Go-Around (TO/GA).
- Maximum Reverse (REV).

For the current flight conditions, the FADEC calculates the power setting for each of these ratings defined in terms of N1. When the throttle is set between detents, the FADEC interpolates between them to set the power.

The ‘corner point’ is used in the calculations, which is the maximum Outside Air Temperature (OAT) where thrust can be held at maximum. After corner point, thrust is decreased in order to maintain EGT margins.

Environmental Control System (ECS) bleed and anti-ice bleed are taken into account in order to maintain the same EGT level with and without bleeds.



CTC-045-058-00

POWER MANAGEMENT FUNCTIONS

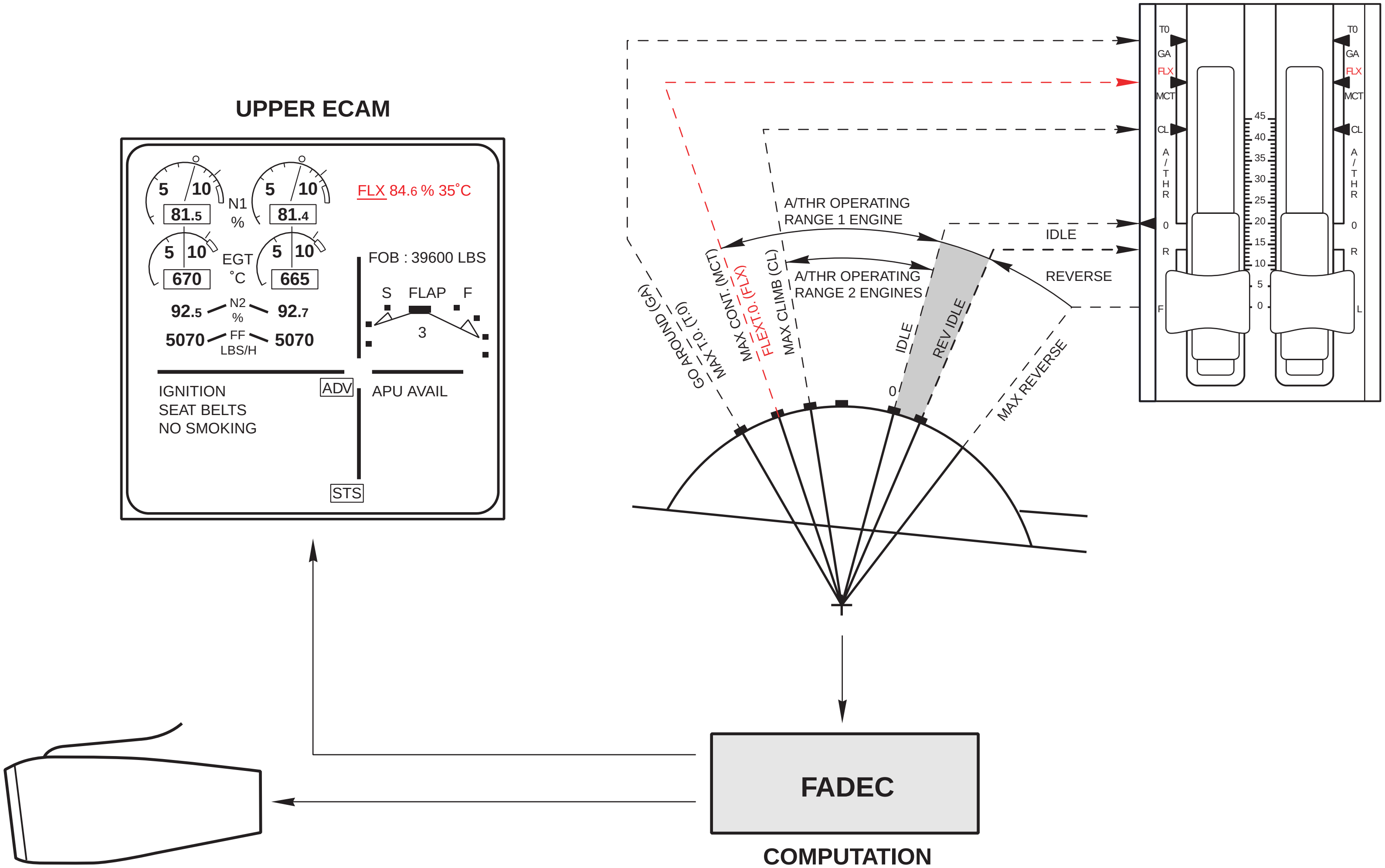
The Flex Take-off function enables the pilot to select a take-off thrust, lower than the maximum take-off power available for the current ambient conditions.

Temperatures for the flexible take-off function are calculated according to the ‘assumed temperature’ method.

This means setting the ambient temperature to an assumed value, which is higher than the real ambient temperature. The assumed ambient temperature (99°C max) is set in the cockpit, using the MCDU.

The flexible mode is only set if the engine is running and the aircraft is on the ground.

However, the power level, which is set by the FADEC in the flexible mode, may be displayed on the ECAM by input of a flexible temperature value, through the MCDU, and setting the TRA to the flex position, before the engine is started.



POWER MANAGEMENT-FLEX TAKEOFF

CTC-045-059-00

Fuel control

The fuel control function computes the Fuel Metering Valve (FMV) demand signal, depending on the engine control laws and operating conditions.

Fuel flow is regulated to control N1 and N2 speed :

- During engine starting and idle power, N2 speed is controlled.
- During high power operations, requiring thrust, N1 speed is controlled and N2 is driven between minimum and maximum limits.

The limits depend on :

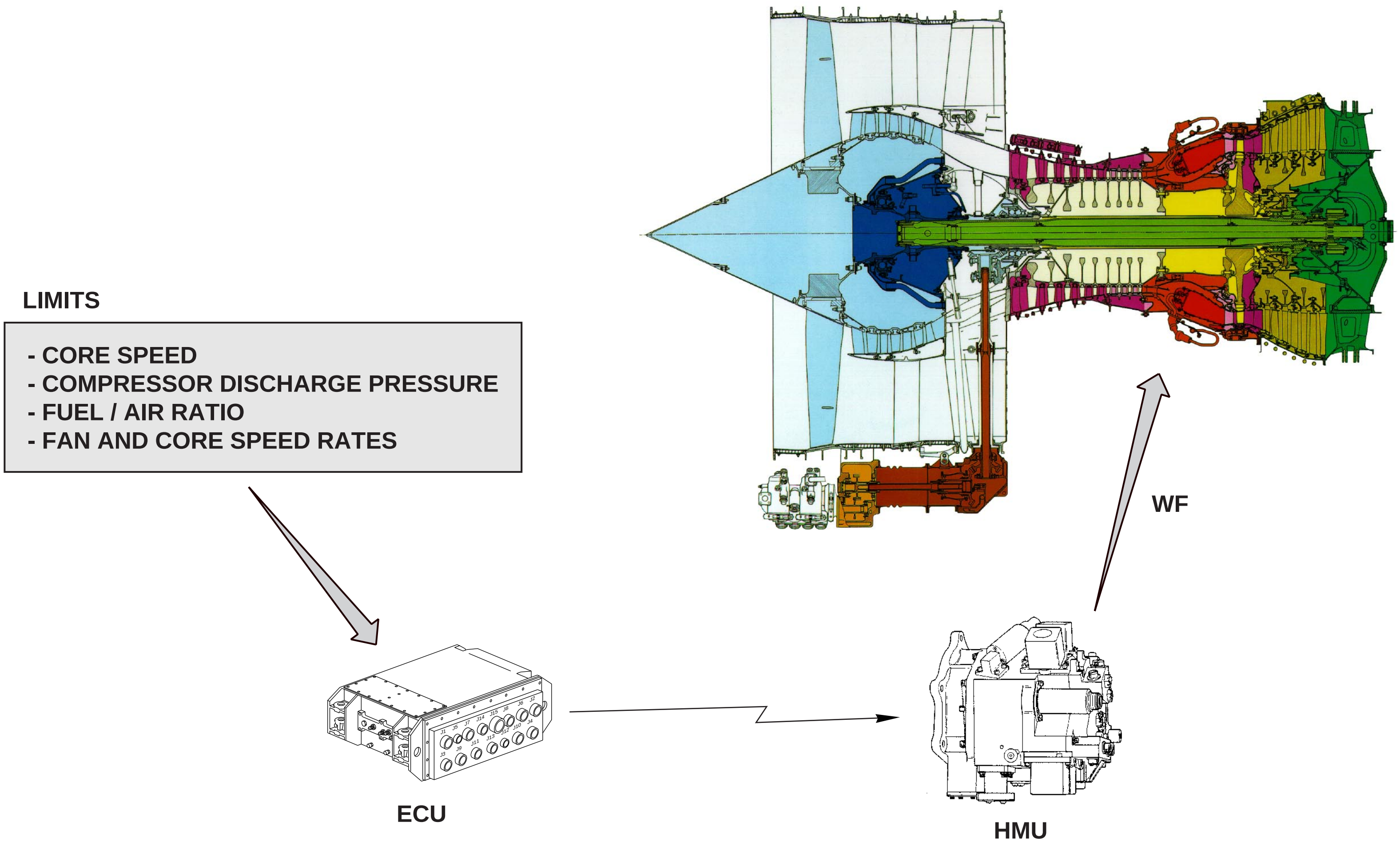
- Core speed.
- Compressor discharge pressure (PS3).
- Fuel / air ratio (WF/PS3).
- Fan & core speed rates (accel and decel).

Idle control.

The FADEC system controls the idle speed:

- Minimum Idle will set the minimum fuel flow requested to ensure the correct aircraft ECS pressurization.

- Approach Idle is set at an engine power which will allow the engine to achieve the specified Go-Around acceleration time.



FUEL CONTROL INTRODUCTION

CTC-045-060-00

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FUEL DISTRIBUTION

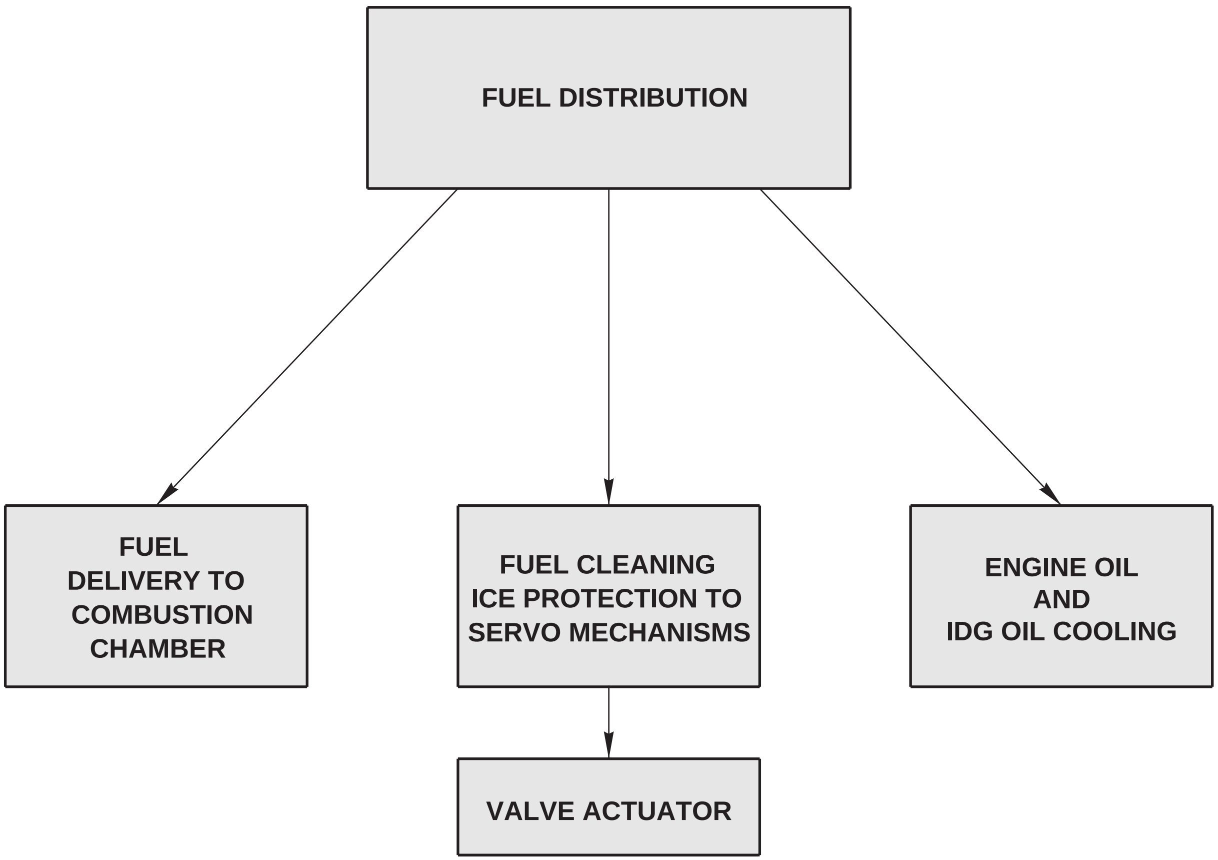
FUEL DISTRIBUTION

The purpose of the fuel distribution system is :

- to deliver fuel to the engine combustion chamber.

- to supply clean and ice-free fuel to various servo-mechanisms of the fuel system.

- to cool down engine oil and Integrated Drive Generator (IDG) oil.



FUEL DISTRIBUTION

CTC-045-061-00

FUEL DISTRIBUTION

The fuel distribution components consist of :

- fuel supply and return lines
- a fuel pump and filter assembly
- a main oil/fuel heat exchanger
- a servo fuel heater
- a Hydro-Mechanical Unit (HMU)
- a fuel flow transmitter
- a fuel nozzle filter
- a Burner Staging Valve (BSV)
- two fuel manifolds
- twenty fuel nozzles
- an IDG oil cooler
- a Fuel Return Valve (FRV)

Fuel from the A/C tank enters the engine fuel pump, through a fuel supply line.

After passing through the pump, the pressurized fuel goes to the main oil/fuel heat exchanger in order to cool down the engine scavenge oil.

It then goes back to the fuel pump, where it is filtered, pressurized and split into two fuel flows.

The main fuel flow goes through the HMU metering system, the fuel flow transmitter and fuel nozzle filter and is then directed to the fuel nozzles and the BSV.

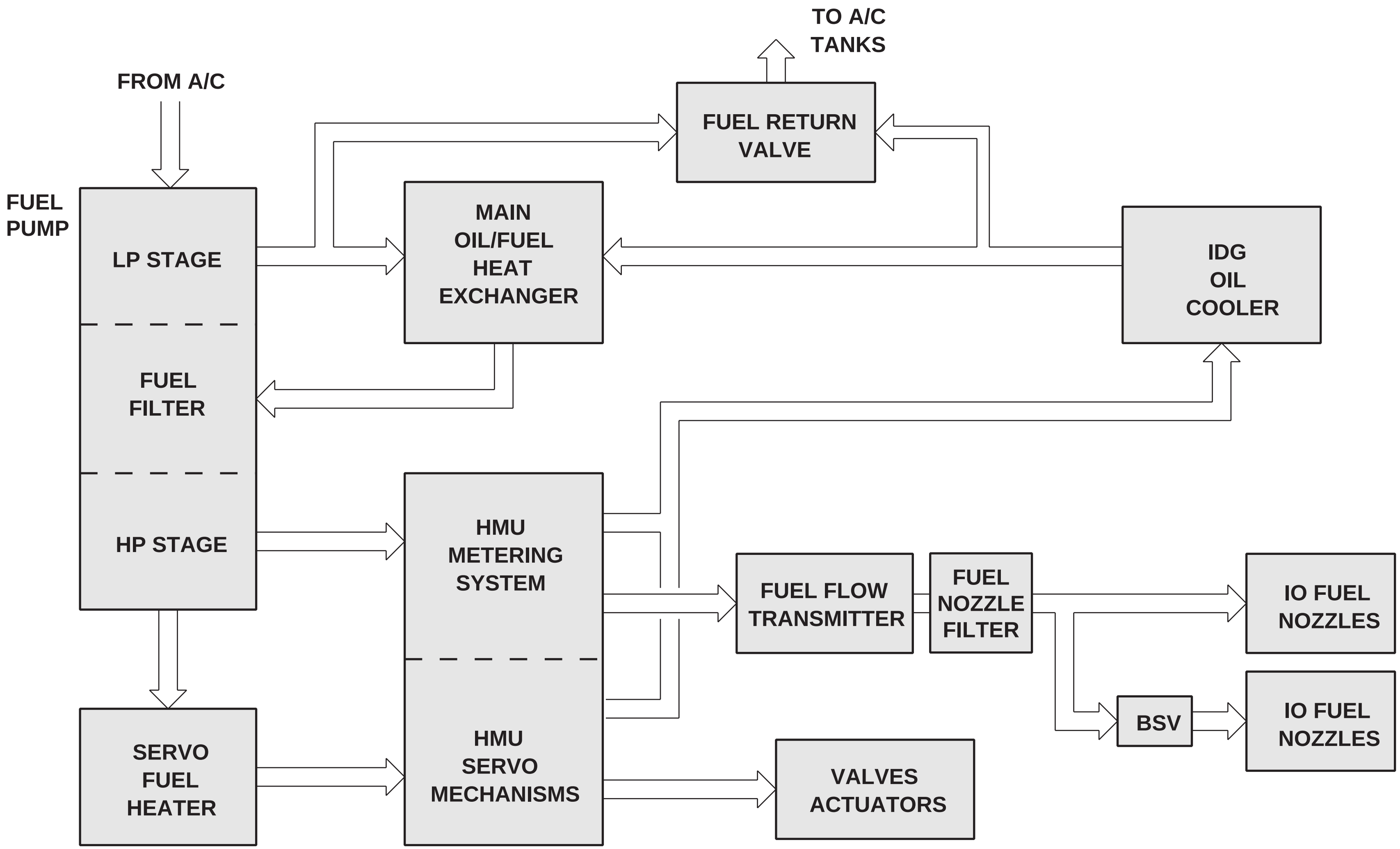
The other fuel flow goes to the servo fuel heater, which warms up the fuel to prevent any ice particles entering sensitive servo systems.

The heated fuel flow enters the HMU servo-mechanism and is then directed to the various fuel-actuated components.

A line brings unused fuel, from the HMU, back to the inlet of the main oil/fuel heat exchanger, through the IDG oil cooler.

A Fuel Return Valve (FRV), also installed on this line, may redirect some of this returning fuel back to the A/C tank.

Before returning to the A/C tank, the hot fuel is mixed with cold fuel from the outlet of the LP stage of the fuel pump.



FUEL DISTRIBUTION

CTC-045-062-00

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FUEL PUMP

FUEL PUMP

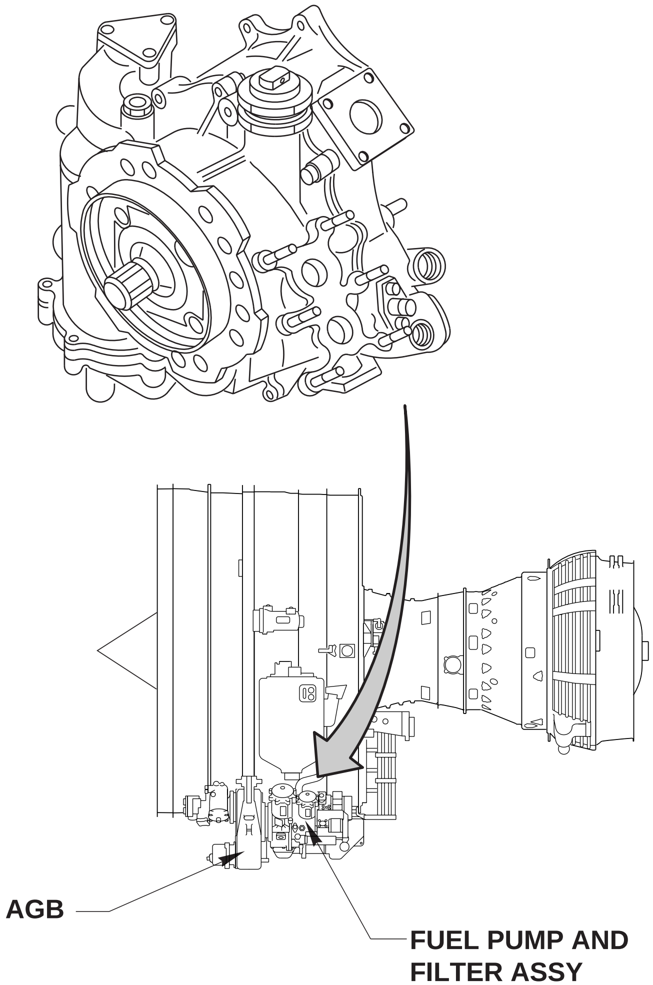
The purpose of the engine fuel pump is :

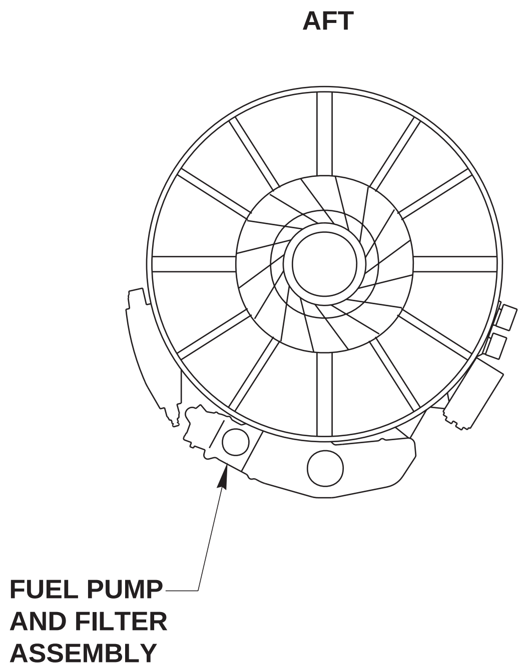
- to increase the pressure of the fuel from the A/C fuel tanks, and to deliver this fuel in two different flows.
- to deliver pressurized fuel to the main oil/fuel heat exchanger.
- to filter the fuel before it is delivered to the fuel control system.
- to drive the HMU.

The engine fuel pump is located on the accessory gearbox aft face, on the left hand side of the horizontal drive shaft housing.

The fuel supply line is routed from a hydraulic junction box, attached to the left hand side of the fan inlet case, down to the fuel pump inlet.

The fuel return line is routed from the Fuel Return Valve (FRV), along the left hand side of the fan case, and back up to the hydraulic junction box.





CTC-045-063-00

FUEL PUMP

FUEL PUMP

The engine fuel pump is a two stage fuel lubricated pump and filter assembly.

First, the fuel passes through the boost stage, where it is pressurized.

At the outlet of the boost stage, it is directed to the main oil/fuel heat exchanger, and the FRV.

The fuel then goes back into the fuel pump, and passes through a disposable main fuel filter.

The clogging condition of the main fuel filter is monitored and displayed on an ECAM, through a differential pressure switch.

A by-pass valve is installed, in parallel with the filter, to by-pass the fuel in case of filter clogging.

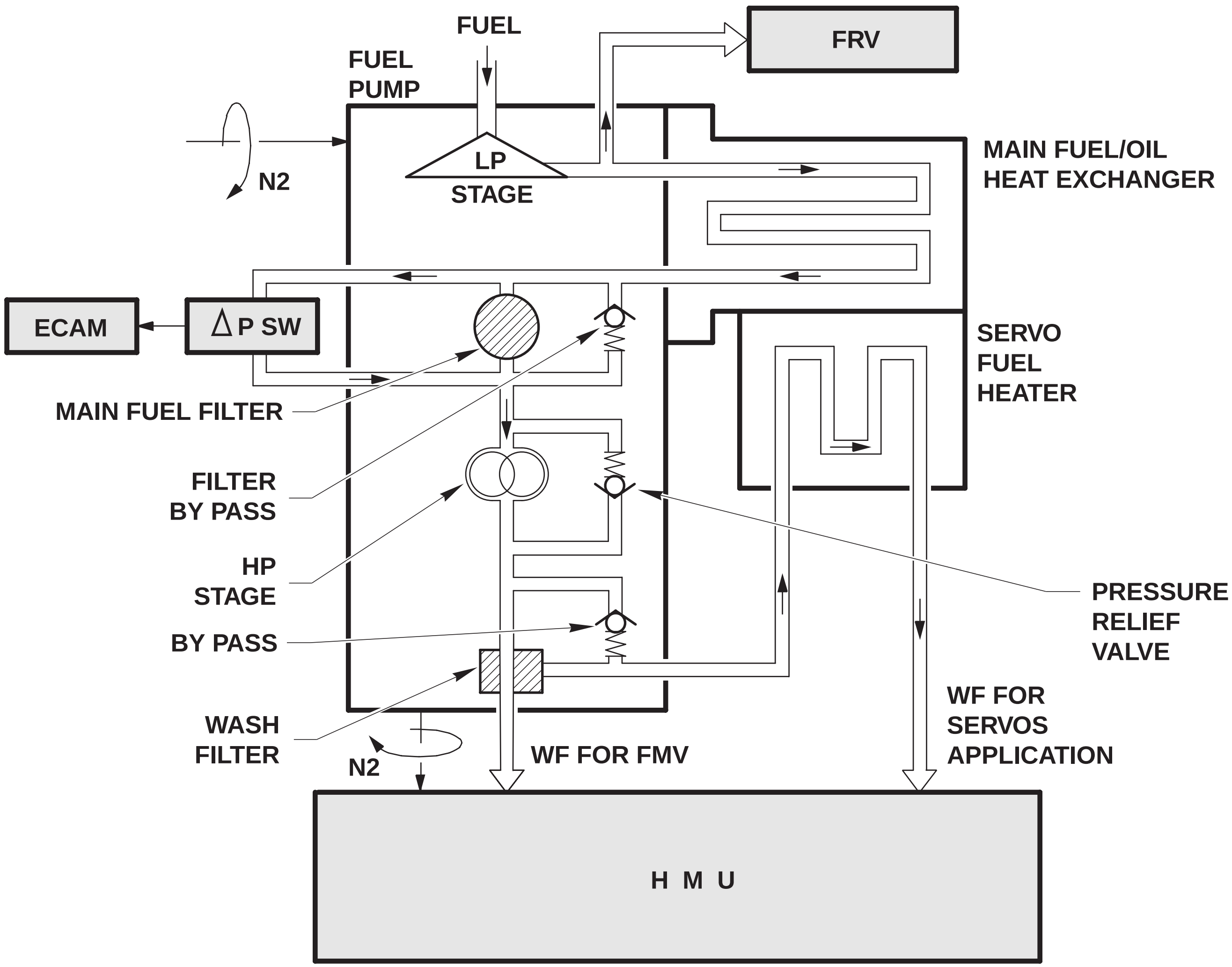
At the filter outlet, the fuel passes through the HP stage pump.

A pressure relief valve is installed, in parallel with the gear pump, to protect the downstream circuit from over pressure.

At the gear stage outlet, the fuel passes through a wash filter, where it is split into two different fuel flows.

The main fuel flow, unfiltered, goes to the HMU. The other fuel flow, which is filtered, goes to the servo fuel heater and the FRV.

A by-pass valve is installed, in parallel with the filter, to by-pass the fuel in case of filter clogging.



FUEL PUMP OPERATION

CTC-045-064-00

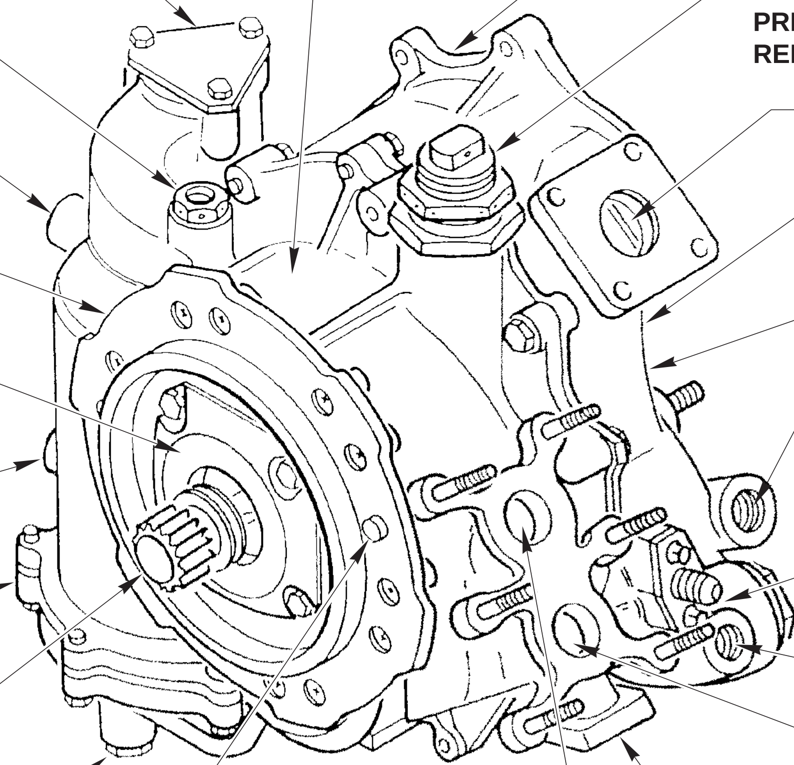
Fuel pump housing.

The fuel pump housing encloses the fuel pump drive system, the LP and HP stages, the fuel filter, and the wash filter.

The fuel pump housing is secured onto the accessory gearbox with a Quick Attach/Detach (QAD) ring. The mounting flange is equipped with a locating pin to facilitate the installation of the fuel pump onto the AGB.

On the housing, fuel ports and covers are provided which are :

- Main filter by-pass valve cover.
- Outlet port to heat exchanger.
- Return port from heat exchanger.
- Filter drain port.
- Upstream and downstream filter pressure taps.
- Gear stage pressure relief valve cover.
- Fuel inlet port.
- Discharge port to HMU.
- Return port from the HMU.
- FRV supply port.
- Servo fuel heat exchange supply port.
- Boost stage flow access port.
- Boost stage discharge pressure tap.
- Gear stage discharge pressure tap.



FUEL PUMP HOUSING

CTC-045-065-00

FUEL PUMP

Fuel pump drive system.

The fuel pump is fuel lubricated, and the necessary rotative motion is provided by a drive system consisting of concentric shafts :

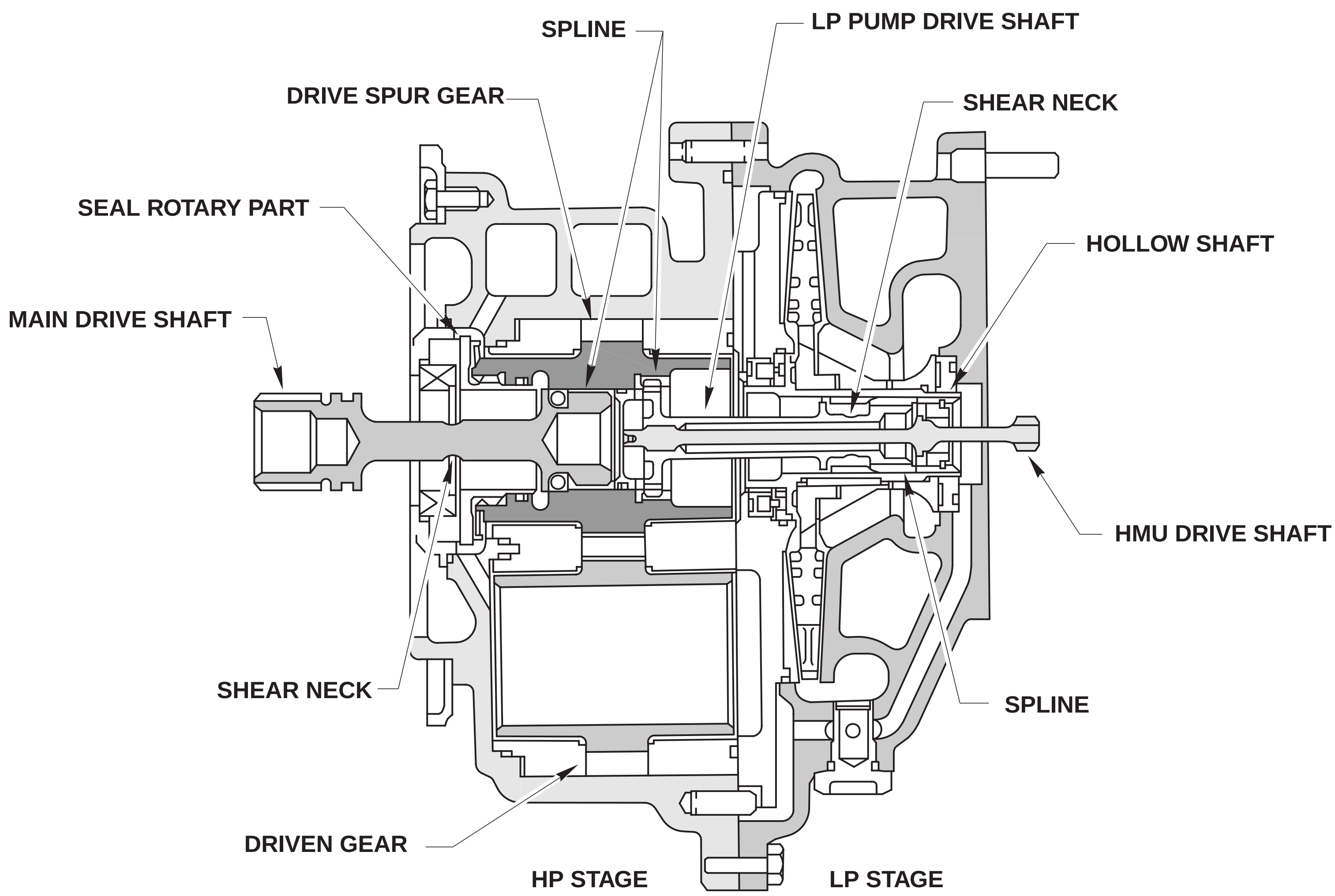
The main drive shaft is driven by the AGB, and drives the HP stage drive spur gear through splines.

The HP stage drive spur gear, through splines, drives the LP stage driveshaft, which in turn drives :

- the HMU, through the HMU drive shaft.
- the LP stage, through the hollow shaft.

The fuel pump drive system is equipped with shear neck sections to provide :

- protection of the AGB against any excessive torque created within the fuel pump assembly.
- assurance of the HMU drive operation, even in case of total failure of the LP stage pump.



CTC-045-066-00

FUEL PUMP DRIVE SYSTEM

FUEL PUMP

Fuel pump Low Pressure (LP) stage.

The LP stage is a centrifugal type pump, which delivers boost pressure to the HP stage to avoid pump cavitation.

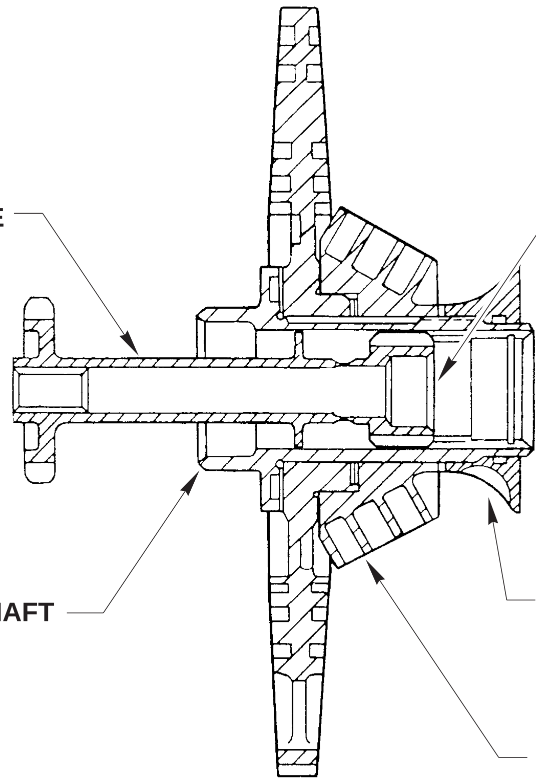
The fuel pump LP stage consists of :

- a swirl inducer, with helical grooves and a scroll.

- an impeller, provided with swirl ramps, supported by two plain bearings.

The cavity for the impeller/inducer cluster is provided by the pump cover.

The front and rear bearings, the LP pump drive shaft splines, and the HMU drive shaft splines are lubricated with fuel tapped from the scroll at the fuel pump LP stage fuel discharge.



CTC-045-067-00

FUEL PUMP LOW PRESSURE STAGE

Fuel pump High Pressure (HP) stage.

The fuel pump HP stage is a positive displacement gear type pump.

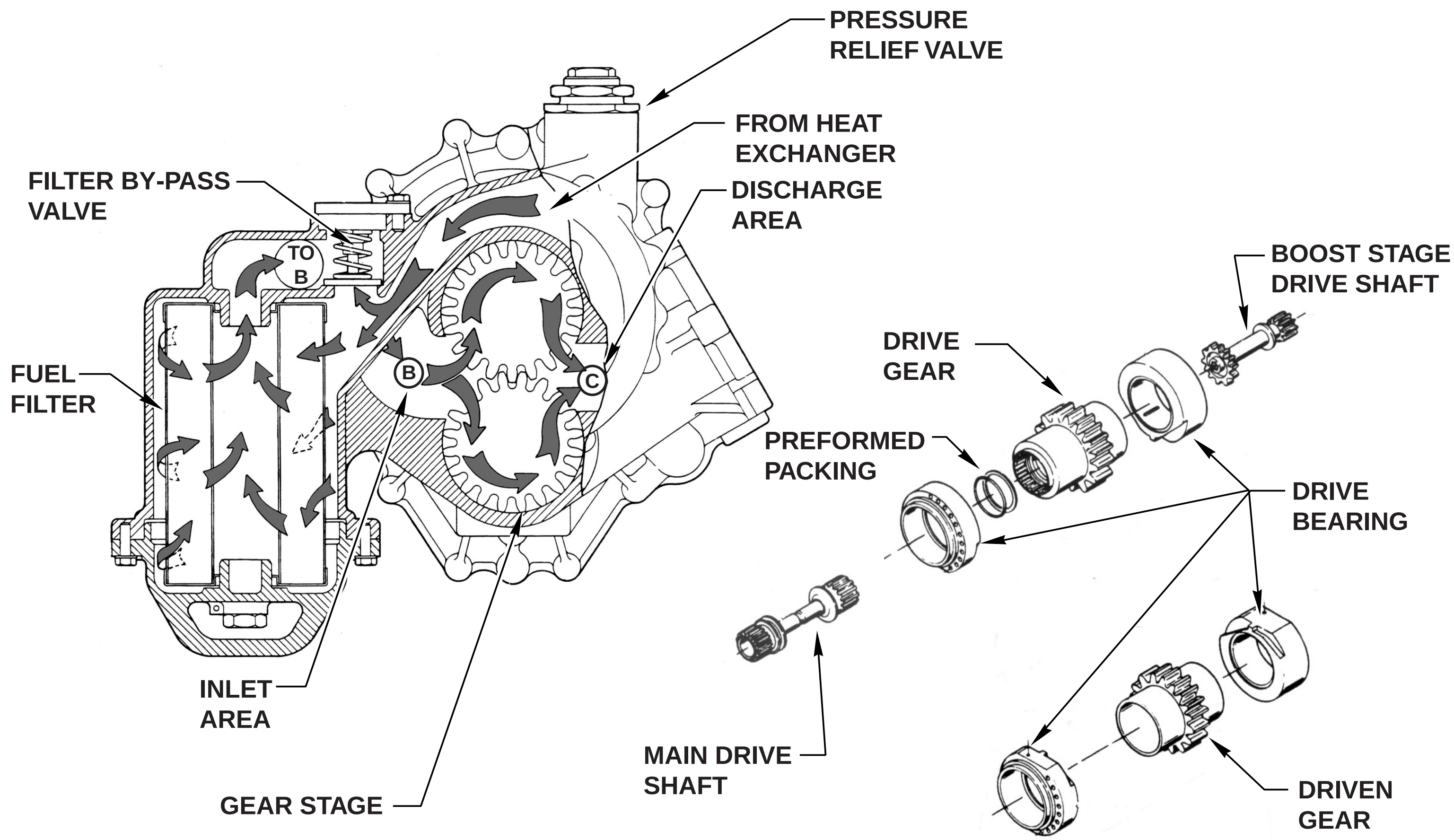
For a given rotational speed input (RPM), the pump delivers a constant fuel flow, regardless of the discharged pressure.

The HP fuel pump consists of two gearshafts, the drive and the driven gears.

The drive gear is driven, through splines, by the main drive shaft connected to the AGB.

Each gearshaft is supported by two plain bearings.

The fuel used to lubricate the LP stage equipment, is also used to lubricate the HP stage bearings and the lubricating fuel then flows back to the fuel filter inlet.



CTC-045-068-00

FUEL PUMP HIGH PRESSURE STAGE

High pressure relief valve.

The high pressure relief valve is installed in parallel with the gear stage pump, and consists of :

- a relief valve housing.
- a relief valve piston.
- a spring.
- an adjusting cap.

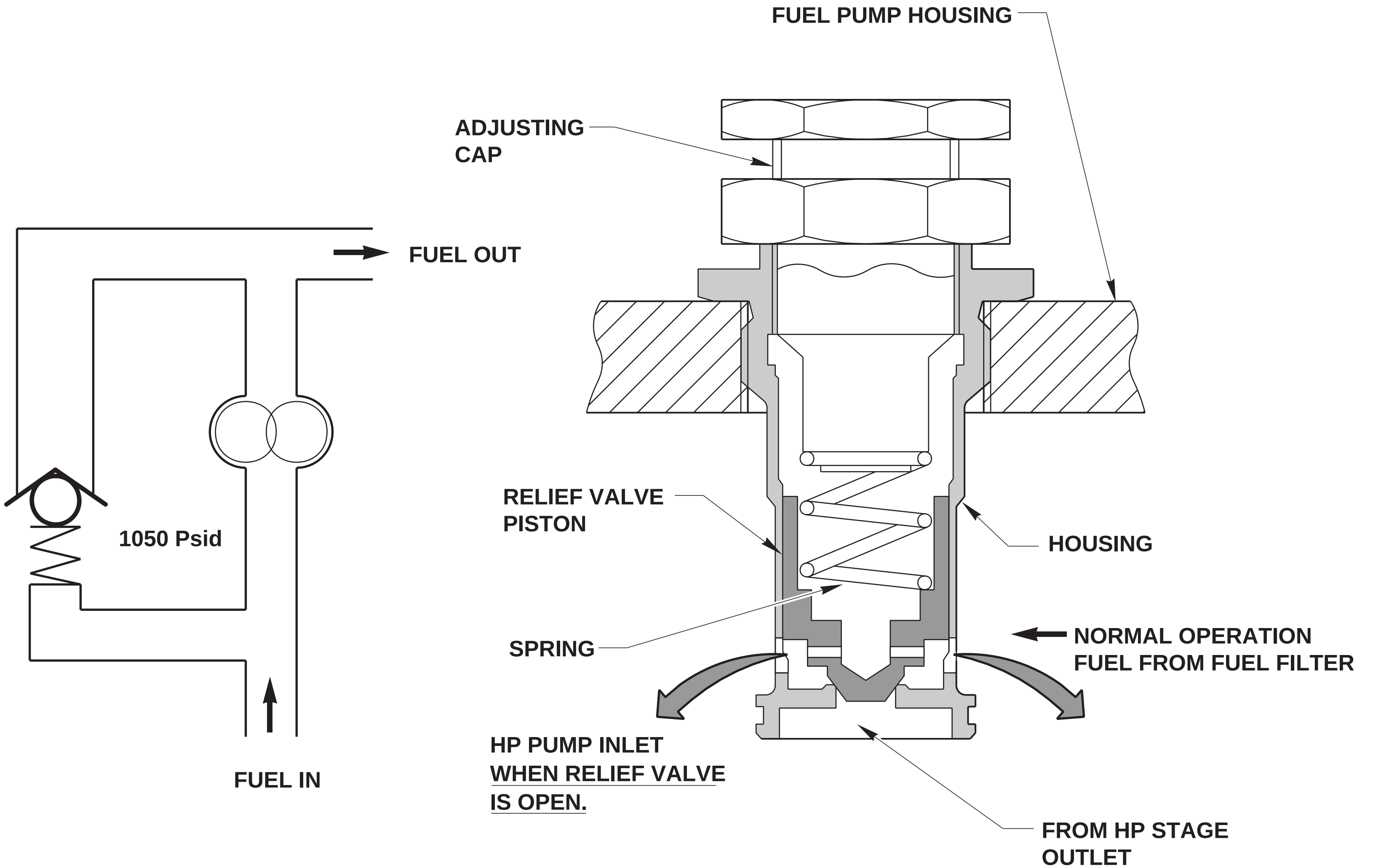
When the differential fuel pressure between the inlet and the outlet of the gear stage reaches 1030 to 1070 psi, the valve opens. The relief valve recovery point is set between 990 and 1010 psid.

The relief valve housing is threaded within the pump case.

The relief valve piston is in contact with the housing through the spring force and the fuel pressure coming out of the filter.

On the other side of the piston, the fuel pressure from the HP stage is applied to the end of the piston.

The fuel goes back to the HP pump inlet when the relief valve is open.



CTC-045-069-00

HIGH PRESSURE RELIEF VALVE

The wash filter.

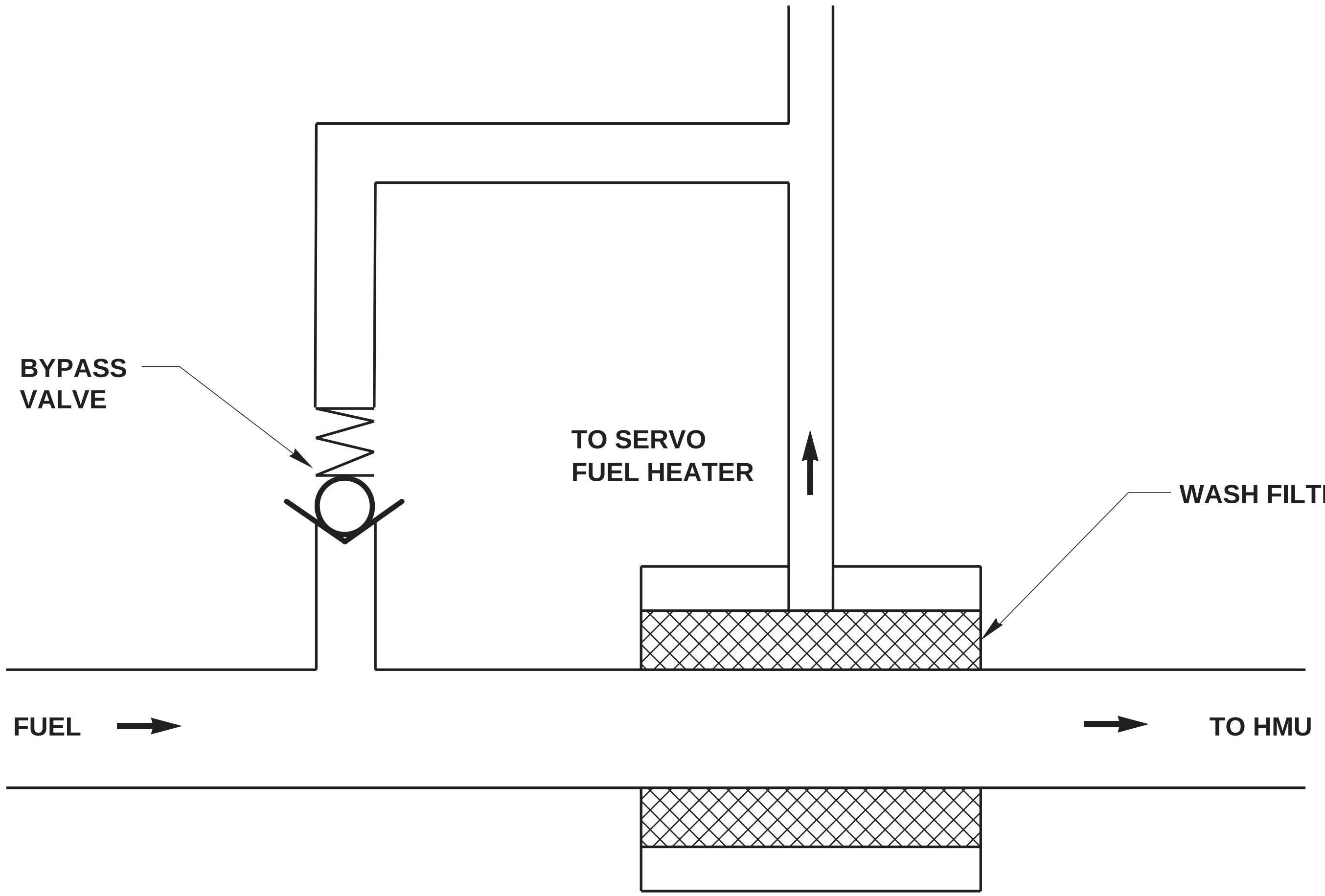
The wash filter, located at the fuel pump HP stage discharge, catches particles remaining in the fuel directed to the servo fuel heater.

The foreign particles, retained by the filter, are removed by the main fuel flow supplying the HMU.

The wash filter is incorporated with the fuel pump housing, and consists of a filtering element and a by-pass valve.

The by-pass valve opens if the filter becomes clogged.

The cartridge has a filtering capability of 65 microns.



WASH FILTER

CTC-045-070-00

FUEL PUMP

Fuel filter

The fuel filter protects the downstream circuit from particles in the fuel.

It consists of a filter cartridge and a by-pass valve.

The filter cartridge is installed in a cavity in the fuel pump body. The fuel circulates from the outside to the inside of the filter cartridge.

In case of a clogged filter, the by-pass valve opens to allow fuel to pass to the fuel pump HP stage.

Tappings on the filter housing enable the installation of a differential pressure switch that transmits filter clogging conditions to the A/C monitoring system.

The cartridge has a filtering capability of 32 microns absolute.

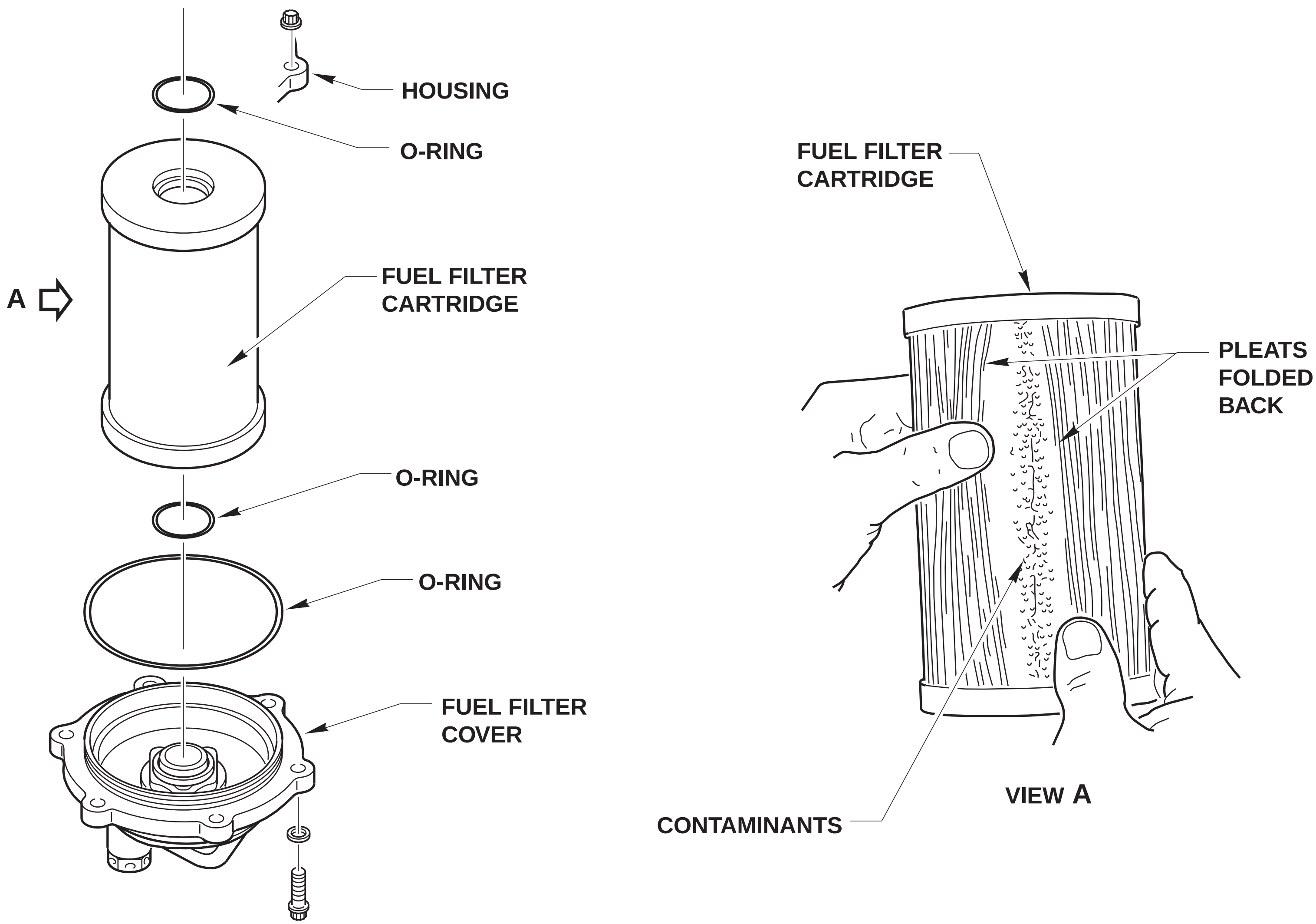
Maintenance practices

Fuel filter removal/installation and check.

The filter must be removed and visually inspected after any ECAM “Fuel filter clogged” warning messages, or when significant contamination is found at the bottom of the filter cover. This inspection can help to determine any contamination of aircraft, or engine fuel systems.

During re-installation of the fuel filter cover, carefully follow the torquing sequence.

Perform a wet motoring check for leakage.



CTC-045-071-00

VISUAL INSPECTION OF THE FUEL FILTER CARTRIDGE

Maintenance practices

Visual inspection of impeller rotation.

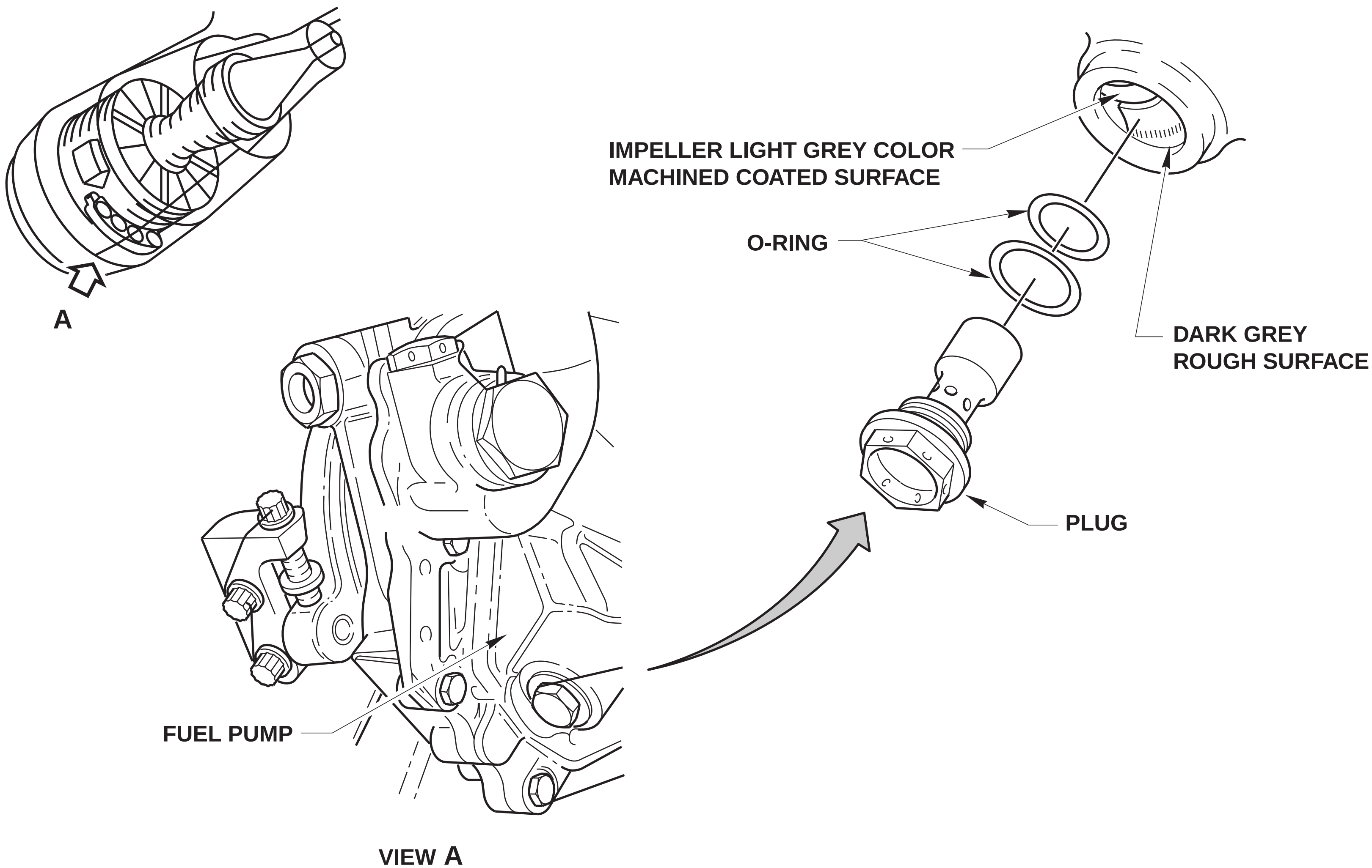
This inspection must be done during troubleshooting when the procedure calls for it, or when a broken shaft is suspected and the rotation of the LP impeller has to be checked.

The plug is removed, and the engine is cranked through the handcranking pad.

If the impeller turns, the check is positive.

If the impeller does not turn, replace the fuel pump and continue the troubleshooting procedure to determine if there is any further engine damage.

After fuel pump replacement, perform an idle leak check and FADEC ground test with motoring.



VISUAL INSPECTION OF IMPELLER

CTC-045-072-00

Maintenance practices

Check of fuel pump discharge pressures.

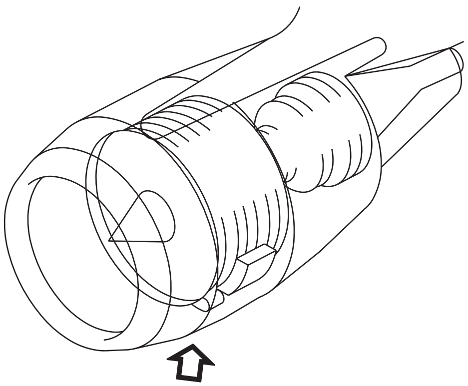
This check is performed during troubleshooting, if the engine does not meet the required performance. This procedure, specified in the AMM, checks the mechanical condition of the fuel pump.

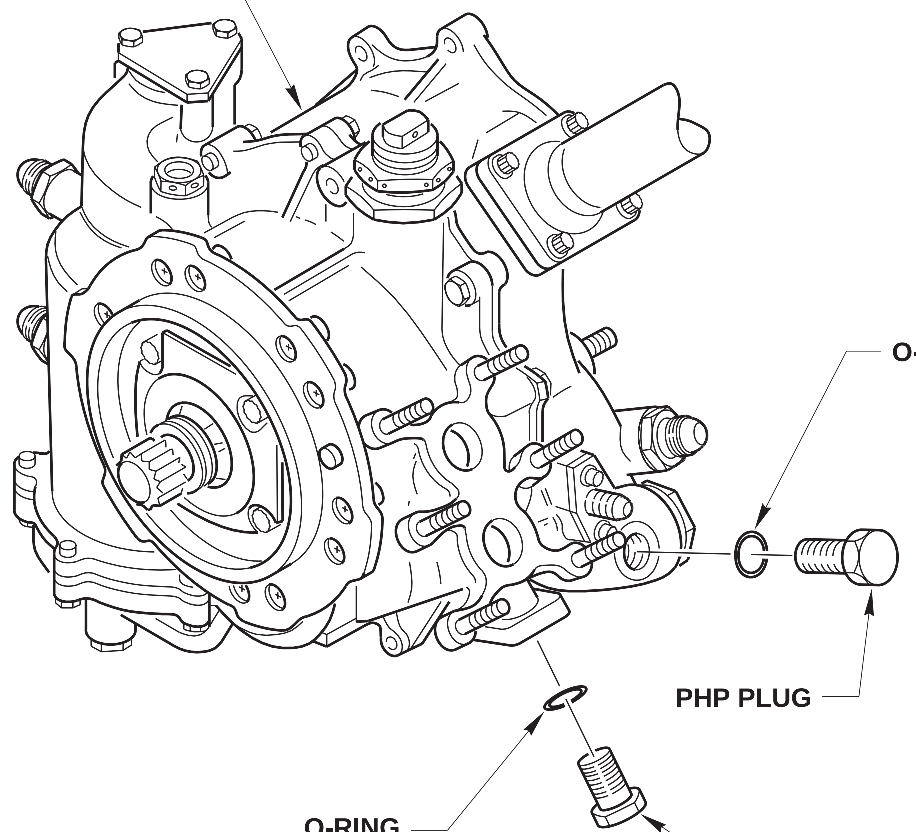
The procedure involves installing pressure gauges on the PBP port (low pressure stage discharge) and the PHP port (high pressure stage discharge).

When the gauges are installed, the engine is dry-motored at 20% N2 minimum.

The delta pressure between the two gauges is measured and must be within the limits specified in the AMM.

The fuel pump is removed if the delta pressure is outside of these limits.





CTC-045-073-00

CHECK OF FUEL PUMP DISCHARGE PRESSURE

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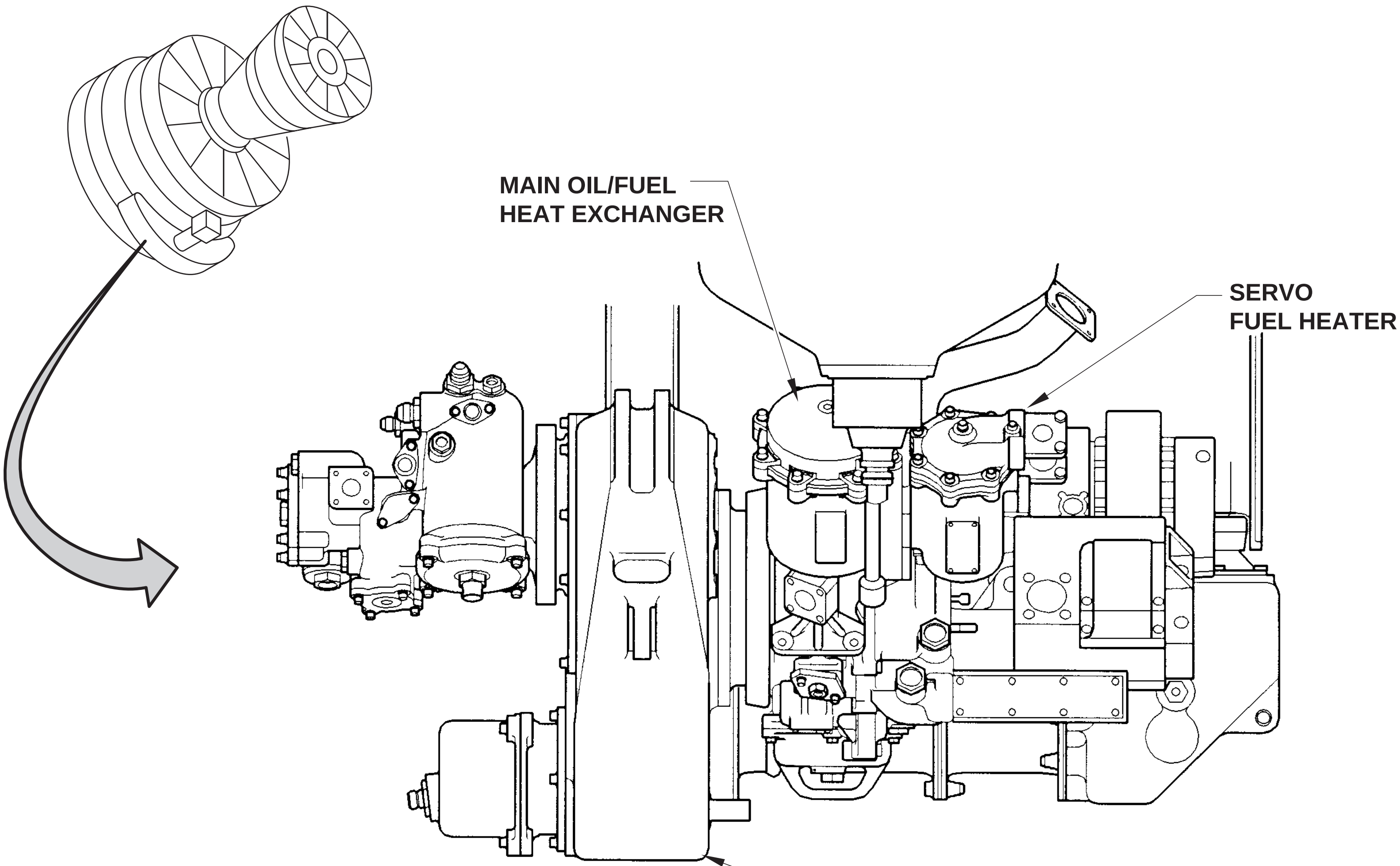
MAIN OIL/FUEL HEAT EXCHANGER

MAIN OIL/FUEL HEAT EXCHANGER

The purpose of the main oil/fuel heat exchanger is to cool the scavenged oil with cold fuel, through conduction and convection, inside the exchanger where both fluids circulate.

The exchanger is installed at the 7 o’clock position, on the fuel pump housing.



CTC-045-074-00

MAIN OIL/FUEL HEAT EXCHANGER

MAIN OIL FUEL HEAT EXCHANGER

The connections with the other systems are:

- -an oil IN port from the servo fuel heater.
- -an oil OUT tube to the oil tank.
- -two fuel ports connected with the fuel pump.
- -a fuel return line from the HMU, through the IDG oil cooler.

The mechanical interfaces are the mating flanges with the fuel pump, the servo fuel heater, plus one other with a fuel tube.

Heat exchanger core.

The heat exchanger is a tubular design consisting of a removeable core, a housing and a cover.

The core has two end plates, fuel tubes and two baffles.

The fuel tubes are attached to the end plates and the baffles inside lengthen the oil circulation path around the fuel inlet tubes.

Sealing rings installed on the core provide insulation between the oil and fuel areas.

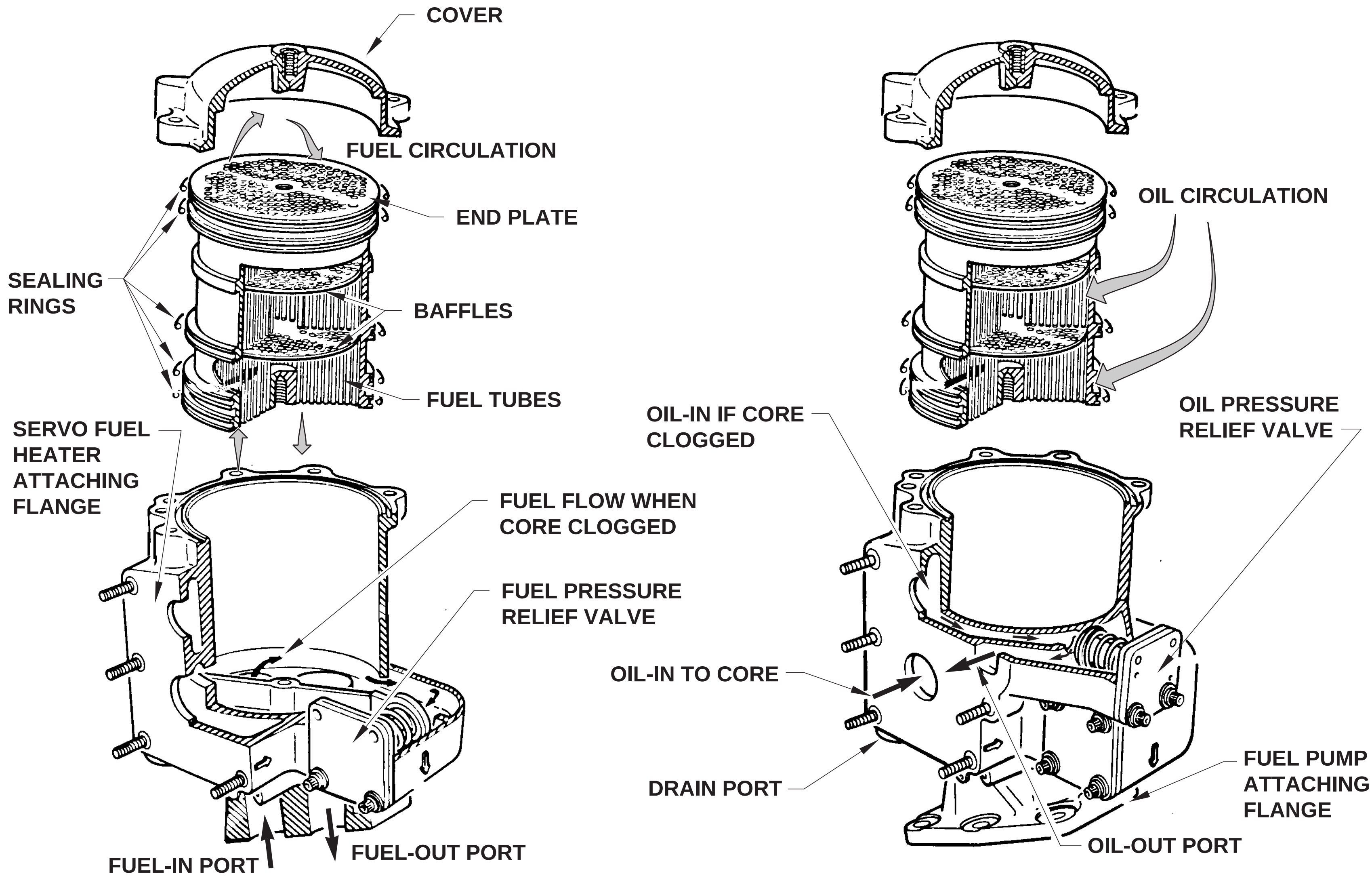
Heat exchanger housing.

The housing encloses the core, and the following items are located on its outer portion :

- An oil pressure relief valve, which by-passes the oil when the differential pressure across the oil portion of the exchanger is too high.
- A fuel pressure relief valve, which by-passes the fuel when the differential pressure across the fuel portion of the exchanger is too high.
- A drain port, for fuel leak collection from inter-seal cavities, that prevent oil cavity contamination.
- An optional fuel-out temperature probe port.
- Two attachment flanges; one with the fuel pump which also provides fuel IN and OUT passages, and one with the servo fuel heater which also provides oil IN and OUT tubes.
- One fuel IN port for fuel from the HMU, via the IDG oil cooler.

Maintenance practices

If there is contamination in the fuel, both the servo fuel heater and main oil/fuel exchanger must be replaced.



MAIN OIL/FUEL HEAT EXCHANGER OPERATION

CTC-045-075-00

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SERVO FUEL HEATER

SERVO FUEL HEATER

The servo fuel heater is a heat exchanger which uses engine scavenge oil as the heat source to warm up fuel in the fuel control system. This prevents ice particles entering sensitive servo mechanisms.

Heat exchange between oil and fuel is by conduction and convection inside the unit, which consists of :

- a case, enclosing the exchanger core and supporting the unit and oil lines.
- the exchanger core, or matrix, where heat is transferred.
- the cover, which supports the fuel lines.
- a screen, which catches particles in suspension in the oil circuit.

Fuel from the pump wash filter enters the unit and passes through aluminium alloy, 'U'-shaped tubes immersed in the oil flow. The tubes are mechanically bonded to a tube plate, which is profiled to the housing and end cover flanges. The fuel then exits the unit and is directed to the HMU servo mechanism area.

Oil from the lubrication unit enters the case and passes into the matrix where it circulates around the fuel tubes.

At the matrix outlet, the oil is directed to the main oil/fuel heat exchanger. In case of clogging, a by-pass valve, installed in the main oil/fuel heat exchanger, will open.

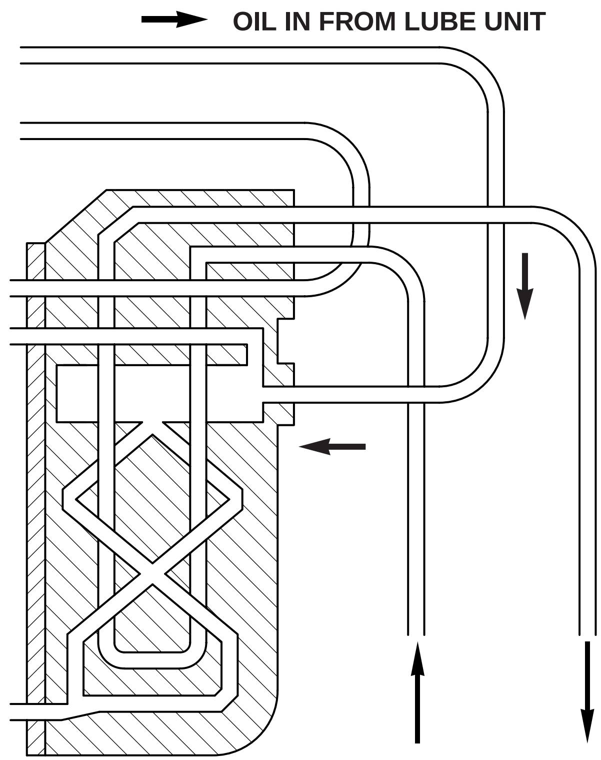
Oil will then be directed to the main oil/fuel heat exhanger oil outlet port, pass through the servo fuel heater and go back to the engine oil tank.

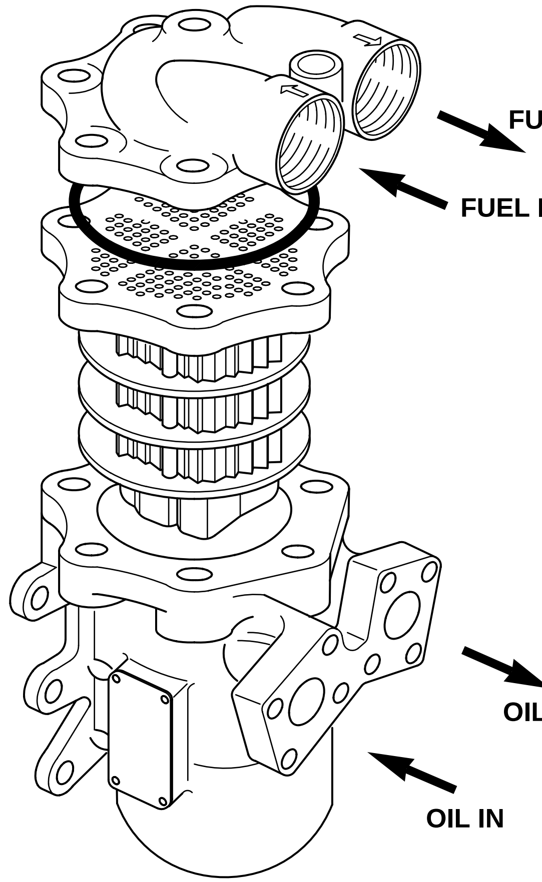
Servo fuel heater casing.

At the flanged end of the case, facing outward, there are two square oil inlet/outlet mounting pads.

The flange has threaded inserts to allow the installation of the cover attachment screws.The mounting flange is part of the housing casting, and has 6 holes to accommodate the main oil/fuel heat exchanger securing studs.

A side port chamber is provided to run the oil by-pass flow from the main oil/fuel heat exchanger to the oil outlet line connected to the engine oil tank.





CTC-045-076-00

SERVO FUEL HEATER

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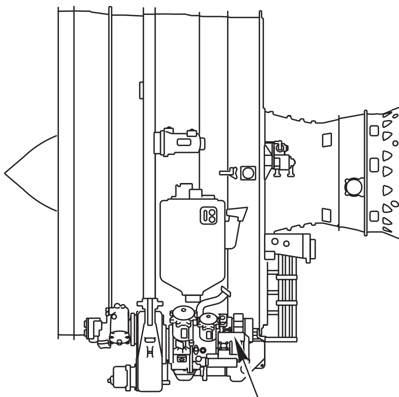
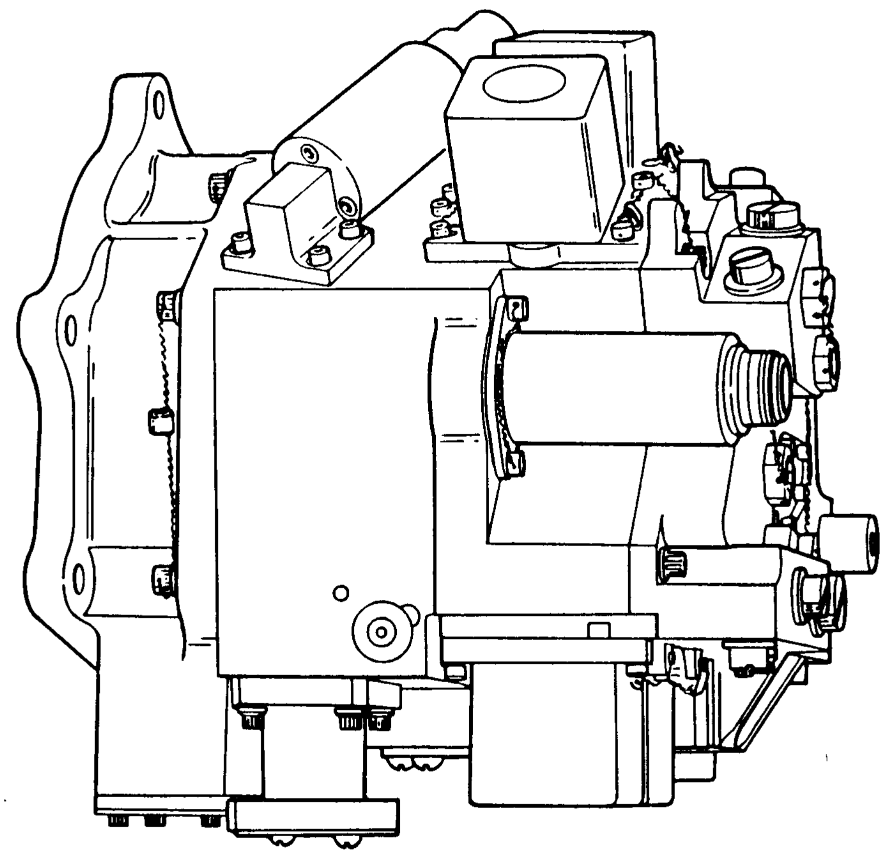
HYDROMECHANICAL UNIT

HYDROMECHANICAL UNIT

The Hydro-Mechanical Unit (HMU) transforms electrical signals sent from the ECU into hydraulic pressures in order to actuate various actuators used in engine control.

It is installed on the aft side of the accessory gearbox at the 7 o' clock position and mounts directly onto the fuel pump.





CTC-045-077-00

HYDROMECHANICAL UNIT LOCATION

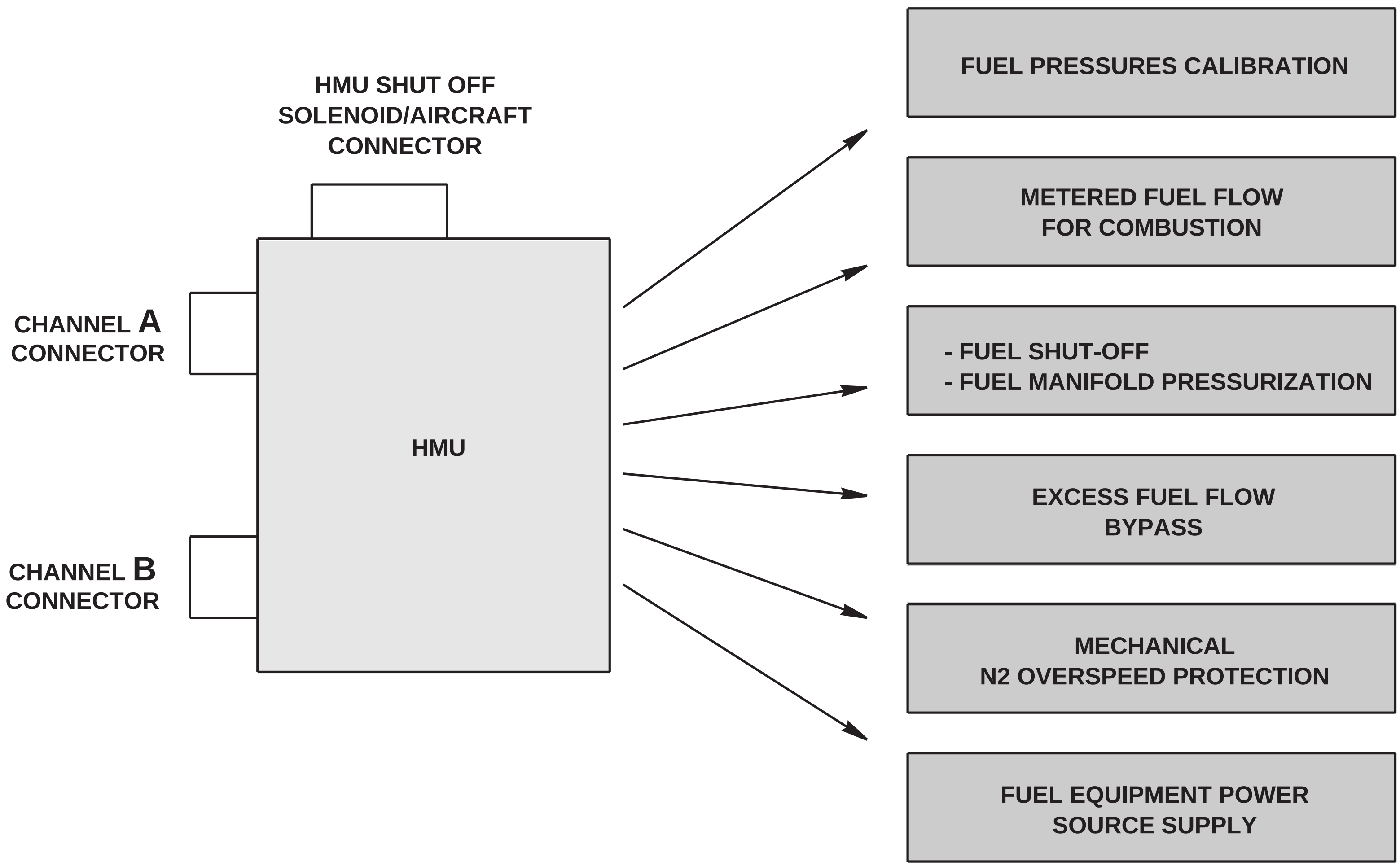
HYDROMECHANICAL UNIT

The HMU has different functions :

- It provides internal calibration of fuel pressures.
- It meters the fuel flow for combustion.
- It provides the fuel shut-off and fuel manifold minimum pressurization levels.
- It by-passes the return of unused fuel.
- It provides mechanical N2 overspeed protection.
- It delivers the correct hydraulic power source to various engine fuel equipment.

The HMU has :

- two electrical connectors to ECU channels A and B.
- an electrical connection between the shut-off solenoid and the A/C.



CTC-045-078-00

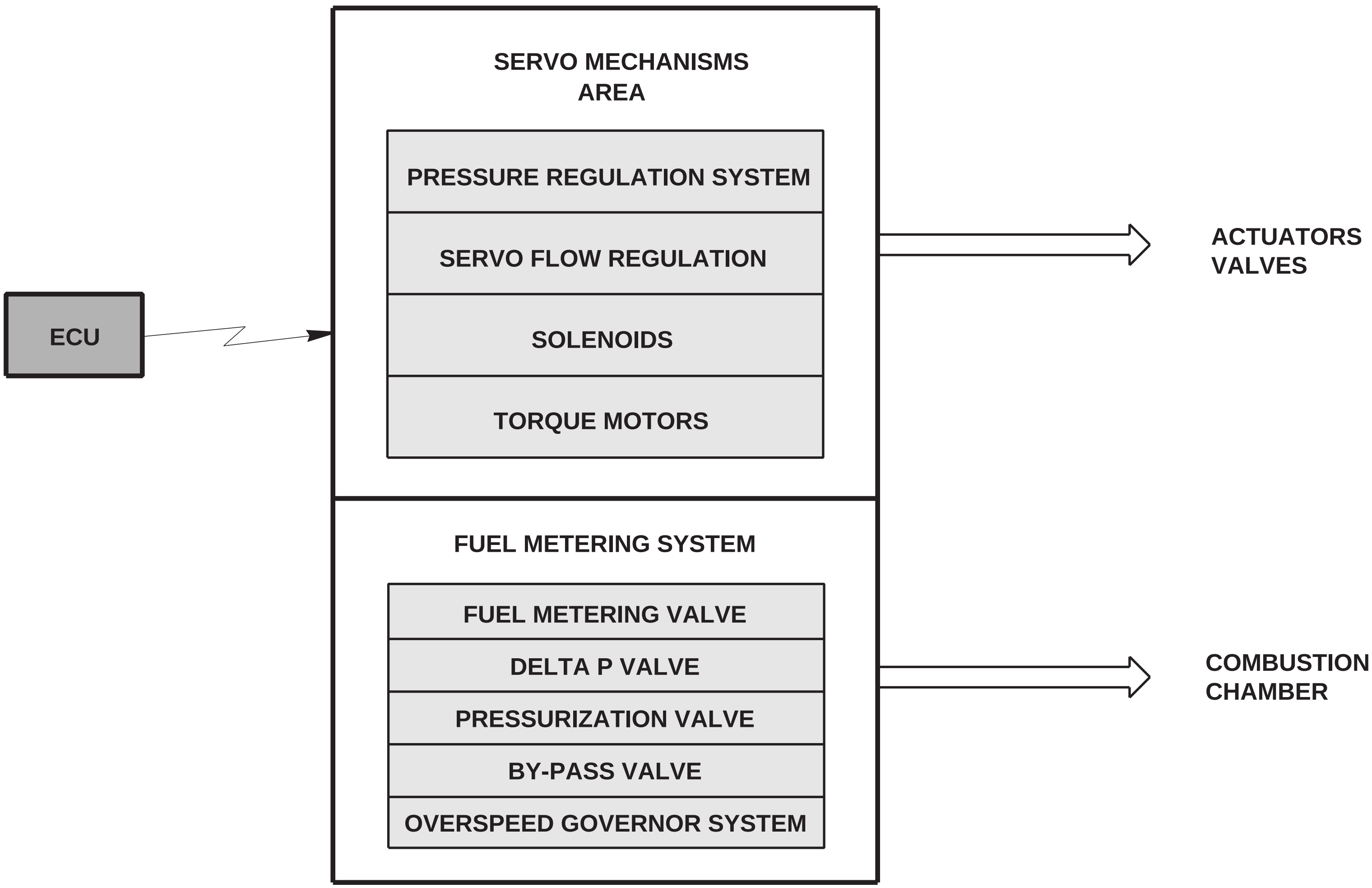
HYDROMECHANICAL UNIT PURPOSES

HYDROMECHANICAL UNIT

To manage and control the engine systems and equipment, the HMU houses two different internal subsystems, which are :

- The fuel metering system, including the fuel metering valve, the delta P valve, the pressurization valve, the by-pass valve, and the overspeed governor system.

- The servo-mechanism area, including the pressure regulation system, the servo flow regulation system, solenoid valves and torque motors to supply fuel to the various valves and actuators of the engine.



HYDROMECHANICAL UNIT DESIGN

CTC-045-079-00

General description.

To achieve all the different engine functions, the HMU has 6 torque motors (TM), one of which is not used. The remaining 5 are used for the control of :
- FMV.
- VSV.
- VBV.
- HPTCC.
- LPTCC.

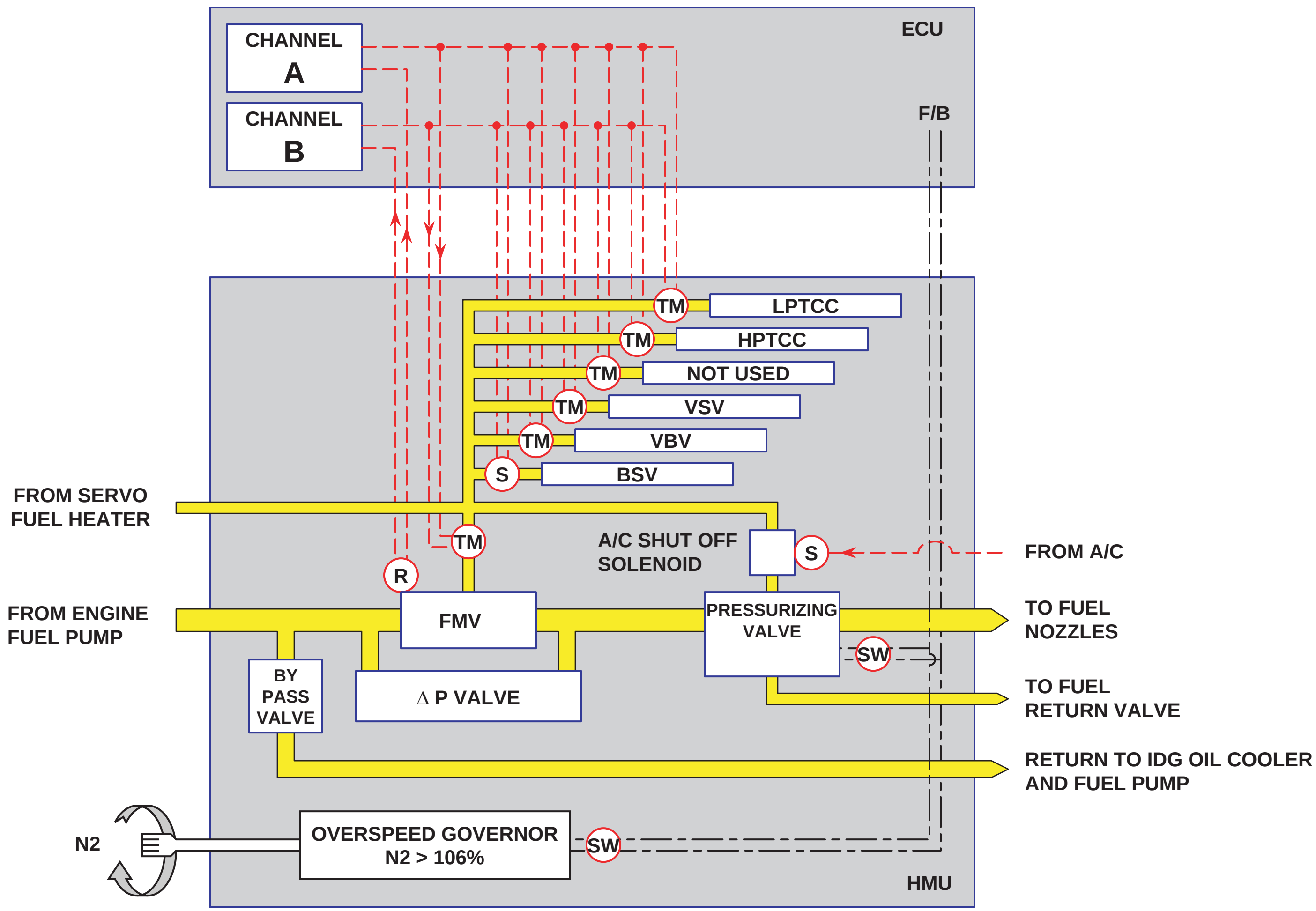
It also has:

2 solenoids (S) for :
- -BSV controls.
- -A/C shut-off valve signal generation. (this solenoid is not controlled by the ECU, but by the A/C Master Lever).

1 resolver (R), to track the FMV position.

2 sets of switches (one set for the overspeed governor, one for the pressurizing valve).

Note : The resolver and the switches are dual devices. i.e. their feedback indication is provided to both ECU channels.



HMU DESCRIPTION

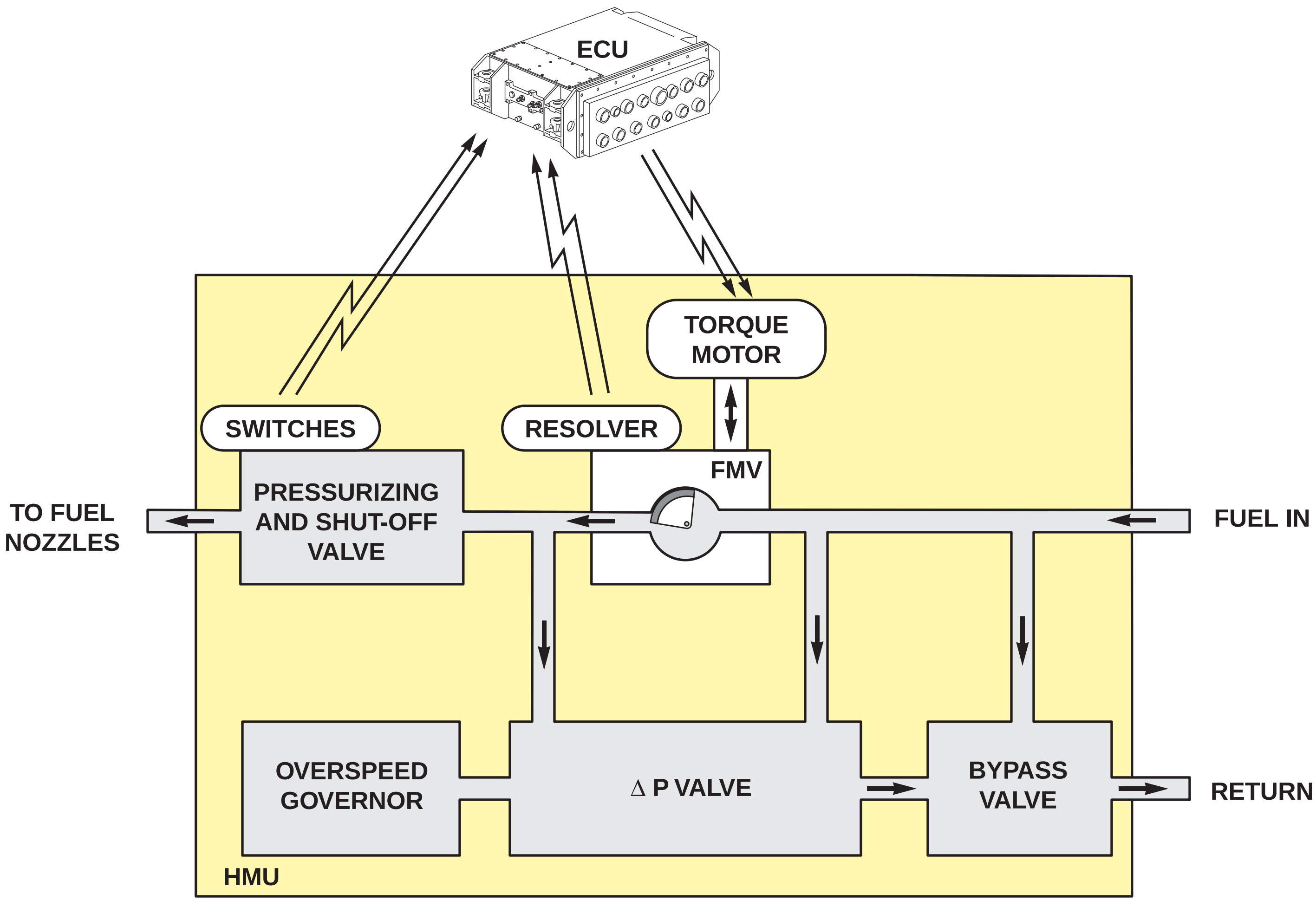
CTC-045-080-00

HYDROMECHANICAL UNIT

The general schematic shows all the components that make up the HMU FMV section.

The main items are :

- the pressure regulators.
- the FMV.
- the delta P valve.
- the by-pass valve.
- the overspeed governor.
- the pressurizing and shut-off valve.



HMU FMV SECTION

CTC-045-081-00

HYDROMECHANICAL UNIT

The HMU is supplied by two fuel pressures, Ps and Psf, that come from the fuel pump HP stage discharge.

Under certain operating conditions, some of the fuel pressure may be by-passed, and is known as Pb.

Ps pressure.

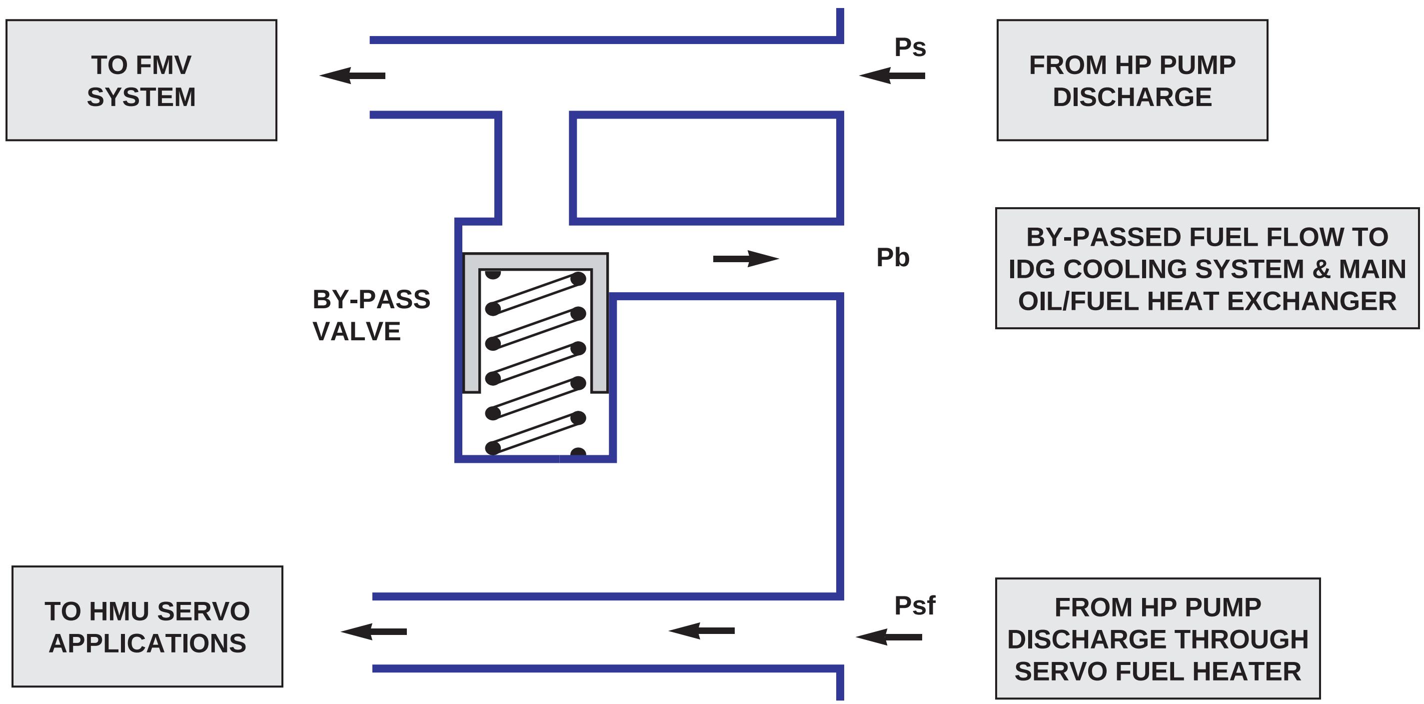
From HP pump discharge stage to the FMV system :
This is the fuel for the combustor.
Max Ps = 1250 psig.

Psf pressure.

From HP pump discharge stage to the HMU servo application, through the servo fuel heater :
This is used to generate the working pressures for the actuators .
Max Psf = 1250 psig.

Pb pressure.

By-passed fuel flow is excess fuel not used in combustion and the servo mechanisms :
It is returned to the main oil/fuel heat exchanger, through the IDG oil cooler.
Max Pb = 235 psig.



CTC-045-082-00

PSF AND PB PRESSURE REGULATION

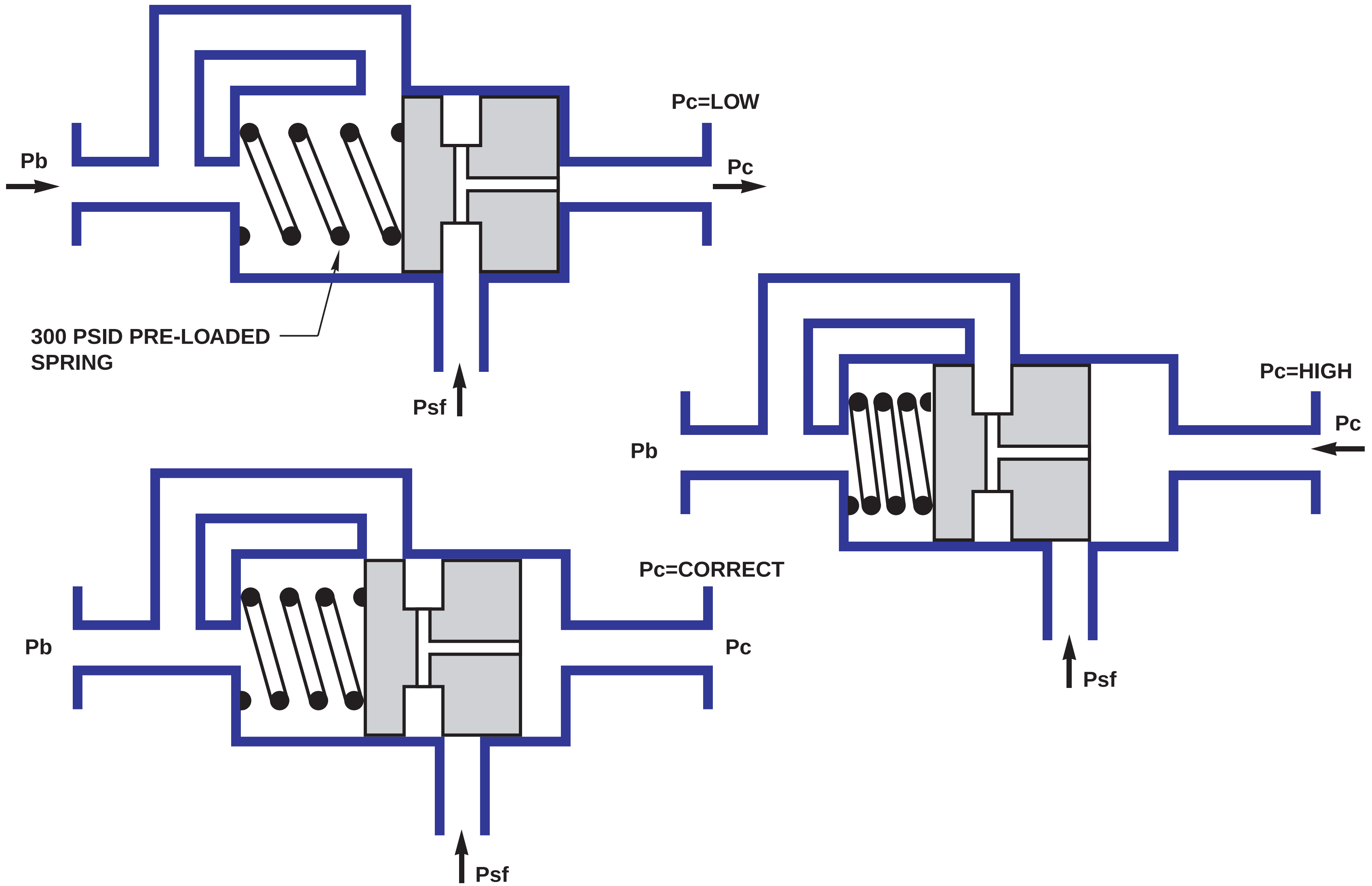
Pc: Control pressure.

(Pc = Pb + 300 psi.)

Pc pressure is regulated at a constant value of 300 psi above Pb.

The regulator controls the Psf supply in order to maintain a constant pressure differential throughout the range of flows required downstream. It also compensates for varying Pb pressures.

A spring in the pressure regulator provides a pre-loaded force that is calibrated to 300 psid.



CTC-045-083-00

PRESSURE CALIBRATION

Pcr: Control return pressure.

(Pcr = Pb + 150 psi.)

Pcr pressure is regulated at a constant value of 150 psi above Pb.

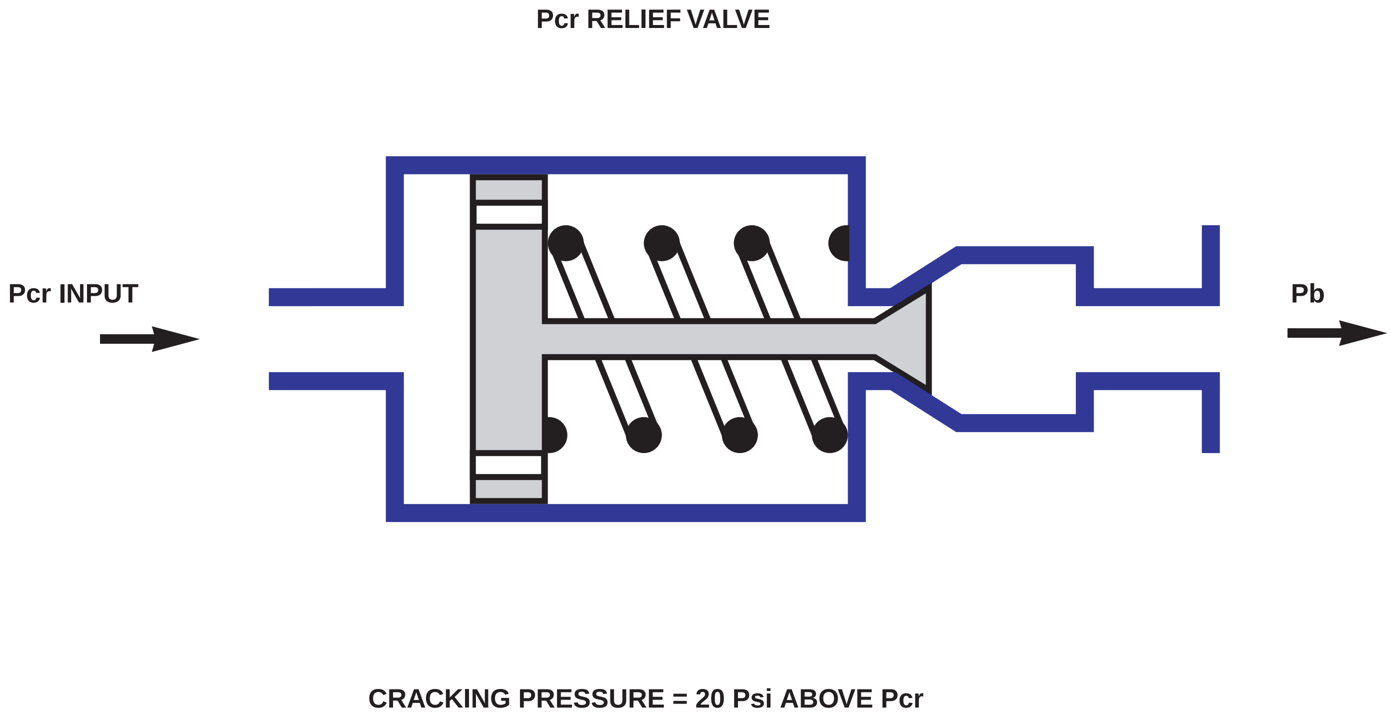
The Pcr regulator functions identically to the Pc regulator, however, the pre-loaded spring is calibrated to 150 psid.

Pcr relief valve.

The Pcr relief valve prevents the HMU case pressure from building up to Psf, in case the Pcr regulator goes to a higher than normal pressure, due to a malfunction.

The cracking pressure is set to 20 psi above Pcr.

Over-pressure in the Pcr cavity is by-passed into the Pb cavity.



PRESSURE CALIBRATION

Fuel Metering System.

The fuel metering system controls fuel flow to the engine fuel nozzles, through the FMV servo and torque motor, according to commands from the ECU.

The fuel metering system consists of :

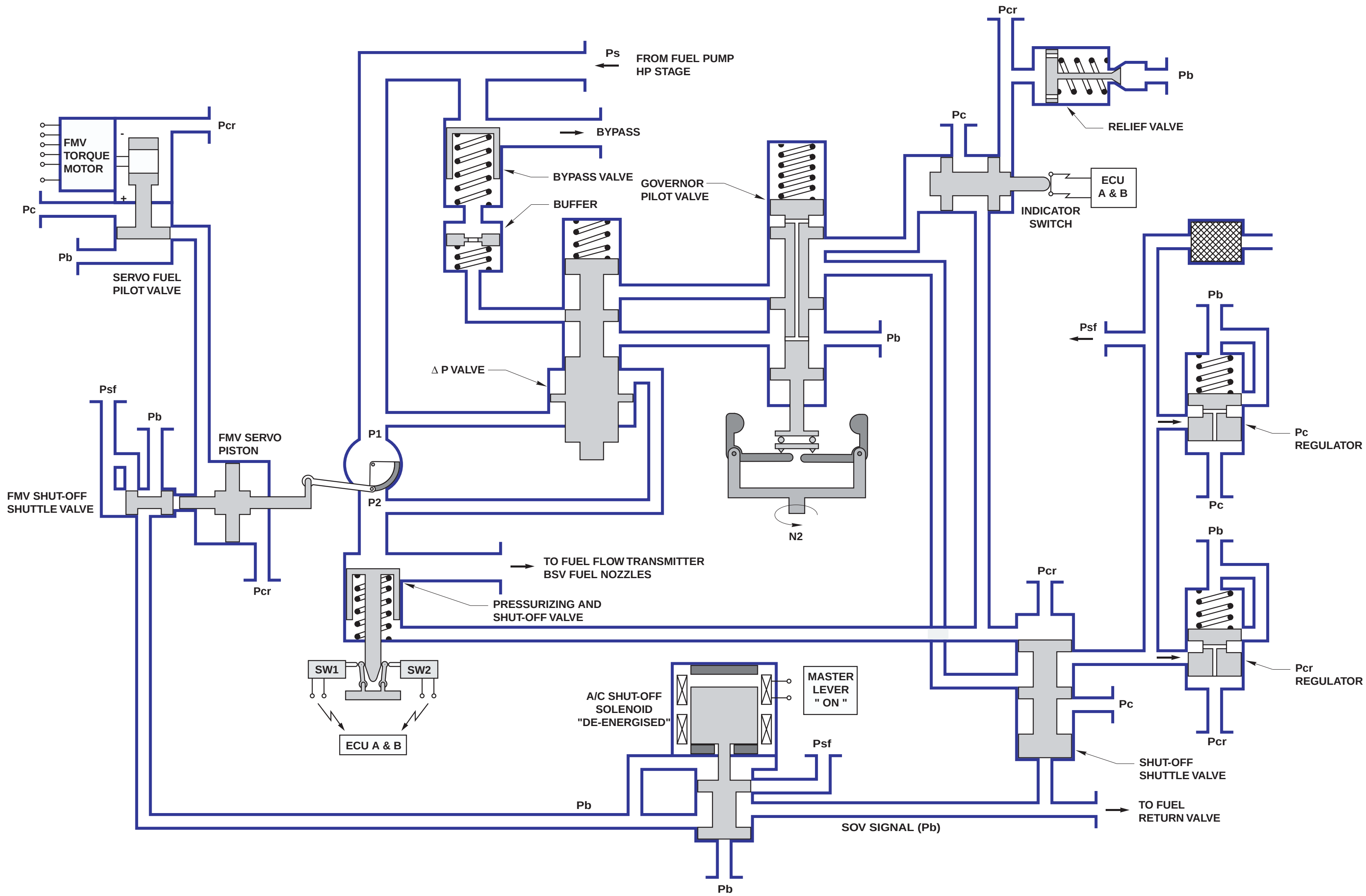
- FMV Control System (ECU logic).
- FMV torque motor.
- FMV.
- FMV Resolver.
- Delta P Regulating System.
- By-pass System.

.

Through the FMV control system, the ECU orders the FMV to rotate to modify the metered fuel flow.

The FMV resolver provides the ECU with an electrical feedback signal, proportional to the FMV position, to achieve closed loop control.

The Delta P and by-pass valves ensure that the metered fuel flow is proportional to the FMV area, by maintaining a constant pressure drop of 36 psid across the valve.



HMU FUEL METERING SYSTEM

CTC-045-085-00

Fuel metering valve control.

The FMV control system positions the FMV, according to an electrical command signal from the ECU.

The control system consists of :

- FMV torque motor.
- Servo fuel pilot valve.
- FMV.
- Resolver.

The FMV torque motor receives electrical commands from the ECU and converts them into an axial movement of the servo fuel pilot valve.

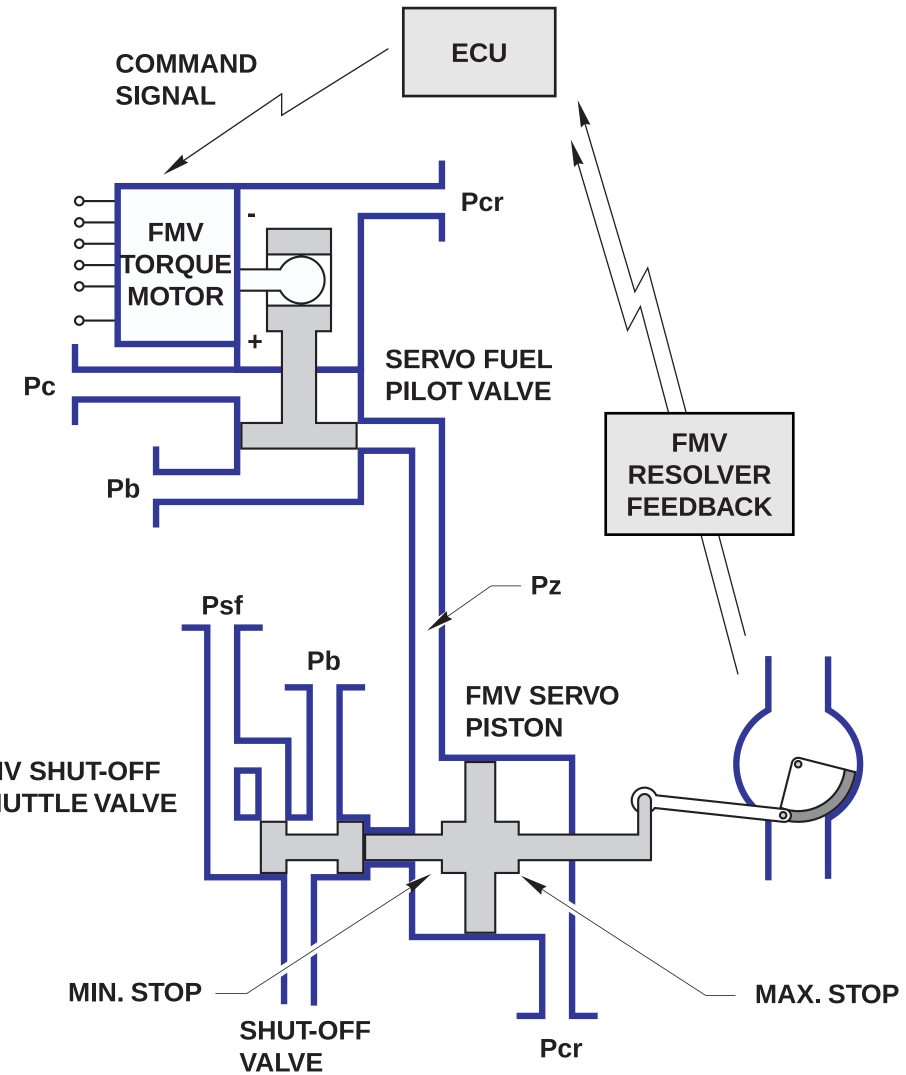
The servo fuel pilot valve controls a modulated pressure (Pz), that is ported to, or from, the FMV. The pilot valve has an axial rotation to reduce hysteresis.

The FMV servo piston is subjected to Pz, on one side, and to Pcr backpressure, on the other side.

The resulting axial movement of the piston causes rotation of the FMV, through a pushrod and bellcrank assembly.

Maximum and minimum stops, in the valve assembly, set the rotational limits of the FMV.

The resolver provides the ECU with electrical feedback of the FMV position.



FUEL METERING VALVE CONTROL

CTC-045-086-00

Delta P and bypass regulating system.

The Delta P valve and by-pass valves regulate a constant pressure drop across the FMV to ensure that the metered fuel flow is proportional to the FMV position.

The system consists of :

- a delta pressure detector.
- a by-pass valve.

The delta pressure detector senses the differential pressure across the FMV.

Ps pressure (P1) acts on one side of the piston.

FMV output pressure (P2), plus force from a pre-loaded spring, act on the other side of the piston.

P1 - (P2 + spring load) = the stable position.

The pre-loaded spring is calibrated to 36 psi.

At the stable position, the by-pass valve control signal is a constant value.

When changes occur in the Delta P across the FMV, the piston becomes unbalanced and moves axially.

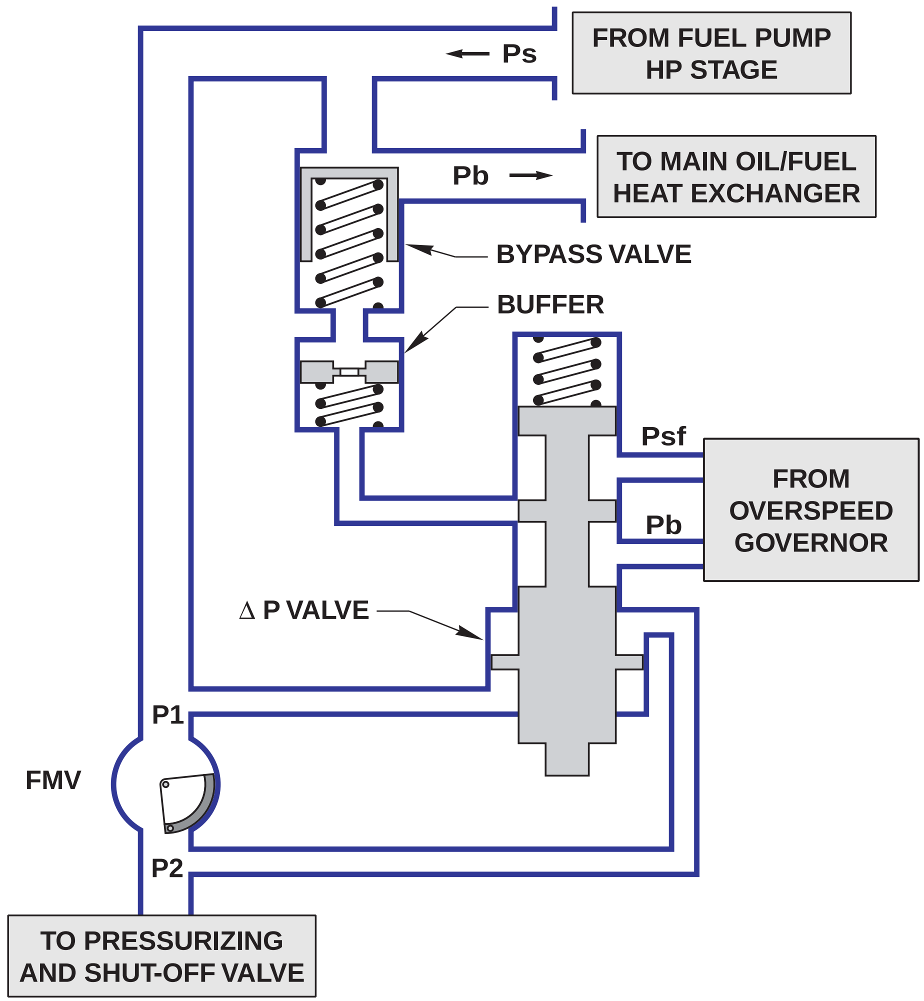
This will either increase, or decrease, the by-pass valve control pressure. The by-pass valve piston will move to a more open, or closed position, thus increasing, or decreasing the by-passed fuel pressure.

This, in turn, will decrease or, increase the Ps flow (P1), and restore the Delta P to 36 psid.

Buffer.

There is a buffer, located between the Delta P valve and the by-pass valve.

This provides the necessary compensation to prevent speed overshoot and instability that could occur during overspeed limiter conditions.



CTC-045-087-00

Δ P REGULATING AND BY-PASS SYSTEM

Overspeed governor system.

The overspeed governor system limits the core engine speed (N2) to a maximum of 106%, in the event of a malfunction that could drive the engine into an overspeed condition.

The OSG, which is hydro-mechanical and independent of the ECU, is installed on-line with the Delta P valve and consists of :

- A flyweight device, which is an N2 detector consisting of flyweights, pivot pins, bearings, and a ball head gear. It produces a force on a governor pilot valve proportional to the square of the flyweight speed.

- A governor pilot valve, which ports either Psf, or Pb, to the Delta P valve in order to modulate the by-pass valve. The pilot valve translation depends on the flyweight force, versus a pre-loaded spring force.

- A pre-loaded spring, which opposes the force produced by the flyweights, and is calibrated to the overspeed setting.

Overspeed governor test.

At each engine start, N2 increases and the flyweight device applies an upward force on the bottom of the governor pilot valve.

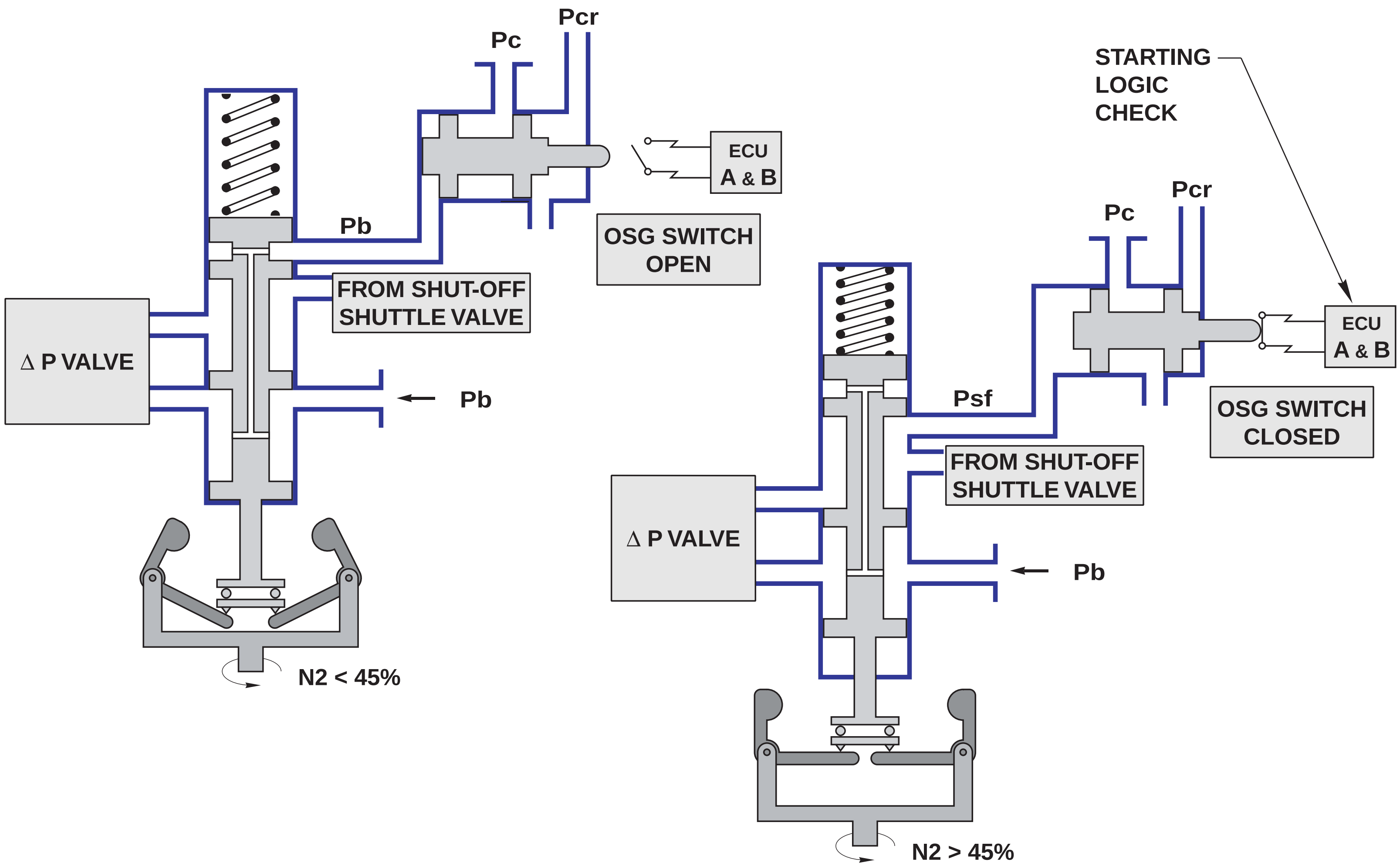
As the governor pilot valve continues to move up, Psf pressure is ported to one side of a piston, which is connected to a micro-switch dedicated to the ECU starting logic.

The micro-switch informs the ECU that the governor system is in operation.

Below 38-45% N2 speed, the micro-switch is open.

Above 45% N2, the switch closes, confirming that the overspeed governor system is in operation.

The switch remains closed until N2 drops below 45%.



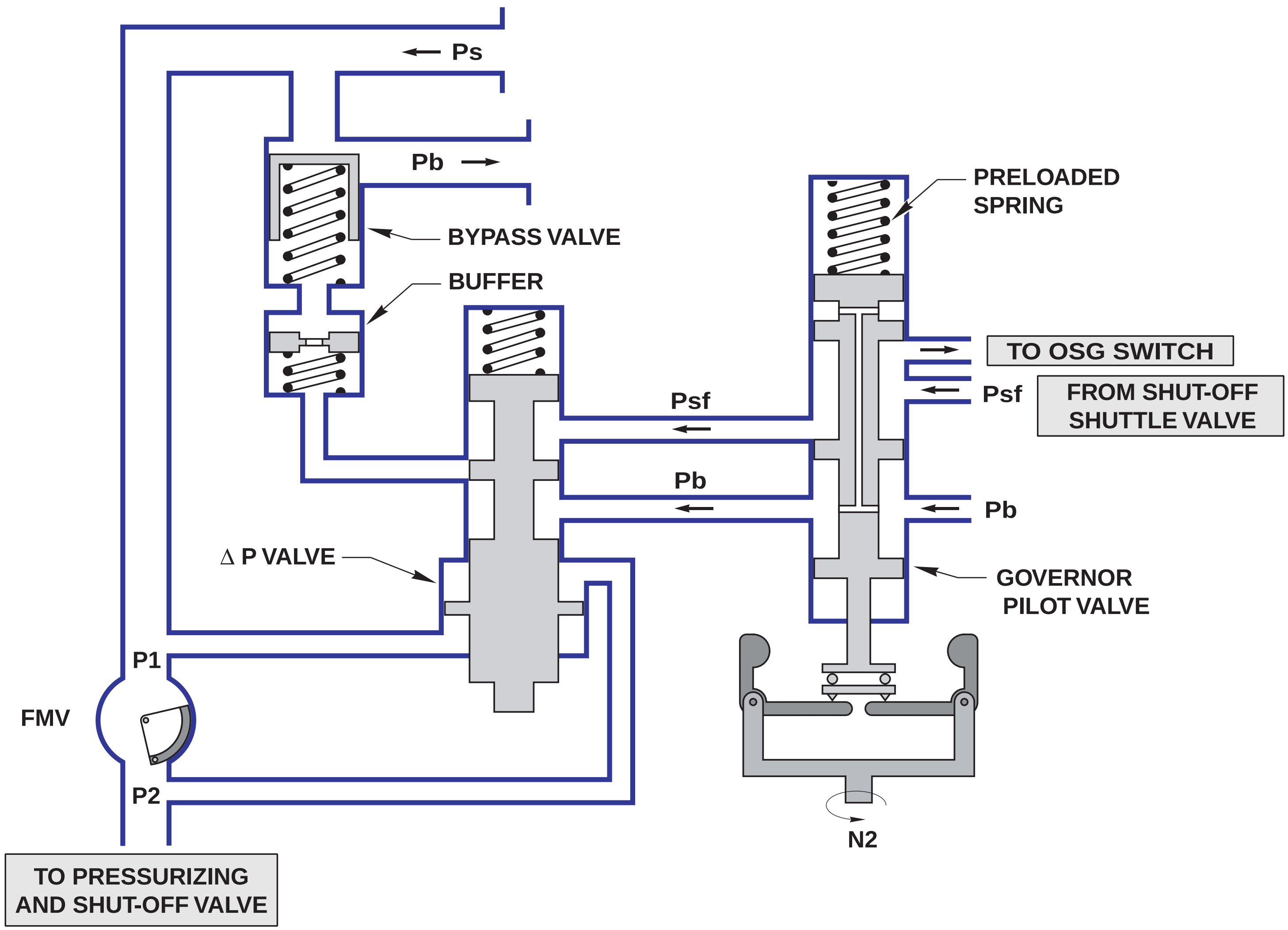
CTC-045-088-00

OVERSPEED GOVERNOR

Overspeed Governor System in-speed condition.

During regular engine operation, the force of the flyweight device is not strong enough to overcome the force of the pre-loaded spring.

In this in-speed condition, the pilot valve continues to send Psf and Pb fuel pressures to the Delta P pilot valve in order to modulate the by-pass valve for normal operations.



CTC-045-089-00

OVERSPEED GOVERNOR SYSTEM IN-SPEED CONDITION

Overspeed Governor System in an overspeed condition.

When N2 reaches 98%, the flyweight force equals the spring force.

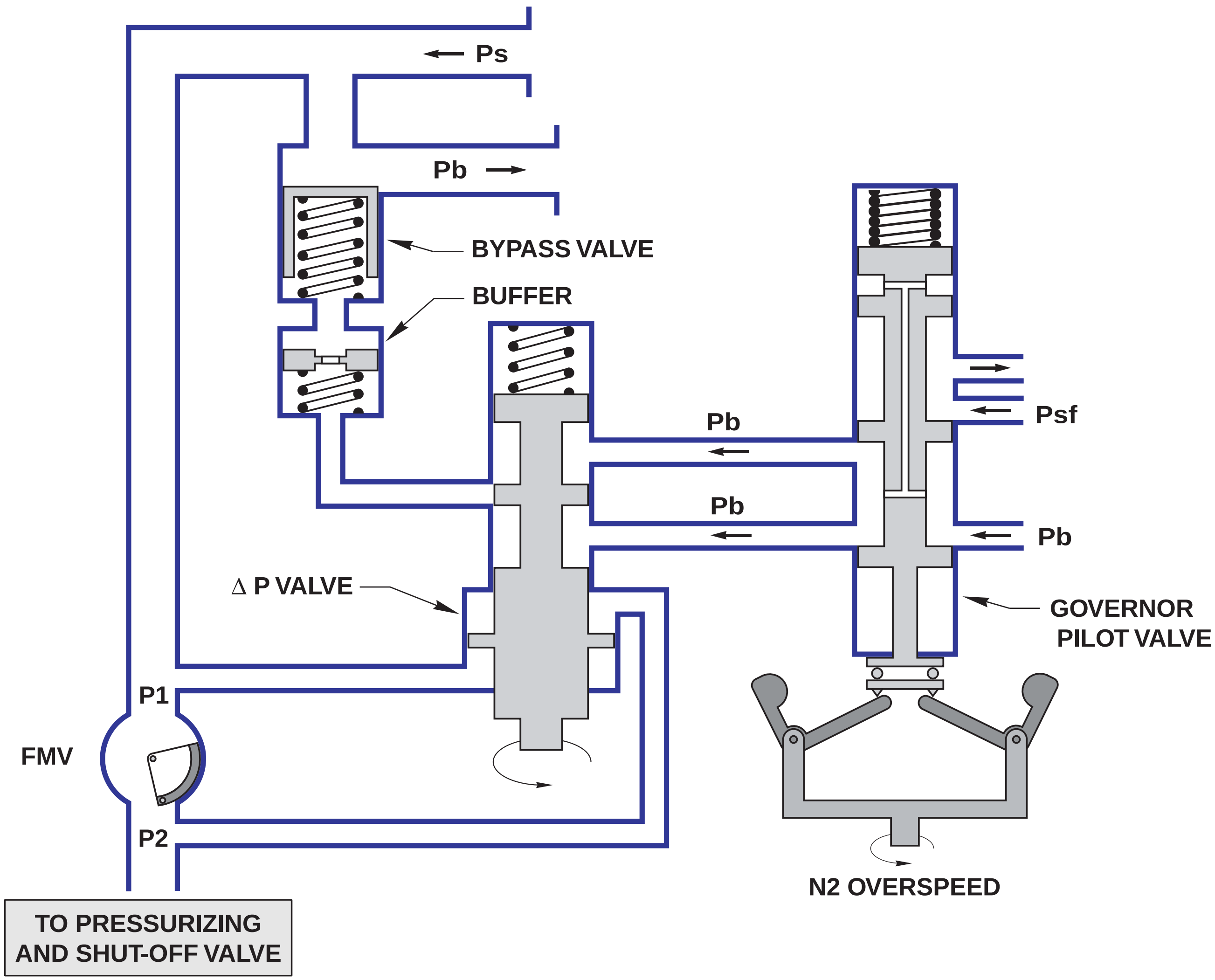
As speed continues to increase, the pilot valve moves up, slightly restricting Psf flow to the Delta P regulator.

When speed reaches the overspeed value of 106%, the Psf supply to the Delta P valve is reduced to Pb and this causes the by-pass valve to stroke further open.

More fuel is by-passed, decreasing fuel flow to the FMV and, therefore, less fuel is available for combustion.

As a result, N2 decreases until it is below the overspeed value.

When N2 returns to the normal range, the preloaded spring can now oppose the force of the flyweights, so the pilot valve moves back down and the pressure ported to the Delta P regulator is returned to Psf.



CTC-045-090-00

OVERSPEED GOVERNOR SYSTEM OVERSPEED CONDITION

Pressurizing and shut-off valve.

During engine start, the pressurizing and shut-off valve establishes a minimum Psf pressure to ensure proper operation of the regulators, and piston force margins.

During engine shut-down, the pressurizing and shut-off valve closes to stop fuel flow to the engine fuel nozzles.

The pressurizing and shut-off valve is composed of :

- a piston.
- a pre-loaded spring.
- two position switches.

Under normal operation, Pcr, or Pc pressure, combined with a pre-loaded spring force, is applied to the pressurization valve rod compartment.

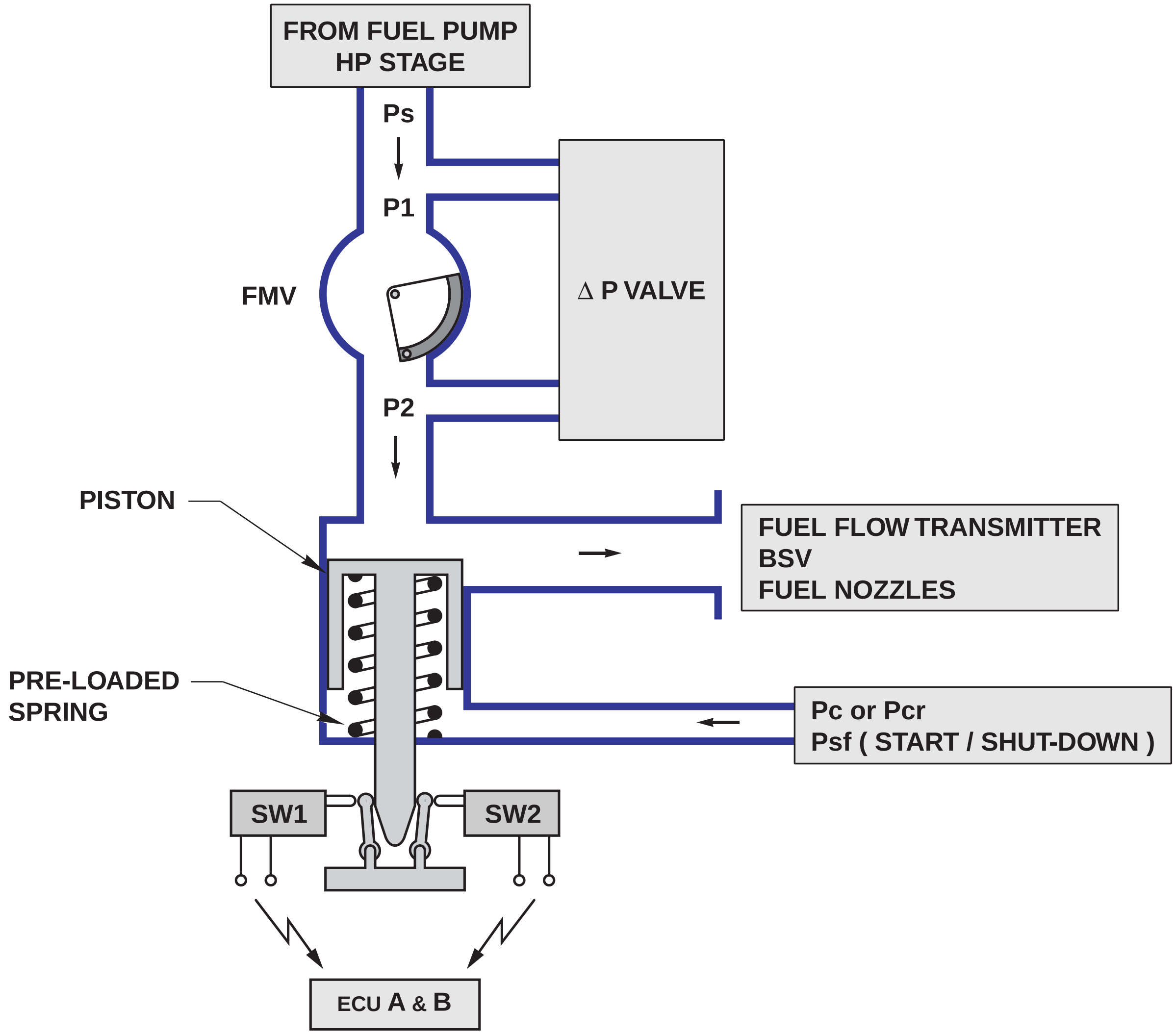
The pre-loaded spring force guarantees enough Psf to operate the Pc, Pcr and Delta P regulator systems, and provides adequate force margins for all pistons and actuators.

FMV downstream pressure is applied on the top of the piston.

A minimum FMV downstream pressure is required to displace the valve piston far enough to open a port.

Under engine shut-down conditions, the shut-off system exchanges Pcr, or Pc, for Psf pressure, resulting in a closed valve position. The fuel supply to the nozzles is stopped, and the engine shuts down.

The pressurizing valve is provided with switches, which inform the ECU that the valve is in the shut-off position.



CTC-045-091-00

PRESSURIZING AND SHUT-OFF VALVE

Fuel shut-off system.

The fuel shut-off system ensures engine shut-down and fuel pump unloading.

The system is composed of :

- an FMV shut-off shuttle valve.
- the A/C shut-off solenoid.
- a shut-off shuttle valve.
- the pressurizing and shut-off valve.

During a shut-down order, the ECU control logic generates a hydraulic Shut-Off Valve (SOV) signal.

The SOV signal activates a shut-off shuttle valve which :

- closes the pressurizing and shut-off valve to stop fuel nozzles supply.
- opens a by-pass valve to avoid fuel pump loading and prevent over-pressure inside the HMU.
- closes the FRV.

The pilot is able to generate a shut-down order, through the Master Lever in the cockpit.

FMV shut-off shuttle valve.

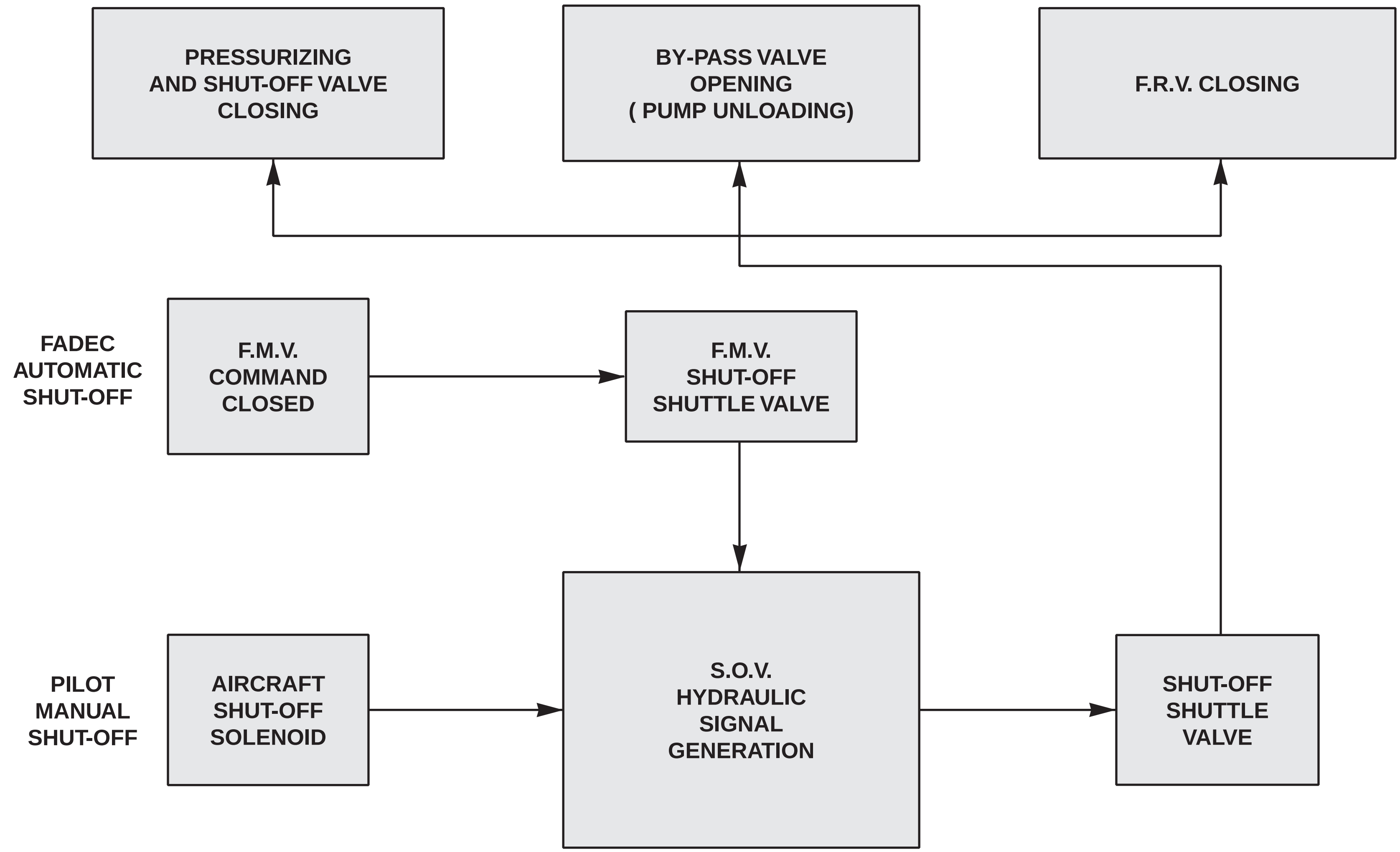
According to its position, the FMV shut-off shuttle valve routes either Pb, or Psf pressure to the A/C shut-off solenoid valve, in order to hydraulically reset the solenoid and also generate an SOV signal to shut down the engine.

A/C shut-off solenoid.

The A/C shut-off solenoid is a magnetic latching solenoid, which provides an independent path through which the engine can be shut down, by actuating the Master Lever. The output of the A/C shut-off solenoid forms the SOV signal.

Shut-off shuttle valve.

The shut-off shuttle valve is a non-rotating spool valve, actuated by the SOV hydraulic signal. It controls the porting of pressure to the pressurizing and shut-off valve and to the by-pass valve, through the OSG and the Delta P regulator system.



CTC-045-092-00

FUEL SHUT-OFF SYSTEM

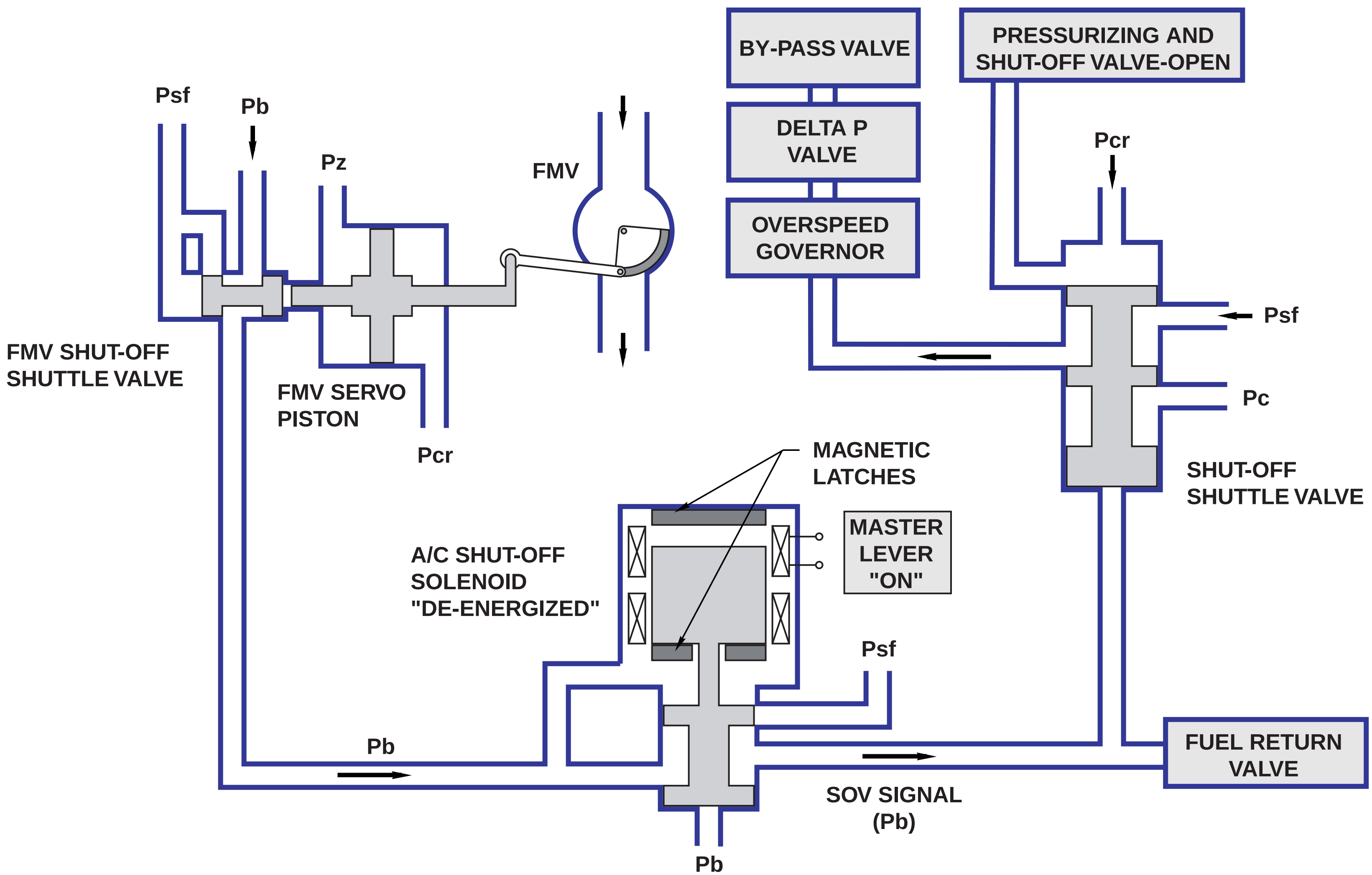
Engine run condition.

When the FMV is in the run condition, the SOV signal supplied through the FMV shut-off shuttle valve is Pb.

The A/C shut-off solenoid plunger is de-energized and held in the ‘down’ position by magnetic latches.

In this position, the SOV pressure signal (Pb) supplied by the FMV shuttle valve, is able to pass through to the bottom of the shut-off shuttle valve and to the FRV.

Pcr pressure is supplied to the top of the shut-off shuttle valve and, because of the differential pressure (Pcr, Pb) across it, the valve is pushed down, allowing normal operation of the Delta P regulator and of the pressurizing and shut-off valve.



ENGINE SYSTEM IN RUN CONDITION

CTC-045-093-00

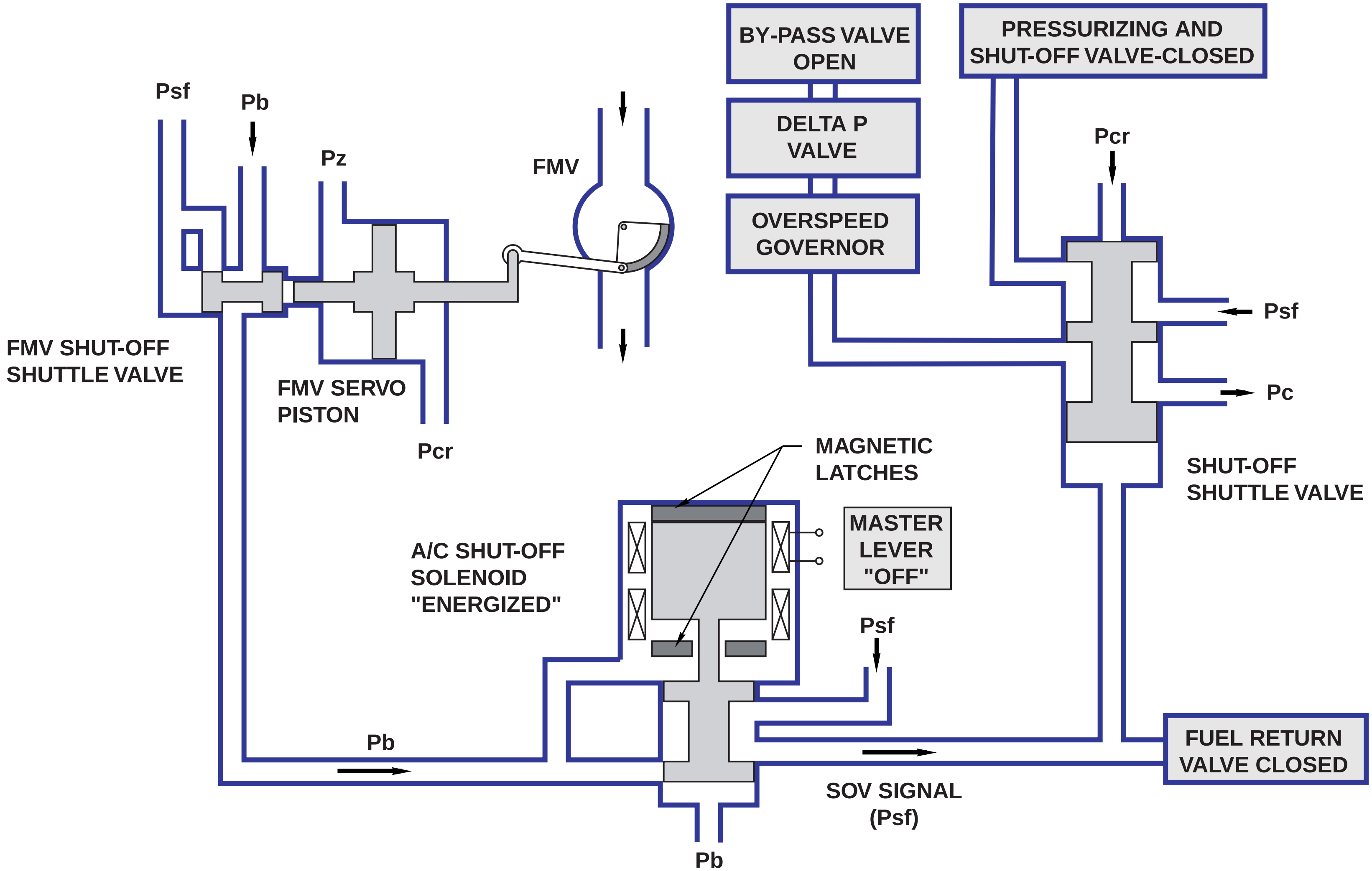
Engine shut-down by cockpit order.

The cockpit shut-down order is activated by the pilot who moves the Master lever to the “OFF” position.

This energizes the A/C shut-off solenoid coil and the magnetic latch force is overcome. Consequently the plunger moves up and ports Psf to the SOV line.

Because of the differential pressure (Psf, Pcr), the shut-off shuttle valve moves up to ensure pressurizing and shut-off valve closure and pump unloading (by-pass valve open).

In addition, the SOV signal closes the FRV.



ENGINE SHUTDOWN - COCKPIT ORDER

CTC-045-094-00

ECU automatic engine shutdown during starting sequence on the ground.

In the event of an abnormal starting sequence on the ground, the ECU determines a need to shut down the engine and triggers a shutdown function.

The shutdown function commands the FMV servo piston towards the minimum stop.

At an FMV angle of approximately 10 degrees, the FMV servo piston's minimum stop screw contacts the plunger of the FMV shut-off shuttle valve.

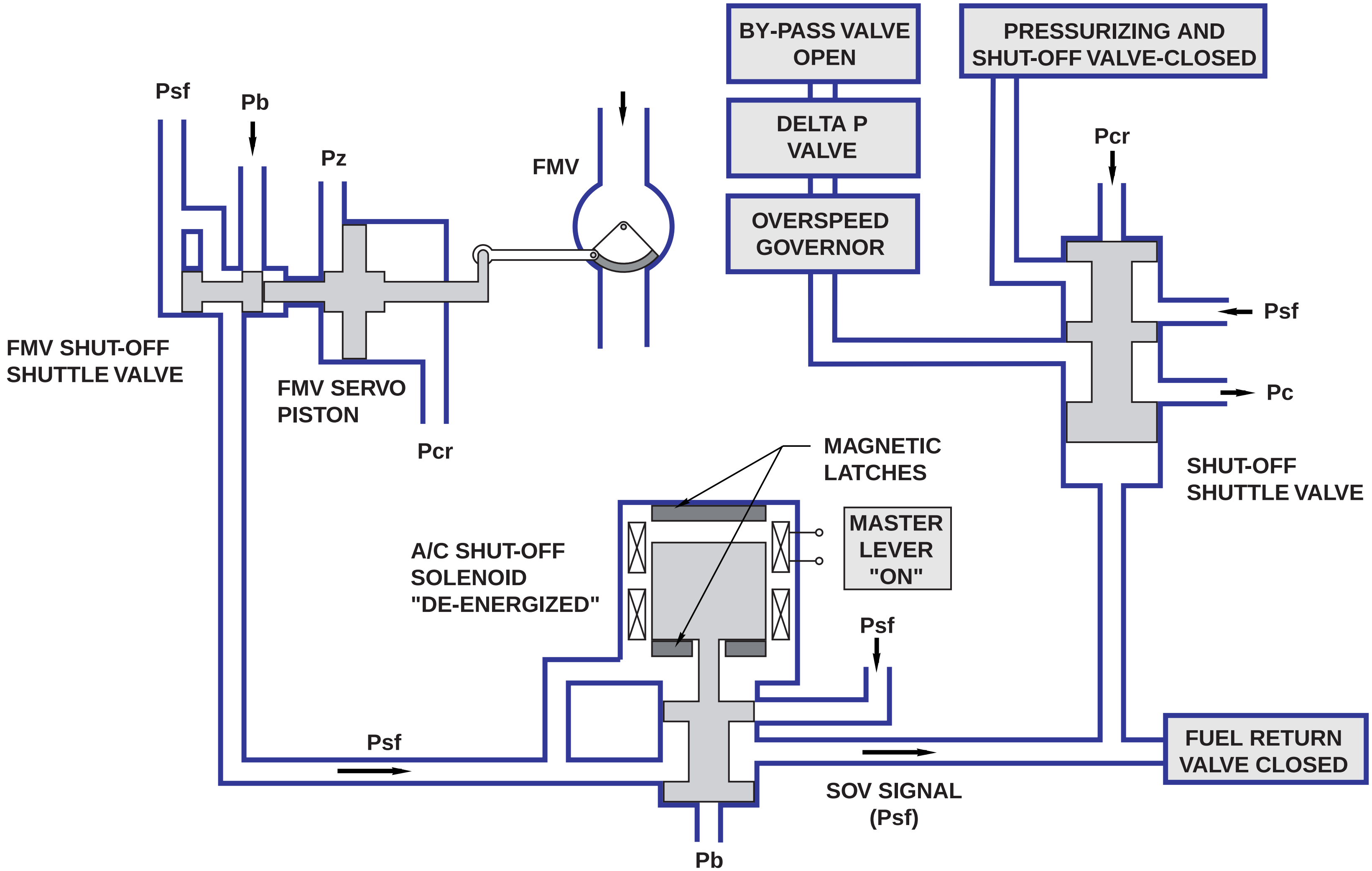
As the metering valve modulated pressure (Pz) is low enough, the servo overcomes the force of Psf pressure exerted on the other side of the FMV shut-off shuttle valve plunger, and continues to move towards the minimum stop position.

At an FMV angle of approximately 7 or 8 degrees, the FMV shut-off shuttle valve plunger moves far enough to switch output pressure (SOV signal) from Pb to Psf.

The FMV continues moving until the metering valve servo contacts the minimum stop (FMV angle of 5 degrees).

The A/C shut-off solenoid valve is still de-energized ("ON" position) and so, Psf pressure is ported to the SOV line. Because of the differential pressure (Psf, Pcr), the shut-off shuttle valve piston moves up porting Psf pressure to the pressurizing and shut-off valve, thus interrupting fuel flow to the fuel nozzles and resulting in an engine shutdown.

The process is reversed when the ECU commands the FMV servo to an angle greater than approximately 8 degrees.



CTC-045-095-00

ECU ENGINE SHUTDOWN - STARTING SEQUENCE / ON GROUND

Reset function.

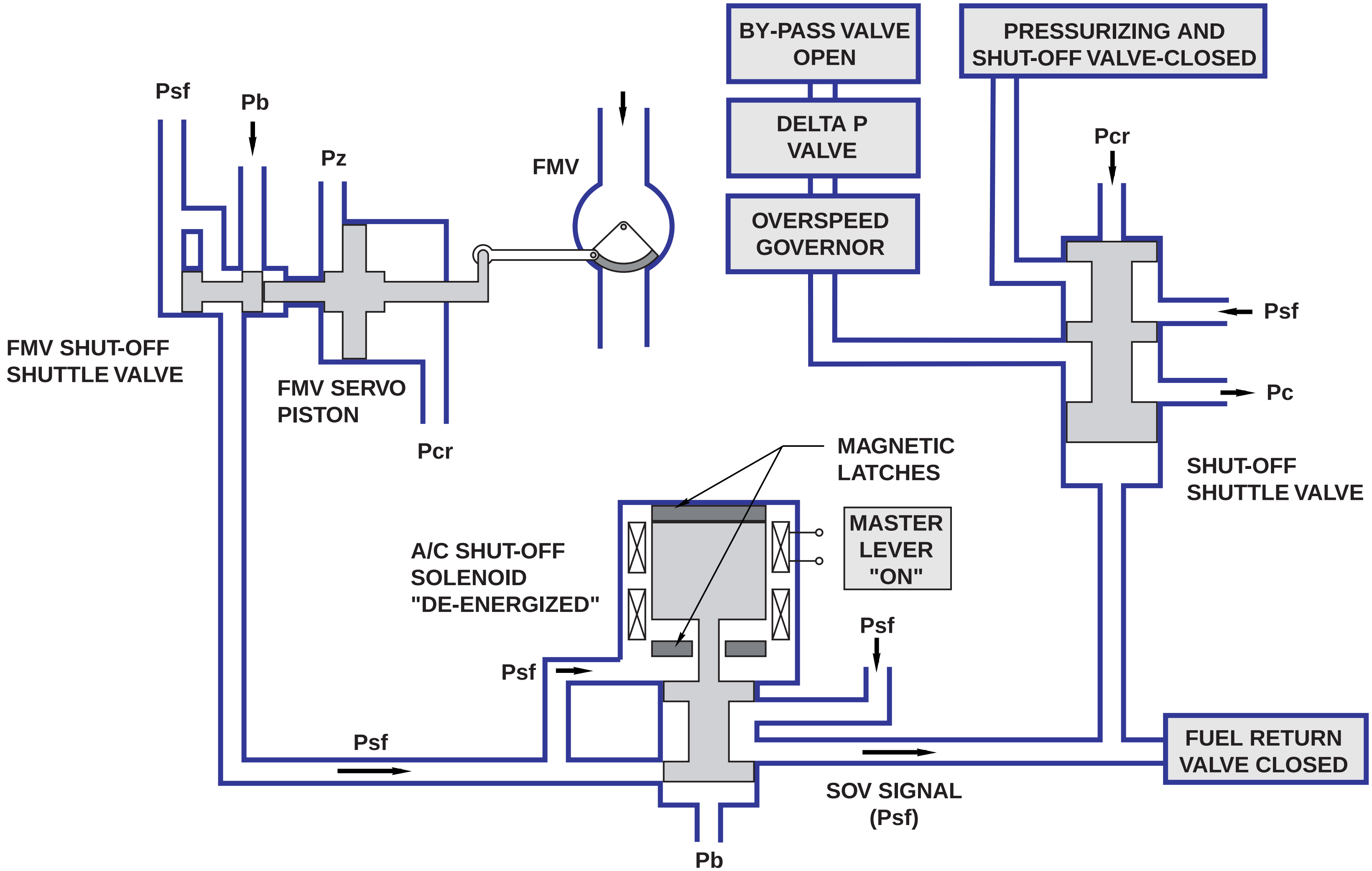
If the A/C solenoid was used to initiate engine shut-down, (Pilot action - Master Lever OFF), the ECU must still command the FMV below 8 degrees in order to port Psf and hydraulically reset the solenoid back to a run state.

During the starting sequence, the master lever is “ON”, therefore the A/C solenoid coil is de-energized.

The ECU control logic sends an electrical signal to the FMV torque motor, which positions the FMV and FMV shut-off shuttle valve to port Psf pressure to the top of the A/C shut-off solenoid valve plunger.

This Psf pressure, applied to the top of the solenoid plunger, is only opposed by Pb at the bottom and so, the plunger moves down, hydraulically resetting the valve.

The ECU reset function then stops and the FMV is positioned to deliver fuel.



RESET FUNCTION

CTC-045-096-00

Servo flow regulation system.

The servo flow regulator system regulates the flow of fuel to actuators.

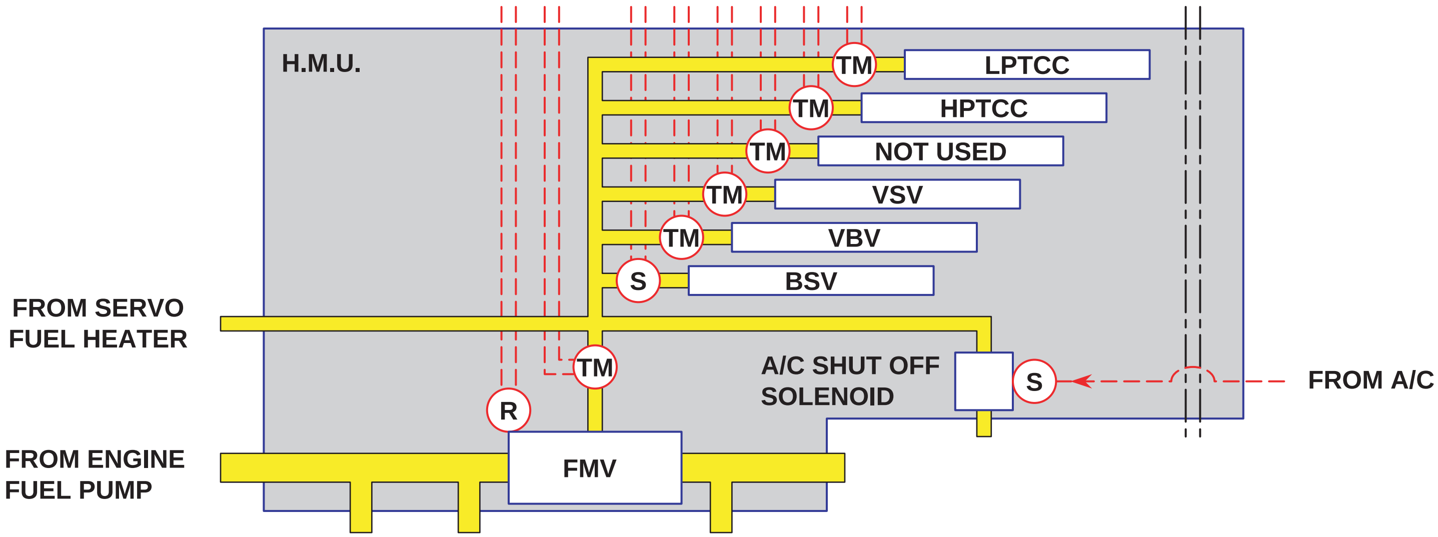
The system is composed of six flow regulators, one of which is not used, for :

- Fuel Metering Servo Valve (already described).
- Variable Stator Vane (VSV).
- Variable Bleed Valve (VBV).
- High Pressure Turbine Clearance Control (HPTCC).
- Low Pressure Turbine Clearance Control (LPTCC).

The regulators use three and four-way pilot valves to produce a defined pressure versus flow schedule.

There are also 2 solenoid valves:

-The Burner Staging Valve (BSV).
-The A/C shut-off solenoid (already described).



HMU DESCRIPTION

CTC-045-097-00

Variable Stator Vane (VSV) and Variable Bleed Valve (VBV) flow regulators.

The VSV and VBV flow regulators are identical.

Each regulator contains a servo valve torque motor, a first stage pilot valve and a second stage flow control valve.

The torque motor can be driven by energizing either of two electrically isolated, independent coils that are attached to it.

The pilot valve is a three-way spool valve, directly coupled to the torque motor and cannot rotate due to an anti-rotation arm. The pilot valve is inside the flow control valve and is positioned depending on torque motor current.

The pilot valve has 2 control ports located in the flow control valve. The control valve rotates and is hydraulically coupled to the pilot valve.

Any changes in the position of the pilot valve due to the position of the torque motor, result in changes in the output pressure (Pz), which modifies the position of the flow control valve.

VSV and VBV flow control valve operation.

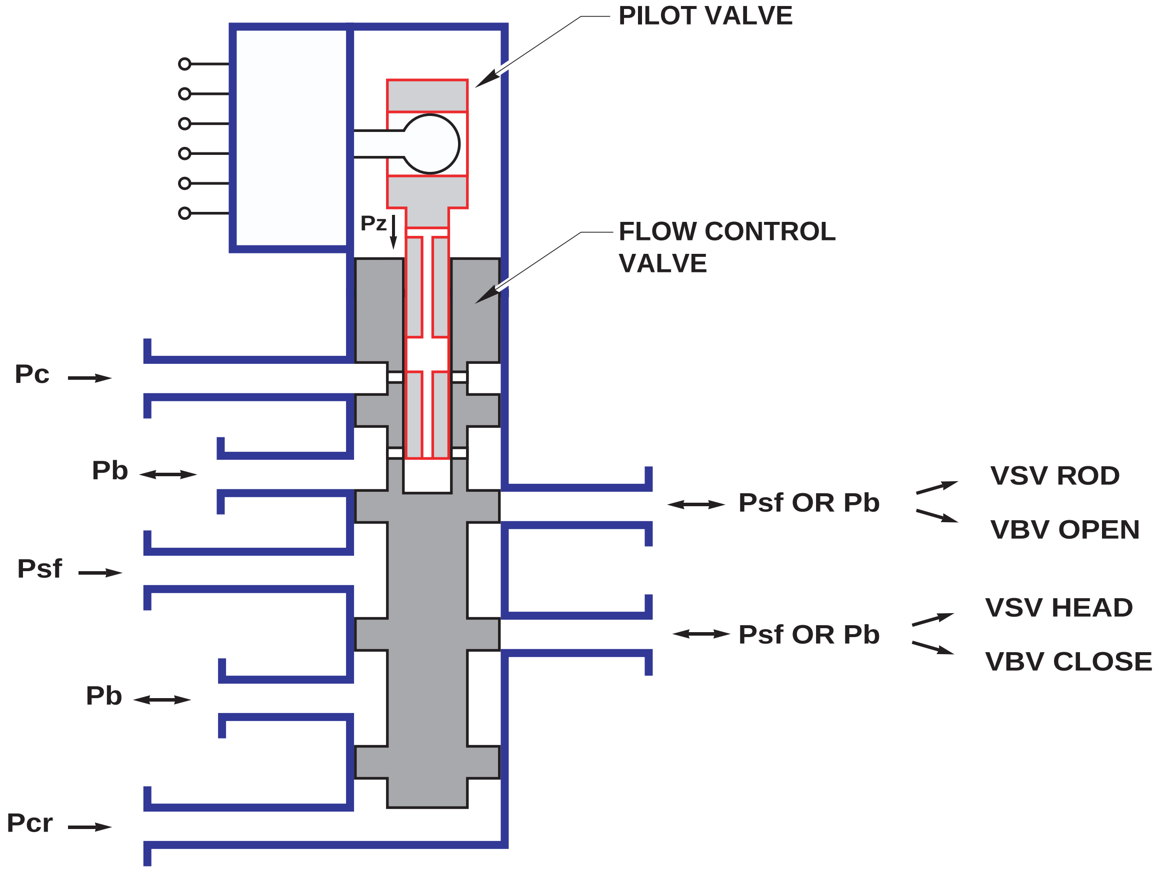
The pilot valve is supplied with Pc and Pb pressures. The pilot valve's regulated output pressure (Pz) is applied to the upper end of the flow control valve and is opposed by Pcr pressure applied to the lower end.

Increasing torque motor current displaces the pilot valve downward and ports Pc to Pz. Pz then becomes greater than Pcr and the flow control valve moves downward.

Psf and Pb are supplied to the flow control valve. The two outputs are connected to the VSV head and rod ports or to the VBV open and close ports.

Downward movement of the flow control valve ports Psf pressure to the head end of the VSV actuator which closes the VSV's, and to the VBV gear motor which closes the VBV's.

The flow control valve rotates constantly to reduce hysteresis, thus increasing the flow regulators positioning accuracy.



CTC-045-098-00

VSV AND VBV FLOW REGULATORS

Clearance control servo flow regulators system.

The flow regulators system consists of :
- -High Pressure Turbine Active Clearance Control (HPTACC).
- -Low Pressure Turbine Active Clearance Control (LPTACC).

These regulators are identical.

Unlike the VSV and VBV flow regulators, the clearance control regulators contain non-rotating pilot valve plungers. Each regulator contains a servo valve torque motor, a first stage bleed valve, and a second stage flow control valve.

The bleed valve is suspended from spring blades and directly coupled to the torque motor. The seat of the bleed valve is in the flow control valve.

The flow control valve is a three-way spool valve, with a preloaded spring, and is supplied by Pc and Pb.

Changes in the position of the bleed valve, due to the position of the torque motor, modulates the Pc pressure supplied to the Pz cavity and the bottom of the flow control valve.

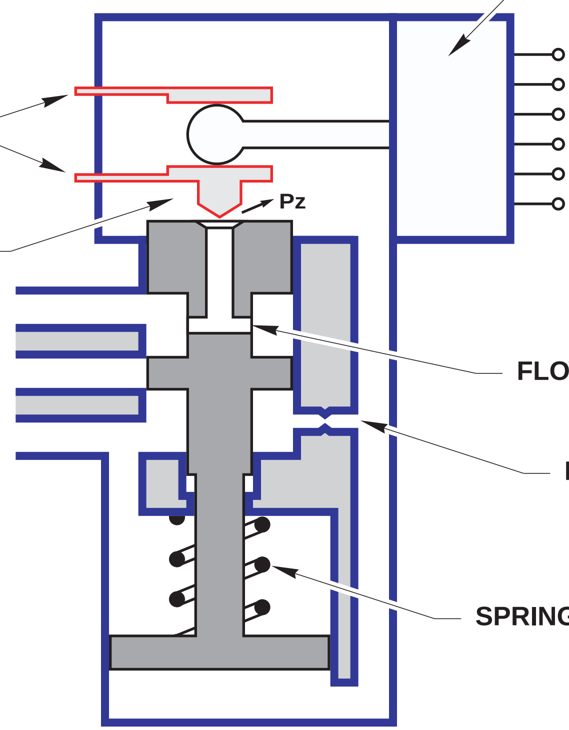
Pz is opposed by Pb, plus the spring force, and the control valve moves up or down to compensate for pressure changes.

Clearance control regulators operation.

An increase in torque motor current moves the bleed valve down, decreasing the amount of Pc supplied to the Pz cavity. A bleed orifice, between the Pz cavity and the Pb line allows Pz to decrease, causing the flow control valve to move downward and port Pc to the output port.

A decrease in torque motor current moves the bleed valve up, increasing the amount of Pc supplied to the Pz cavity causing Pz to increase. This increase causes the flow control valve to move upward and port Pb to the output port.

The output port is connected to one side of the clearance control actuator and the other side of the actuator is always submitted to Pcr pressure.



CTC-045-099-00

CLEARANCE CONTROL SERVO FLOW REGULATORS

Burner staging valve solenoid operation.

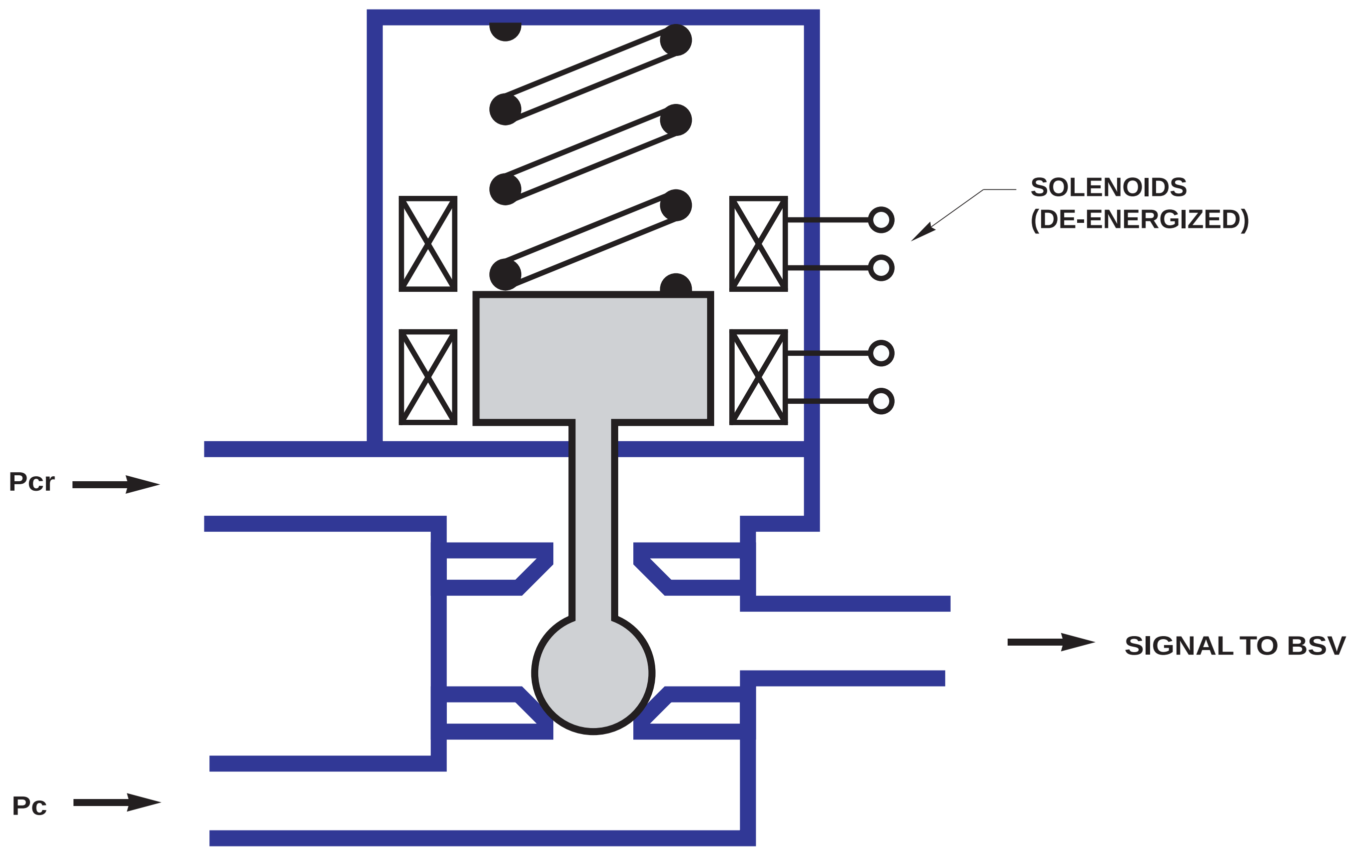
Controlled by the ECU, the output of the Burner Staging Valve (BSV) is used to turn off half of the 20 fuel nozzles during certain flight conditions.

The BSV is a three-way solenoid valve containing a single ball and two valve seats.

Pc and Pcr pressures are supplied to the input of the valve and one of these inputs supplies the output pressure sent to the BSV port on the HMU.

The solenoid can be energized by applying an electrical current to either of two electrically isolated independent coils.

When the solenoid is de-energized, Pcr is supplied to the BSV. The BSV is open and all 20 nozzles are on.



BURNER STAGING VALVE SOLENOID

CTC-045-100-00

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FUEL FLOW TRANSMITTER

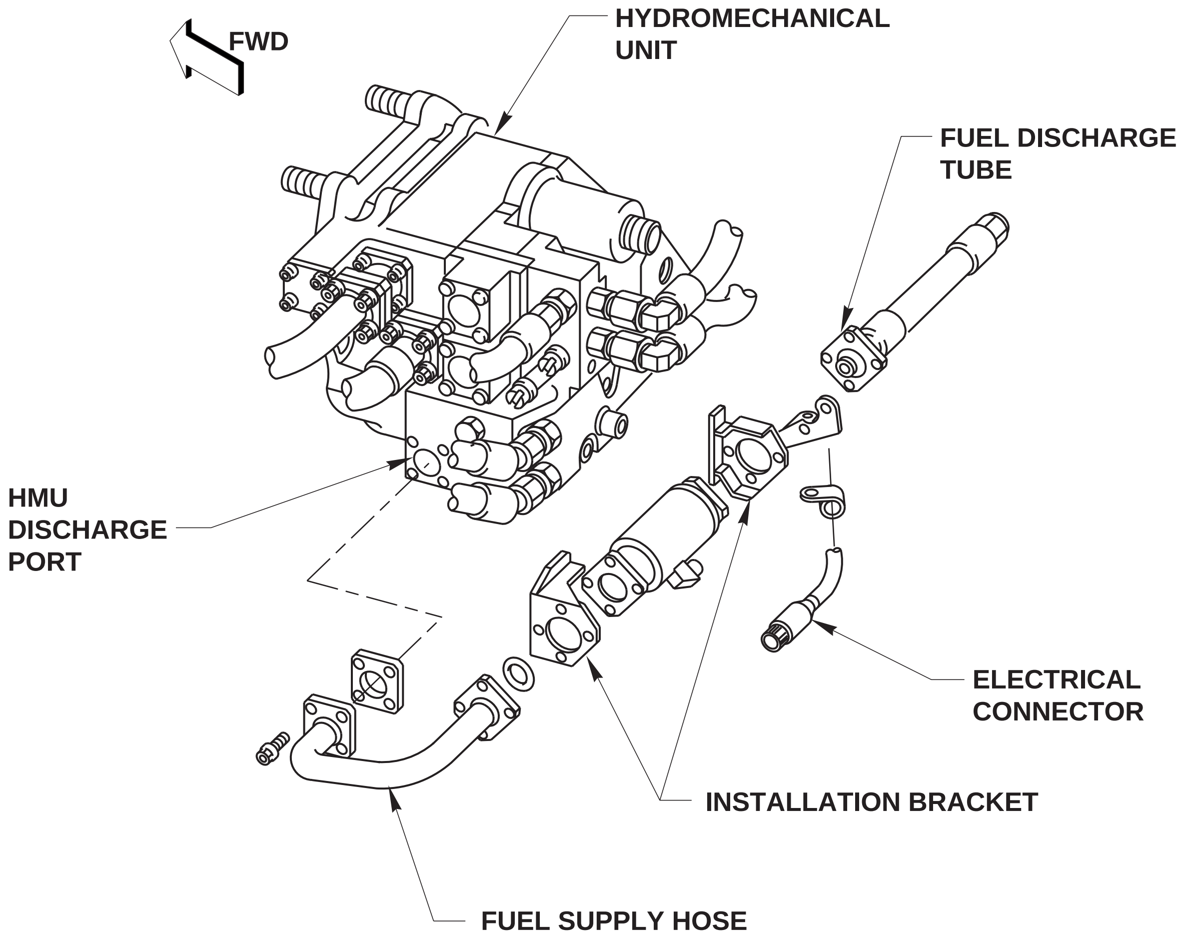
FUEL FLOW TRANSMITTER

The purpose of the fuel flow transmitter is to provide the ECU with information, for indicating purposes, on the weight of fuel used for combustion.

Located in the fuel flow path, between the HMU metered fuel discharge port and the fuel nozzle filter, it is installed on supporting brackets on the aft section of the HMU.

The interfaces are :

- a fuel supply hose, connected from the HMU.
- a fuel discharge tube, connected to the fuel nozzle filter.
- an electrical wiring harness, connected to the ECU.



CTC-045-101-00

FUEL FLOW TRANSMITTER

FUEL FLOW TRANSMITTER

The fuel flow transmitter consists of a housing containing a swirl generator, a free-spinning rotor and a turbine, which is restrained by a spring attached to the housing.

Two permanent magnets are fixed, 180 degrees apart, at the forward and aft end of the rotor.

With each complete revolution of the rotor, the forward end magnet induces an electrical pulse in a small coil mounted on the outer wall of the housing. This is known as the ‘start’ pulse.

The aft end magnet aligns with a signal blade fixed on the turbine. As the magnet passes the signal blade, another pulse is induced into a second, larger coil, which is also on the outer wall of the housing. This is known as the ‘stop’ pulse.

One ‘start’ pulse and one ‘stop’ pulse are generated through the coils at each revolution of the rotor.

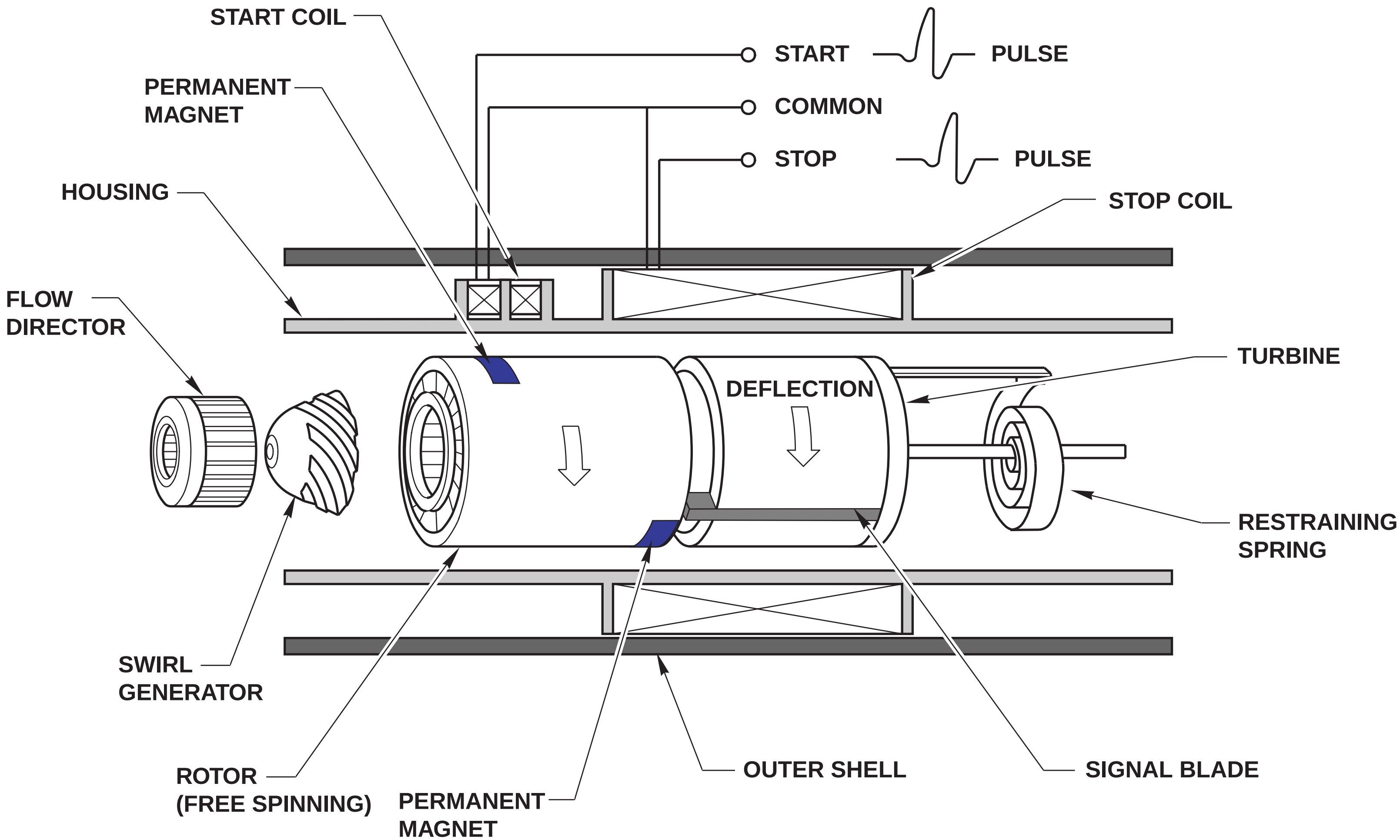
If the rotor could spin without fuel flow, the start and stop pulses would occur simultaneously.

When the fuel starts flowing, the rotor spins at a speed that is proportional to the fuel flow and the signal blade on the turbine, restrained by the spring, begins to deflect along the path of rotation.

The stop pulses now begin to occur after the start pulses.

As the mass flow (weight) of fuel through the transmitter increases, the turbine deflects further and further, and the time difference between the start and stop pulses increases proportionally.

It is this time difference which is measured by the ECU, and converted to Fuel Flow and Fuel Used values, which are then made available to the A/C for cockpit indication.



FUEL FLOW TRANSMITTER

CTC-045-102-00

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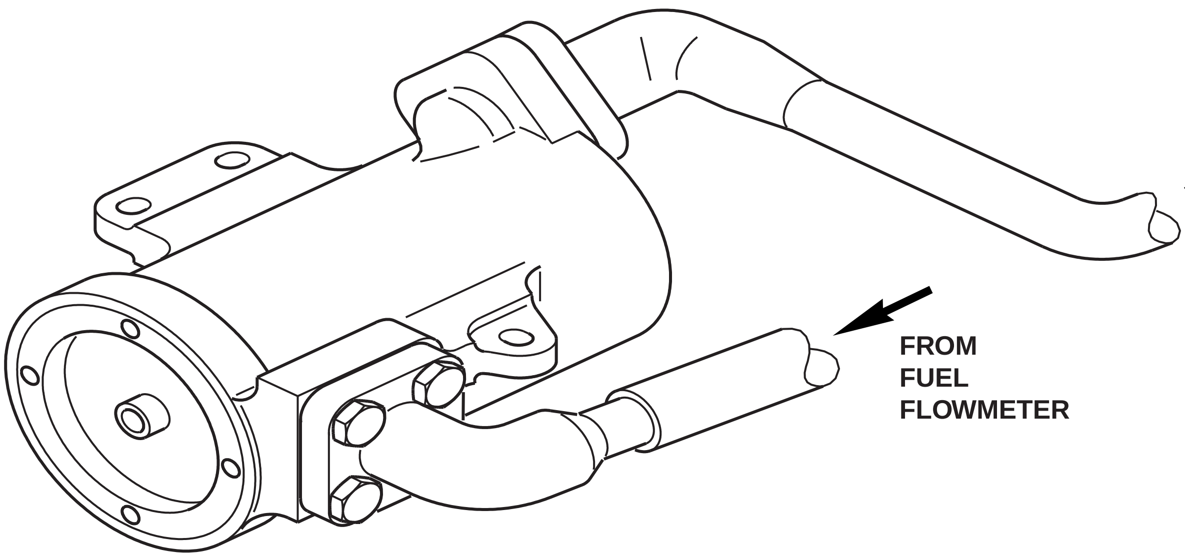
FUEL NOZZLE FILTER

FUEL NOZZLE FILTER

The fuel nozzle filter is installed near the servo fuel heater at 8 o'clock and attached to the fuel flow transmitter.

The fuel nozzle filter collects any contaminants that may still be left in the fuel before it goes to the fuel nozzle supply manifold.



CTC-045-103-00

FUEL NOZZLE FILTER

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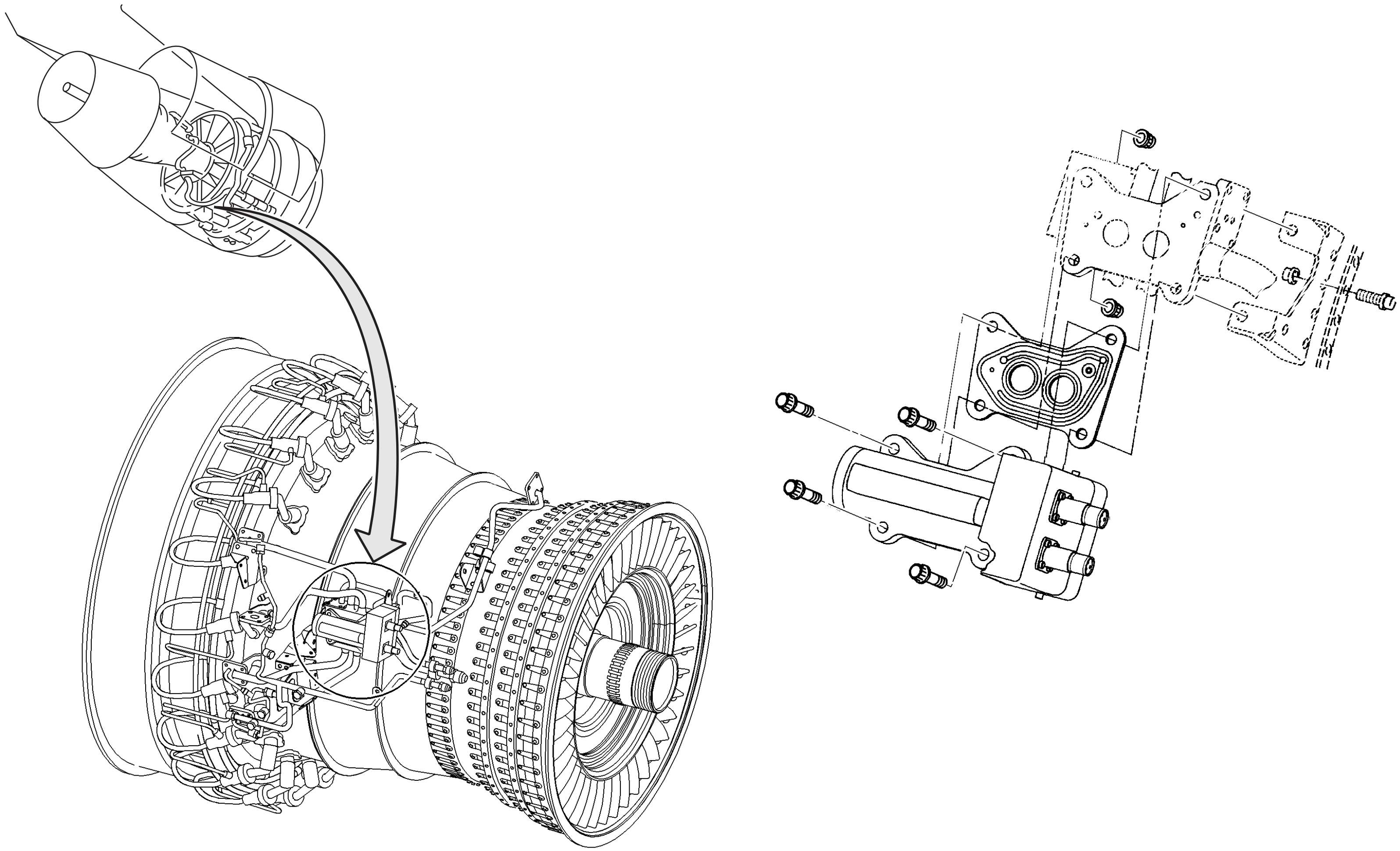
BURNER STAGING VALVE

BURNER STAGING VALVE

The purpose of the Burner Staging Valve (BSV) is to close the fuel supply to the staged manifold.

In this condition, only ten fuel nozzles are supplied with fuel.

The BSV is installed on a support bracket on the core engine at the 6 o'clock position.



CTC-045-104-00

BURNER STAGING VALVE

BURNER STAGING VALVE

The BSV is used in decel to keep the fuel flow above the lean flame-out limit.

To safely work close to this limit, the ECU cuts 10 of the 20 engine fuel nozzles.

The effect is that the same amount of fuel is provided in the combustion chamber, but on 10 fuel nozzles only. In this condition, the lean flame-out is well above the flame-out limit and it is impossible to extinguish combustion.

The diagram indicates the switch limits between 20 and 10 fuel nozzles.

Two fuel supply manifolds, staged and unstaged, are installed on the fuel supply system.

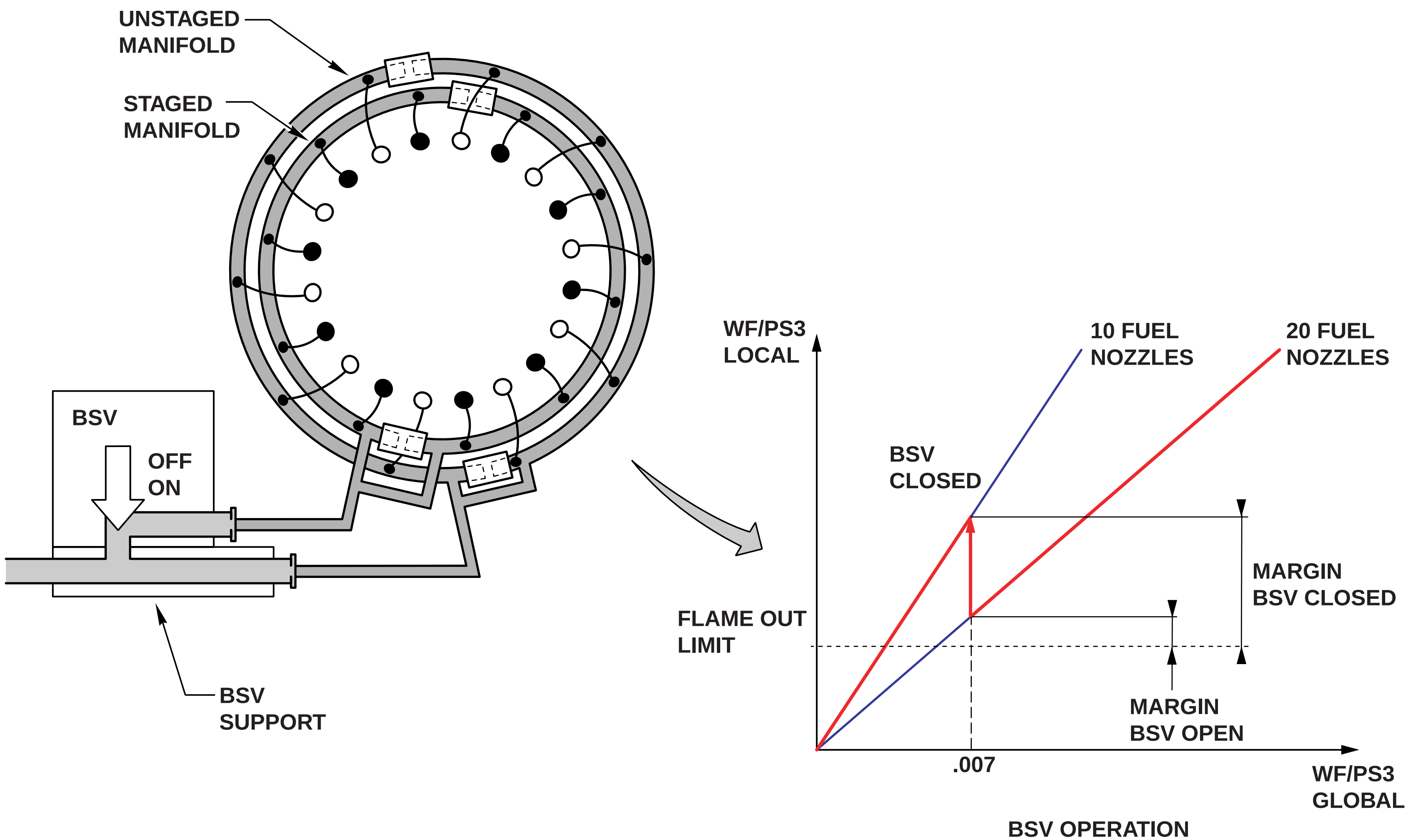
Within the BSV support, the metered fuel is split into two flows, which are then delivered to the nozzles, through the two manifolds.

The unstaged manifold always supplies 10 fuel nozzles, and the staged manifold supplies the 10 remaining fuel nozzles, depending on the BSV position.

At the outlet of the BSV, each fuel supply manifold is connected to a “Y” shaped supply tube at approximately the 5 and 6 o’clock positions.

Each supply manifold is made up of two halves, which are mechanically coupled, and include 5 provisions to connect the fuel nozzles.

To improve the rigidity in between the manifold halves, connecting nuts are installed at the 6 and 12 o’ clock positions.



BURNER STAGING VALVE PURPOSE

CTC-045-105-00

BURNER STAGING VALVE

The BSV is a normally open, fuel shut-off valve that is controlled by the ECU, and fuel operated by the HMU.

The valve shuts off every other fuel nozzle in certain engine operations, to provide a better spray pattern and improve the engine flame-out margin.

The valve has dual redundant signal switches, which are open when the valve is open.

All open ports terminate in the mounting surface of the valve body and when the valve is installed on the mounting bracket, the ports are automatically connected. No external hydraulic or pneumatic lines are required.

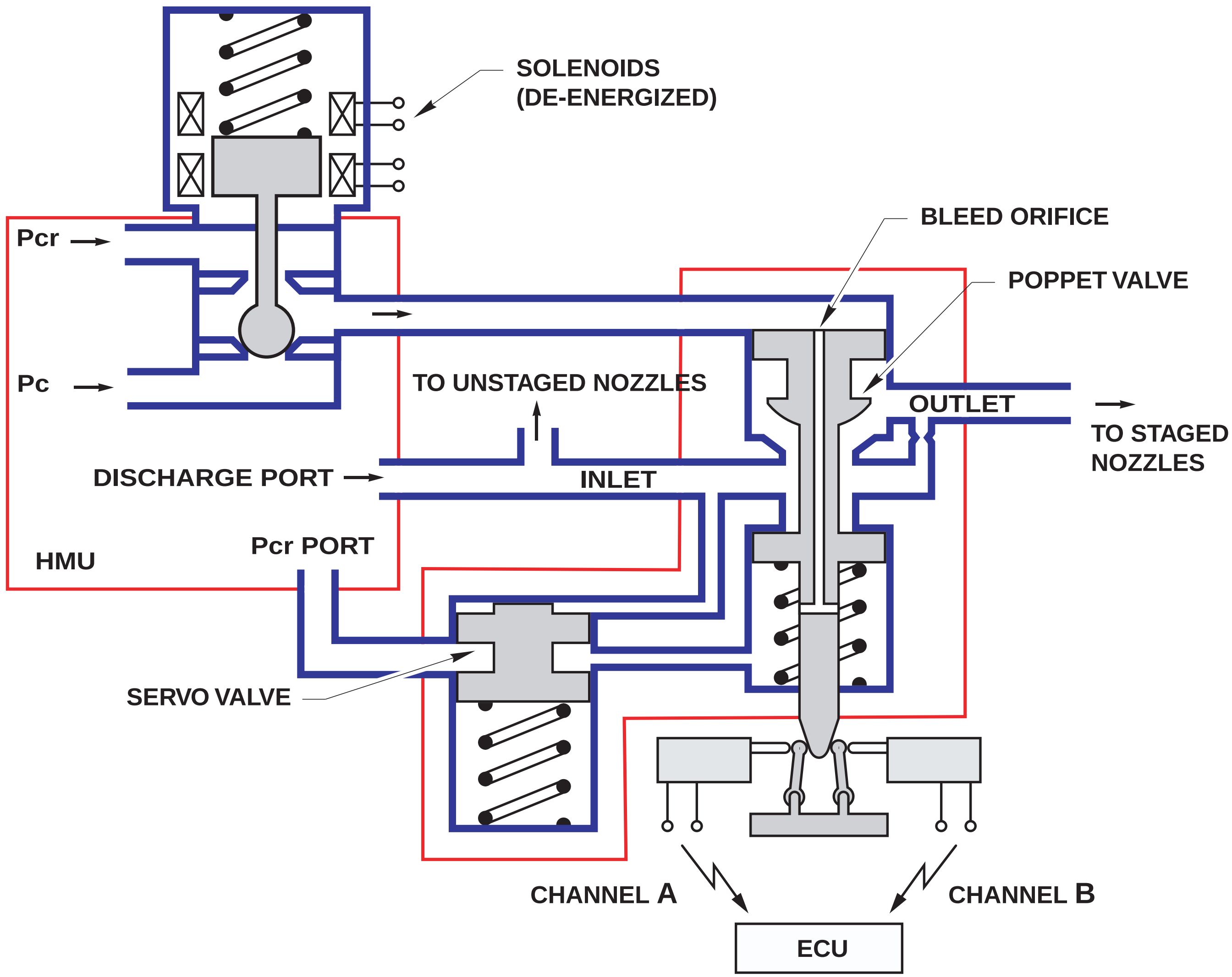
The valve encloses :

- a poppet valve, which allows metered fuel delivery to the staged manifold.
- a servo valve, to override and/or hold the poppet valve open.

Twenty fuel nozzle operation.

A three-way dual solenoid, located in the HMU, is de-energized and low fuel pressure (Pcr) is applied to both ends of the poppet valve.

A spring keeps the poppet valve in the BSV open, allowing fuel to flow from the inlet port to the outlet port.



20 FUEL NOZZLES OPERATION

CTC-045-106-00

BURNER STAGING VALVE

10 fuel nozzle operation.

To close the poppet valve, an electrical signal is applied to the dual solenoid valve in the HMU.

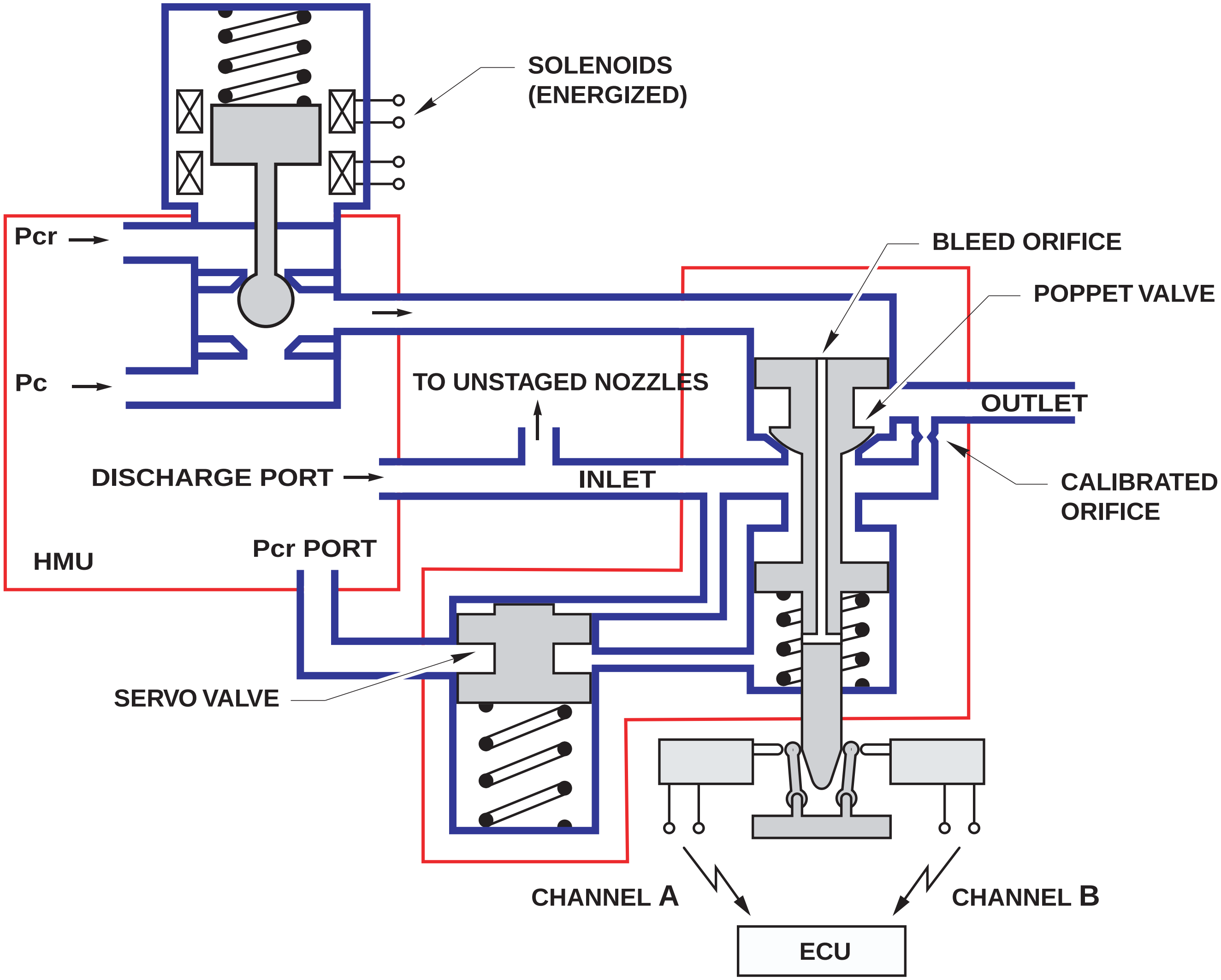
This allows high pressure fuel (Pc) to be directed to the top of the valve, to close the poppet.

In the closed position, the differential pressure moves the valve down.

A bleed orifice in the poppet keeps the pressure in the spring cavity at Pcr pressure.

There are two position switches located on the valve, one for ECU channel A and one for channel B. The switches click closed when the poppet valve is about to close.

A calibrated orifice allows a small amount of fuel to pass to the nozzles to avoid fuel nozzle tip coking.



CTC-045-107-00

10 FUEL NOZZLES OPERATION

BURNER STAGING VALVE

Failsafe Operation.

The BSV is equipped with a servo valve installed in parallel with the fuel supply inlet port.

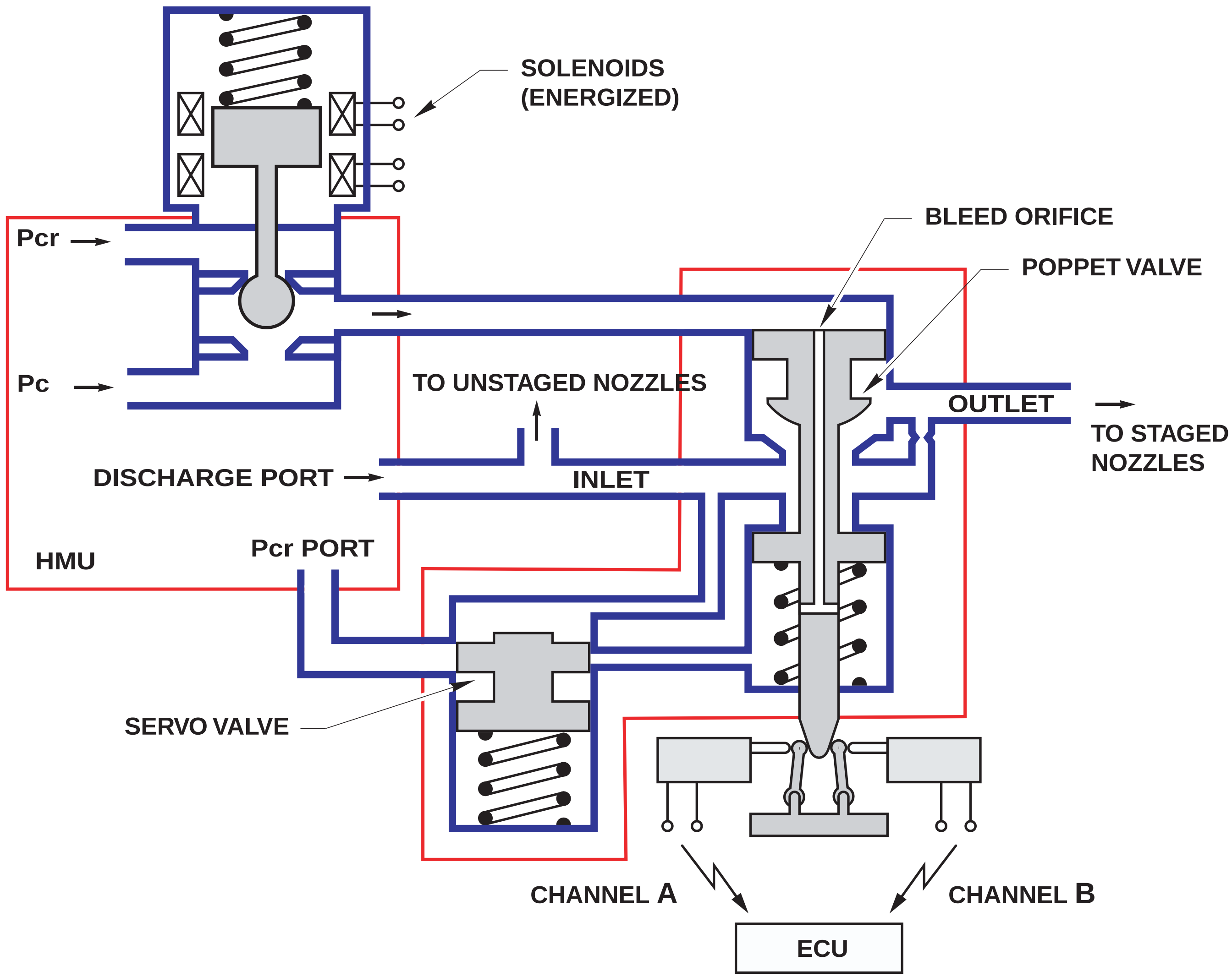
When the inlet pressure reaches 250 psi, the servo valve moves down, thus restricting and blocking the Pcr port.

The bleed orifice in the poppet enables the pressure to be balanced in the top and bottom cavities.

The poppet valve cavity is now ported to Pc fuel pressure, and the spring lifts the poppet valve.

Metered fuel passes through the valve and is delivered to the fuel nozzles.

The two position switches click open just as the poppet valve begins to open.



FAILSAFE OPERATION

CTC-045-108-00

Burner staging valve control.

The control laws logic in the ECU calculates the BSV position demand.

The process has four parts :

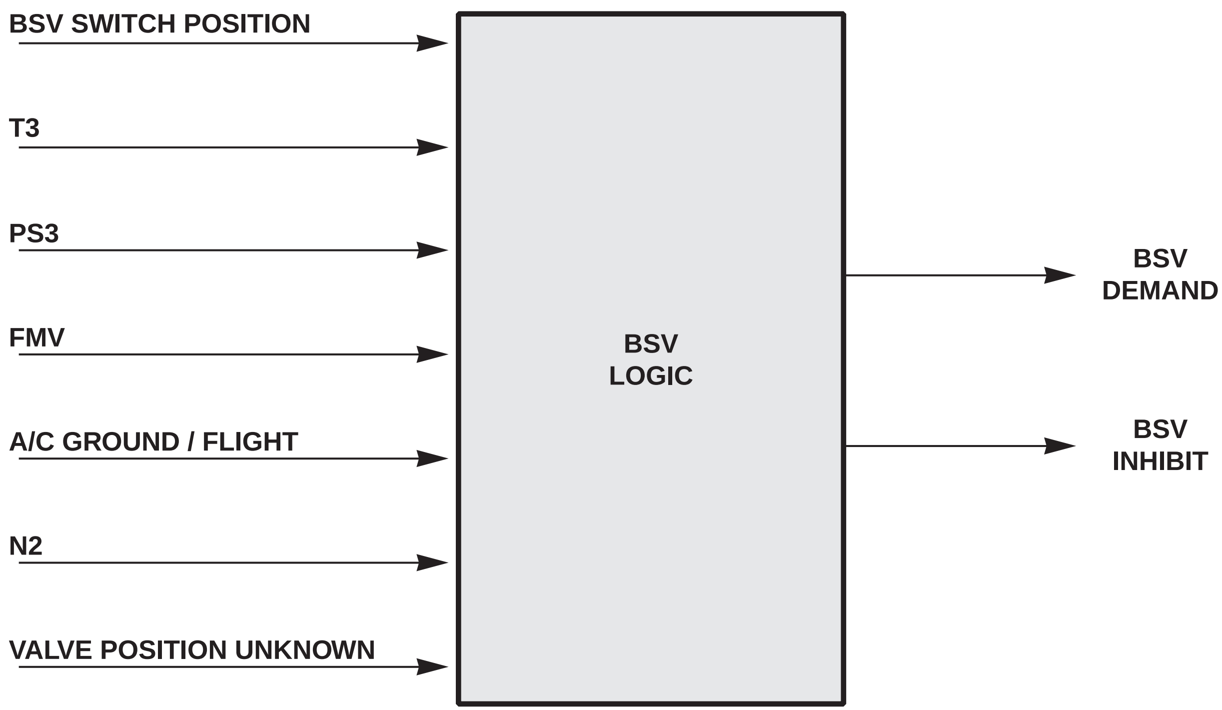
- BSV status.
- Fuel/air ratio calculations.
- BSV inhibition logic.
- BSV position demand logic.

The BSV status is provided through the two position switches, located on the valve itself.

The fuel/air ratio calculation uses PS3 and T3 parameters.

The BSV inhibition logic uses different parameters: Engine speed N2, valve position unknown, A/C flight/ground position.

The BSV position demand logic uses the Fuel Metering Valve (FMV) position feedback signal.



BURNER STAGING VALVE CONTROL

CTC-045-109-00

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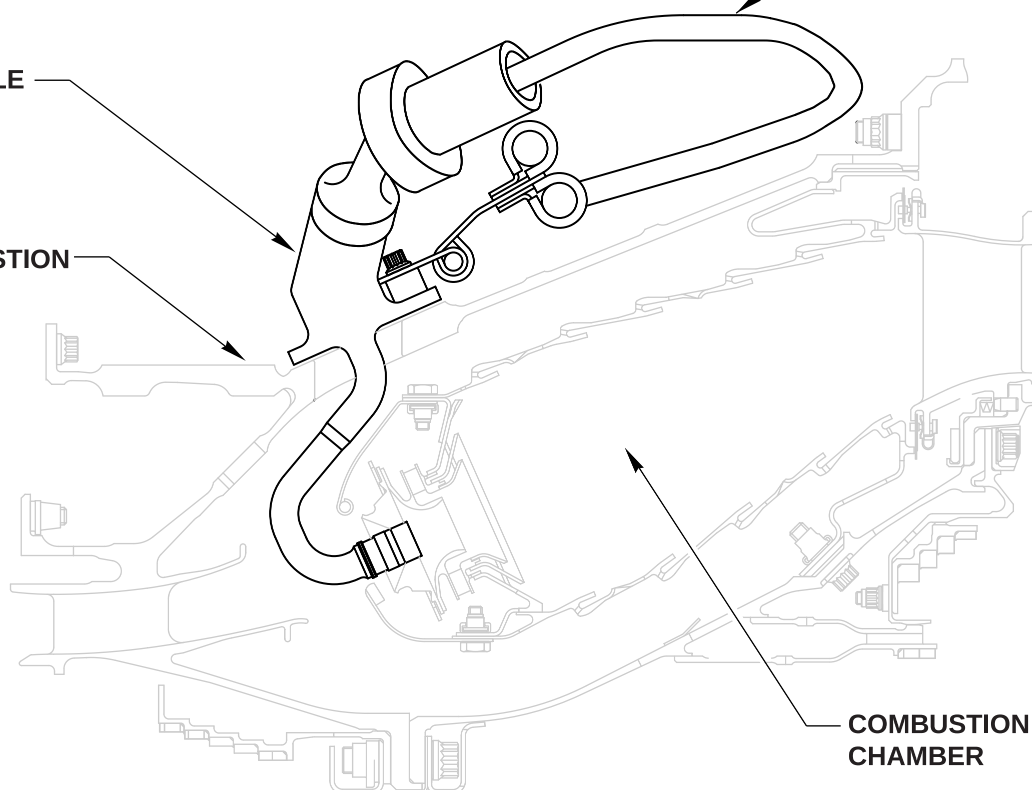
FUEL NOZZLE

FUEL NOZZLE

The fuel nozzles spray fuel into the combustion chamber and ensure good light-off capability and efficient burning at all engine power settings.

There are twenty fuel nozzles, which are installed all around the combustion case area, in the forward section.



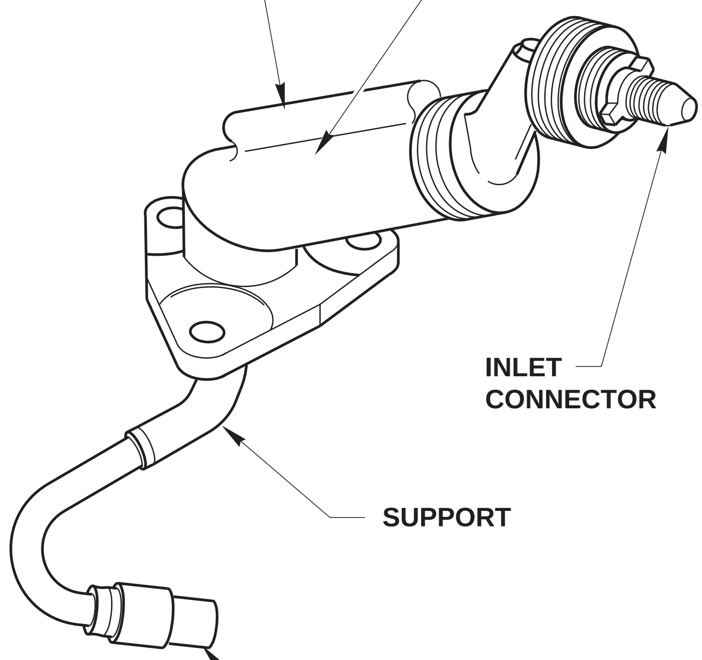
CTC-045-110-00

FUEL NOZZLE

FUEL NOZZLE

The fuel nozzle is a welded assembly which delivers fuel through two independent flows, and consists of :

- a cover, where the nozzle fuel inlet connector is located.
- a cartridge assembly, which encloses a check valve and a metering valve.
- a support, used to secure the fuel nozzle onto the combustion case.
- a metering set, to calibrate primary and secondary fuel flow sprays.



CTC-045-111-00

FUEL NOZZLE DESIGN

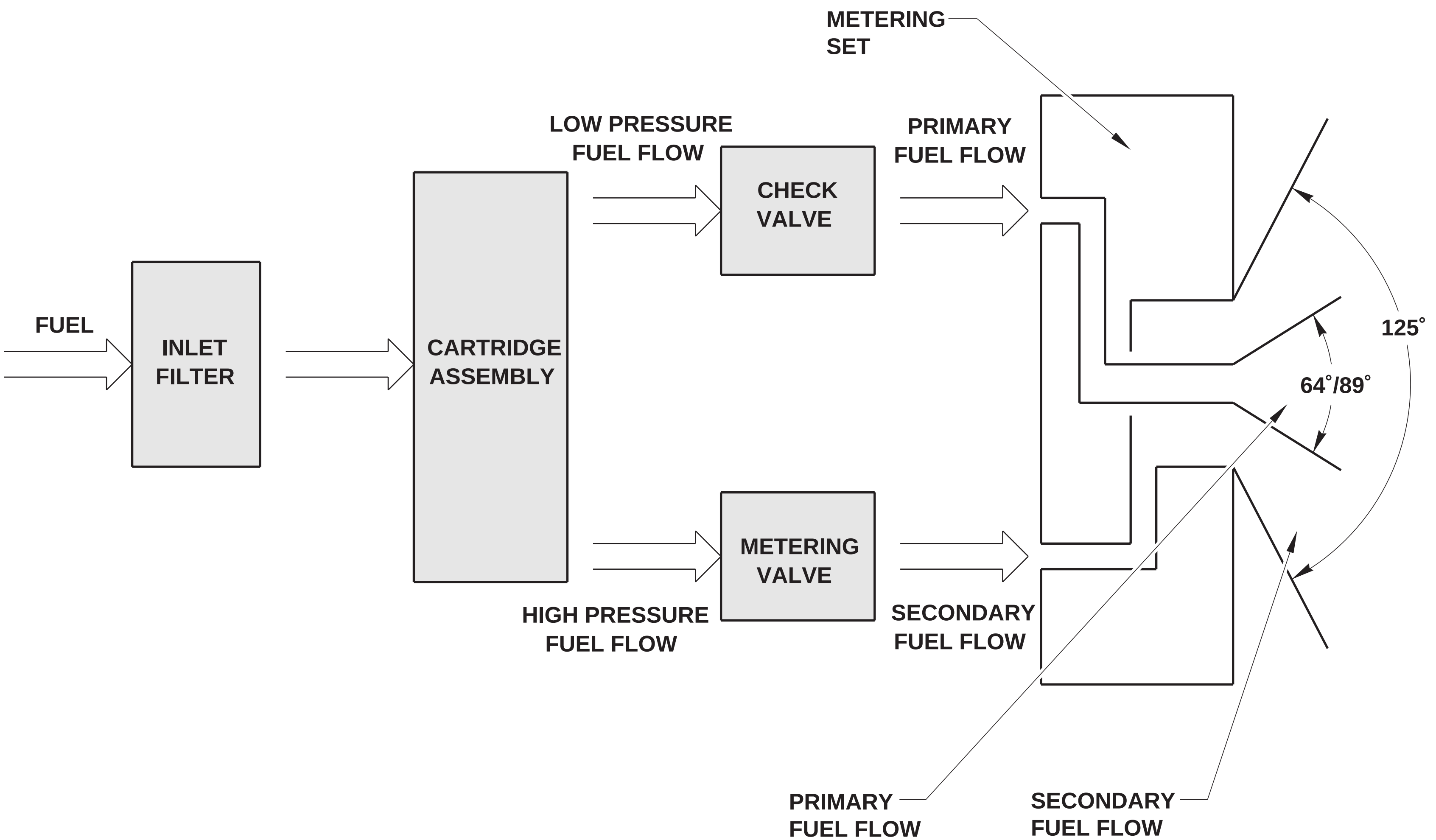
FUEL NOZZLE

From the nozzle inlet, fuel passes through the inlet filter and accumulates within the cartridge assembly.

At 15 psig, the fuel opens the check valve. It is sent to the central area of the metering set which calibrates the spray pattern of the primary fuel flow (narrow angle).

When the fuel pressure reaches 120 psig, it opens the flow divider metering valve and the fuel goes through the outer tube of the support to another port in the metering set.

This port calibrates the spray pattern of the secondary fuel flow (wider angle of 125 °).



CTC-045-112-00

FUEL NOZZLE OPERATION

FUEL NOZZLE

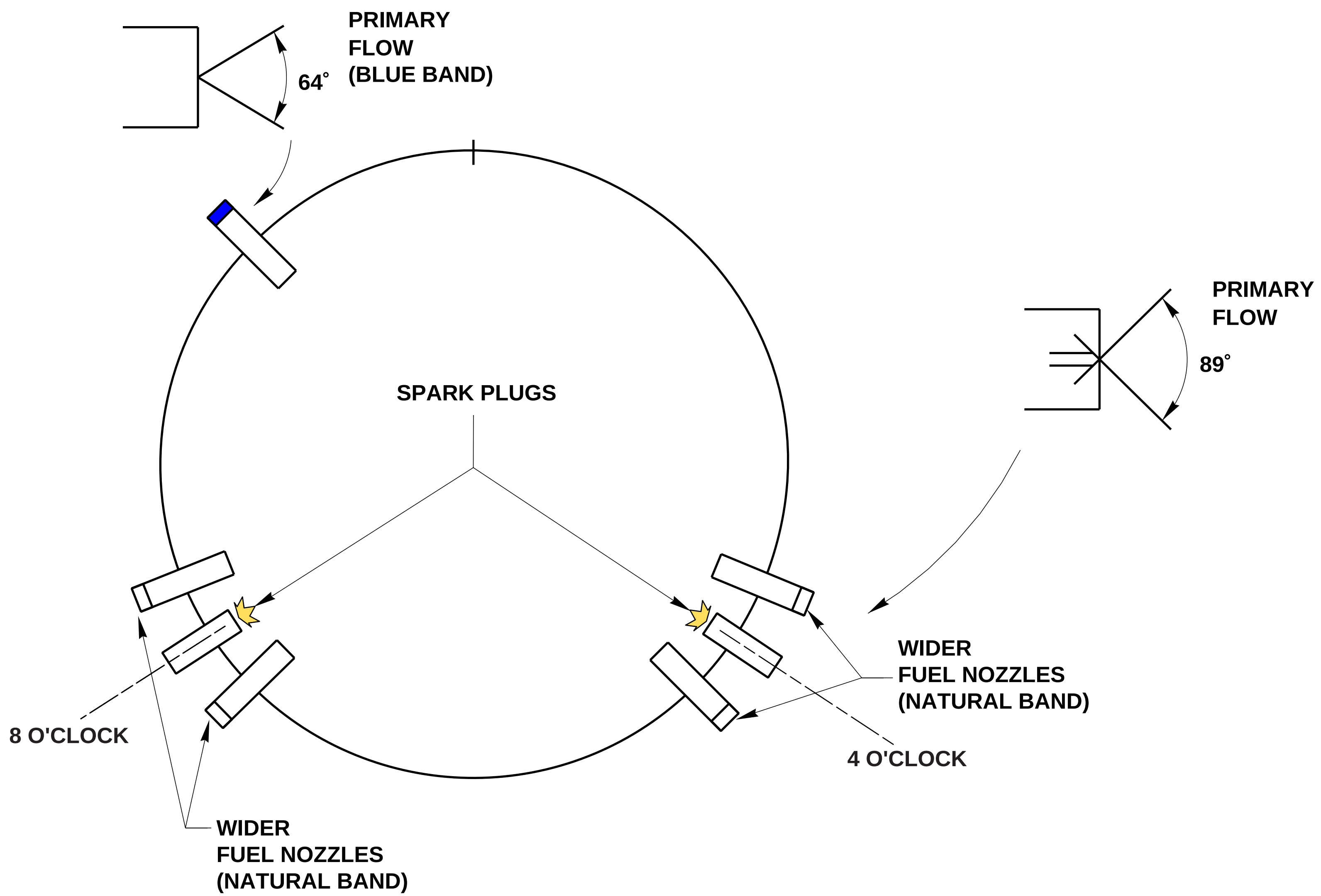
Basically, all fuel nozzle models are similar, provide the same operational performances, and are mounted and connected to the engine in an identical manner.

However, four nozzles located in the pilot burning area in the combustion chamber, on either side of the spark plugs, have a wider primary spray angle.

The wider spray angle is incorporated to improve altitude re-light capability.

To facilitate identification of the nozzle type, a colour band is installed on the nozzle body. The colours are also engraved on the band.

- Blue colour band on the 16 regular fuel nozzles.
- Natural colour band on the 4 wider spray fuel nozzles.



CTC-045-113-00

FUEL NOZZLE IDENTIFICATION

FUEL NOZZLE

Some makes of fuel nozzle have a removeable inlet strainer, which is secured onto the inlet cover with a retaining ring.

Fuel passes through the strainer, enters the main body and reaches a spring-loaded check valve.

When the fuel pressure reaches 15 psig, the spring is compressed and the valve moves down.

Fuel is ported from the inner tube of the support to the primary body of the metering set.

Fuel then passes around the primary plug, and flows in between the plug and the convergent end of the primary body.

Fuel is then delivered, through a calibrated orifice, into the combustion chamber, at a set angle of 64° for regular nozzles, and 89° for wider spray nozzles.

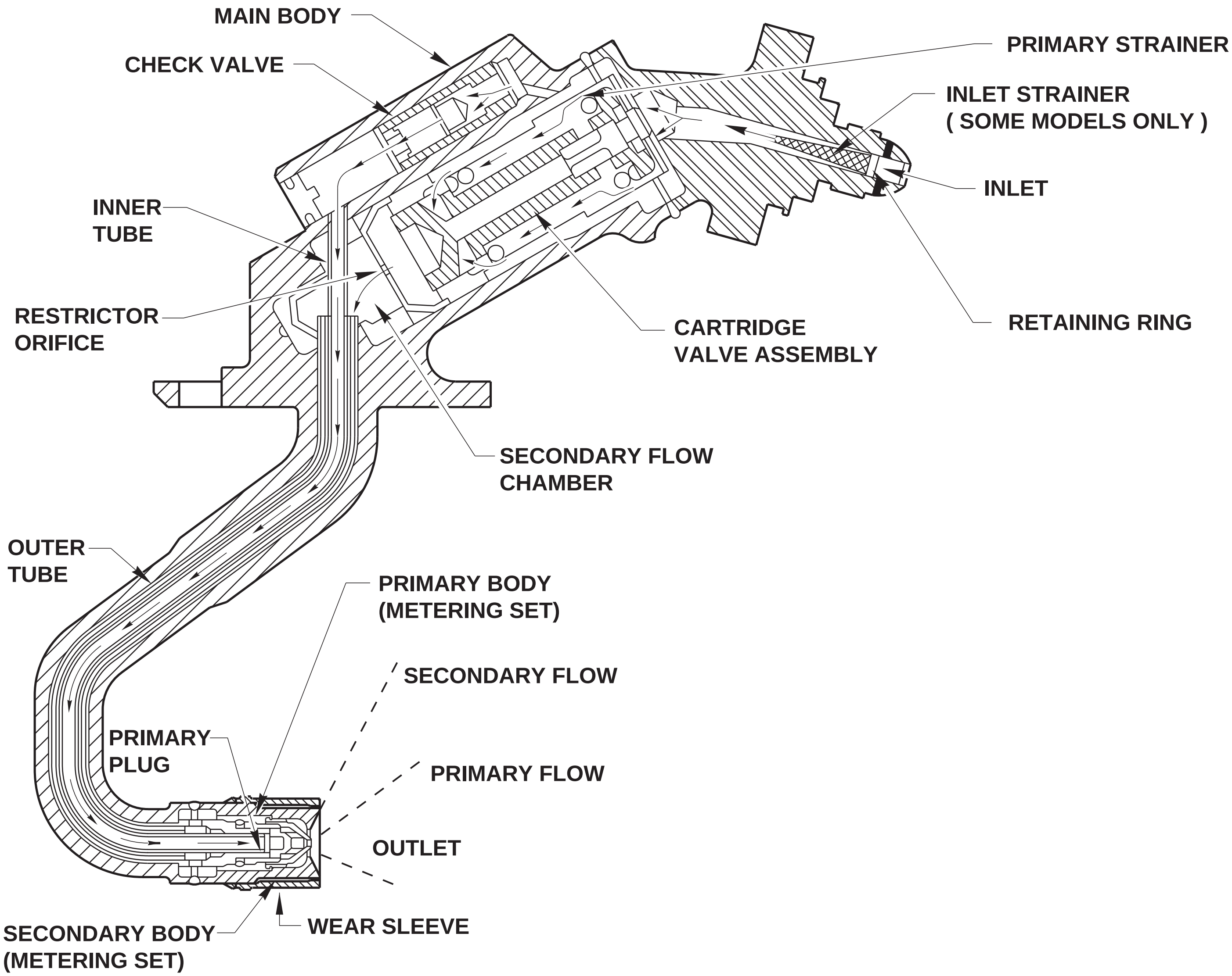
When the fuel pressure is higher than 120 psig, the main spring is compressed, and the cartridge valve assembly moves down.

Fuel still passes through the primary path, and through the restricted orifice, where it enters the secondary flow chamber.

It then goes into the outer tube of the support to the secondary body of the metering set.

It passes around, and in between, the primary body and the secondary body.

Fuel is then delivered, through a Venturi type orifice, into the combustion chamber at an angle of 125°.



FUEL NOZZLE

CTC-045-114-00

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IDG OIL COOLER

IDG OIL COOLER

The Integrated Drive Generator (IDG) oil cooler uses the HMU by-pass fuel flow to cool down the oil used in the IDG mechanical area.

It is installed horizontally on the fan case at the 5.30 clock position, in front of the AGB.

The interfaces are :
- The fuel supply and return lines.
- The oil supply and return lines.

There are two different flows within the unit, the fuel flow, and the oil flow.

The fuel flows inside a tube bundle and the oil circulates around the tube bundle to transfer heat to the fuel.

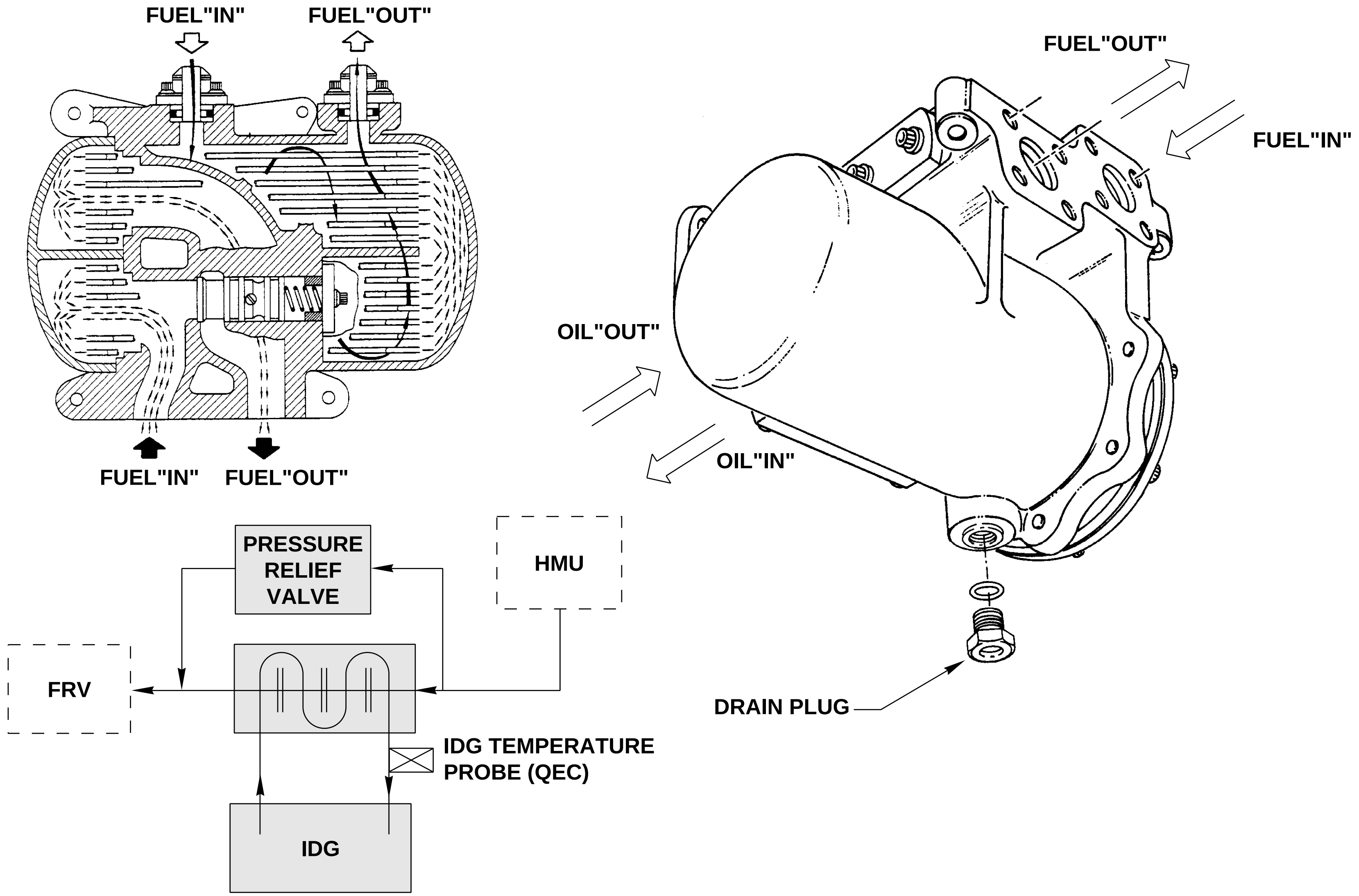
After the heat exchange, the fuel returns to the inlet of the main oil/fuel heat exchanger, and the oil goes back to the IDG.

The oil cooler is of tubular type, and consists of a removable core, a housing and a cover.

-The core consists of a cylinder, containing fuel tubes attached to end plates. It includes baffles which provide oil and fuel circulation paths.

- The housing features one ‘fuel in’ and one ‘fuel out’ port, and a pressure relief valve connected in parallel with the fuel inlet and outlet ports, to bypass the fuel directly toward the heat exchanger if the differential pressure reaches 20.3 psi.

- The cover features one ‘oil in’ and one ‘oil out’ port, and a plug to drain the IDG oil cooler before any maintenance operation.



IDG OIL COOLER

CTC-045-115-00

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FUEL RETURN VALVE

FUEL RETURN VALVE

The oil/fuel temperature exchange within the IDG oil cooler increases the temperature of the HMU by-passed flow.

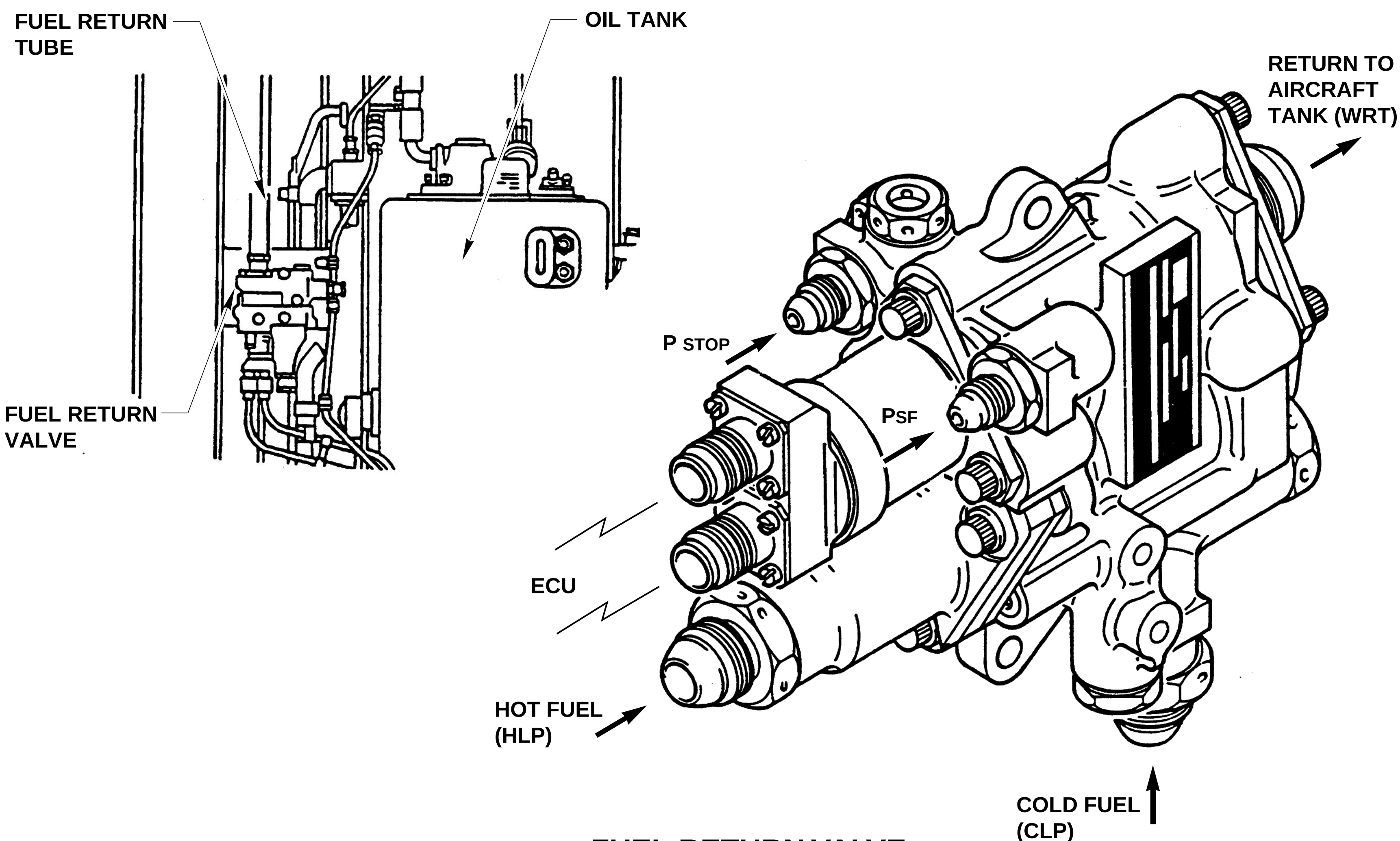
This, in turn, reduces the efficiency of the main oil/fuel heat exchanger .

To prevent an excessive oil temperature increase, the Fuel Return Valve (FRV) opens and returns part of the high temperature fuel to the A/C tanks for recirculation.

The FRV is mounted on a bracket on the left hand side of the fan inlet case, at the 8.30 clock position, next to the oil tank.

The interfaces are:

- The fuel return line to the A/C (WRT).
- The shut-off signal tube (PSTOP).
- The fuel pump HP tube (PSF).
- The fuel pump LP tube (cold fuel) (CLP).
- The IDG oil cooler inlet tube (hot fuel) (HLP).
- Two electrical connectors linked to the ECU.



FUEL RETURN VALVE

CTC-045-116-00

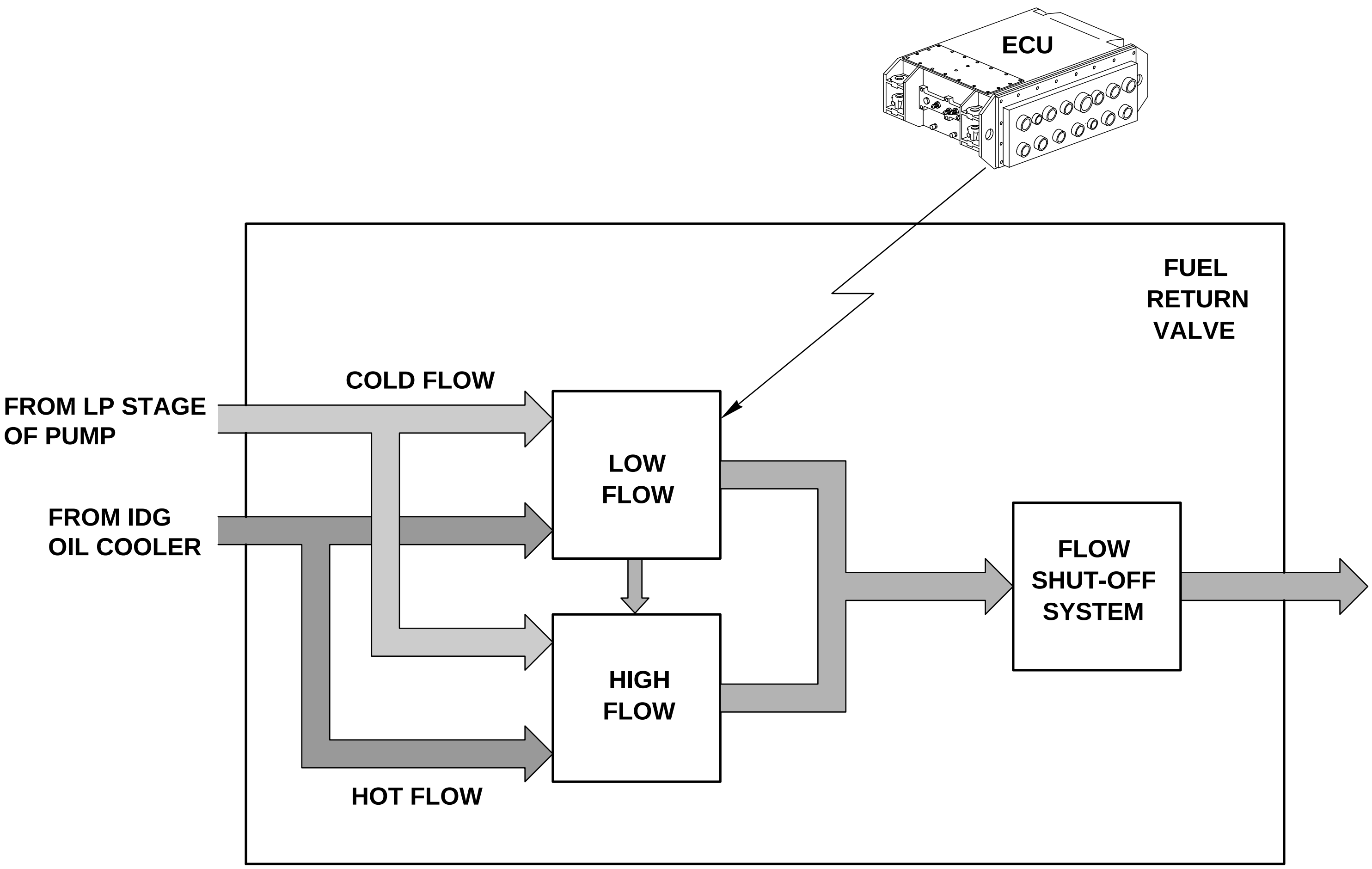
FUEL RETURN VALVE

Inside the FRV, cold fuel from the fuel pump LP stage outlet is mixed with the warm fuel returning from the IDG oil cooler. This is to limit the temperature of the fuel going back to the A/C tank.

A shut-off system is provided to isolate the engine fuel circuit from the A/C fuel tank return circuit.

The FRV is fuel operated and electrically controlled through the ECU control logic.

The control logic of the FRV is dependent on the engine oil temperature.



CTC-045-117-00

FUEL RETURN VALVE PRINCIPLE

FUEL RETURN VALVE

The ECU receives oil temperature indication from a thermocouple in the forward sump line.

When the oil temperature reaches 88°C, the ECU energizes FRV solenoid valve V1. This allows a high pressure signal from the HMU (Psf) to hold the piston of the fuel return shut-off valve open.

Hot fuel from the IDG oil cooler and cold fuel from the LP stage of the fuel pump are mixed within the FRV to keep the return fuel temperature below 100°C.

A control valve, featuring a constant section restrictor and a delta P regulator, keeps the flow level constant.

If the IDG fuel temperature does not exceed 131°C, thermostatic valve V2 will allow a LOW return flow of 1100 pph (500 kg/h).

The FRV will stop returning fuel when the oil temperature goes back down to 78°C.

If the IDG fuel temperature exceeds 131°C, thermostatic valve V2 will progressively open more, to finally allow a HIGH return flow of 2200 pph (1000 kg/h) when the fuel temperature reaches 140°C.

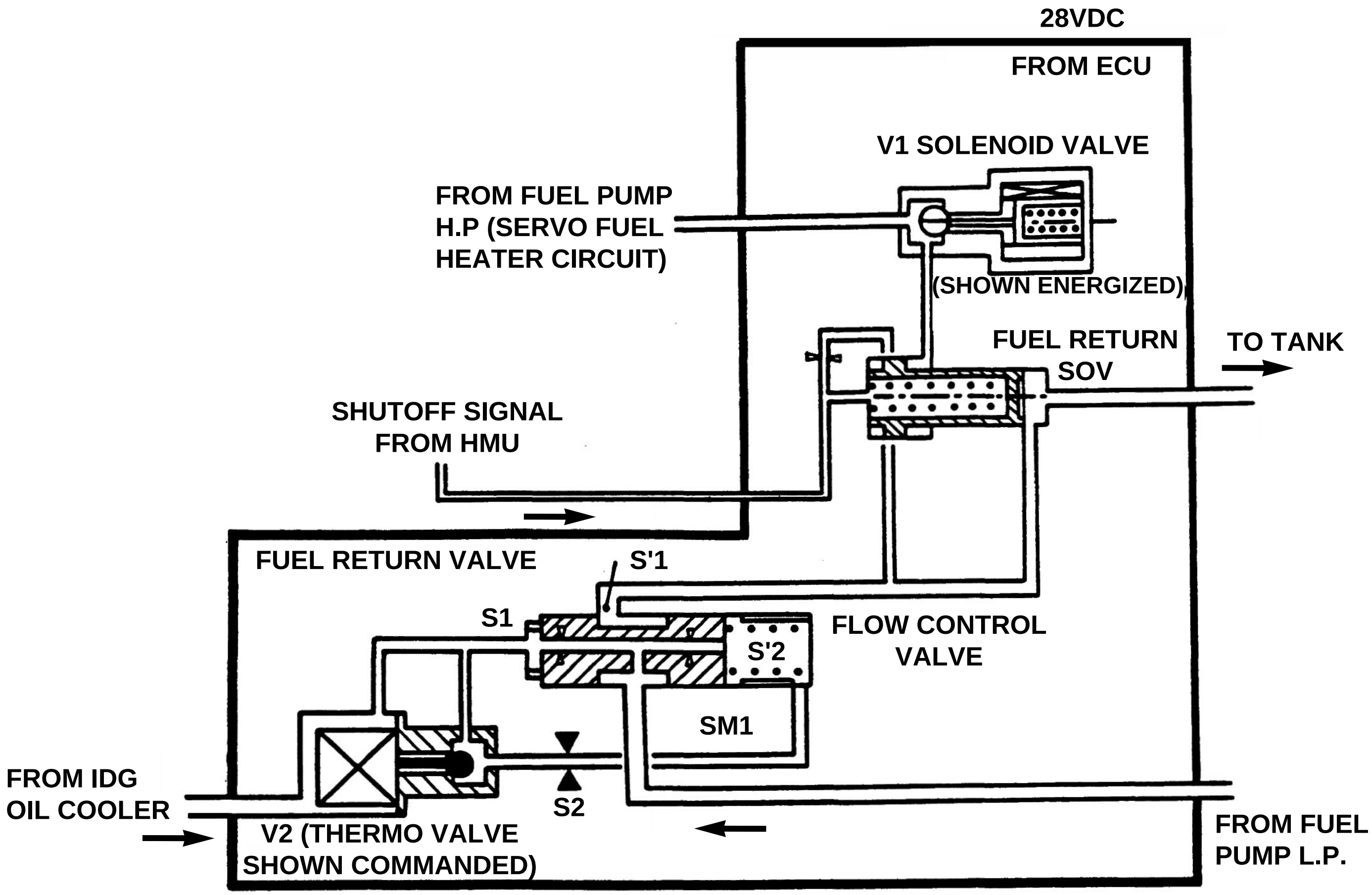
Again, the FRV will stop returning fuel when the oil temperature goes back down to 78°C.

The FRV has a dual shut-off function:

- From the HMU shut-off valve, at engine shut down.
- From the ENG/MASTER control switch in the cockpit which overrides the ECU.

At engine shut down, the Psf signal from the HMU plus the counteracting spring load push the piston of the shut-off valve closed.

During engine operation, an A/C digital signal can override the normal ECU command to inhibit FRV opening (fuel temperature high and fuel tank full).



CTC-045-118-00

FUEL RETURN VALVE OPERATION

Modulated idle.

The High return fuel flow may, in some cases, not be enough to cool down the engine oil temperature.

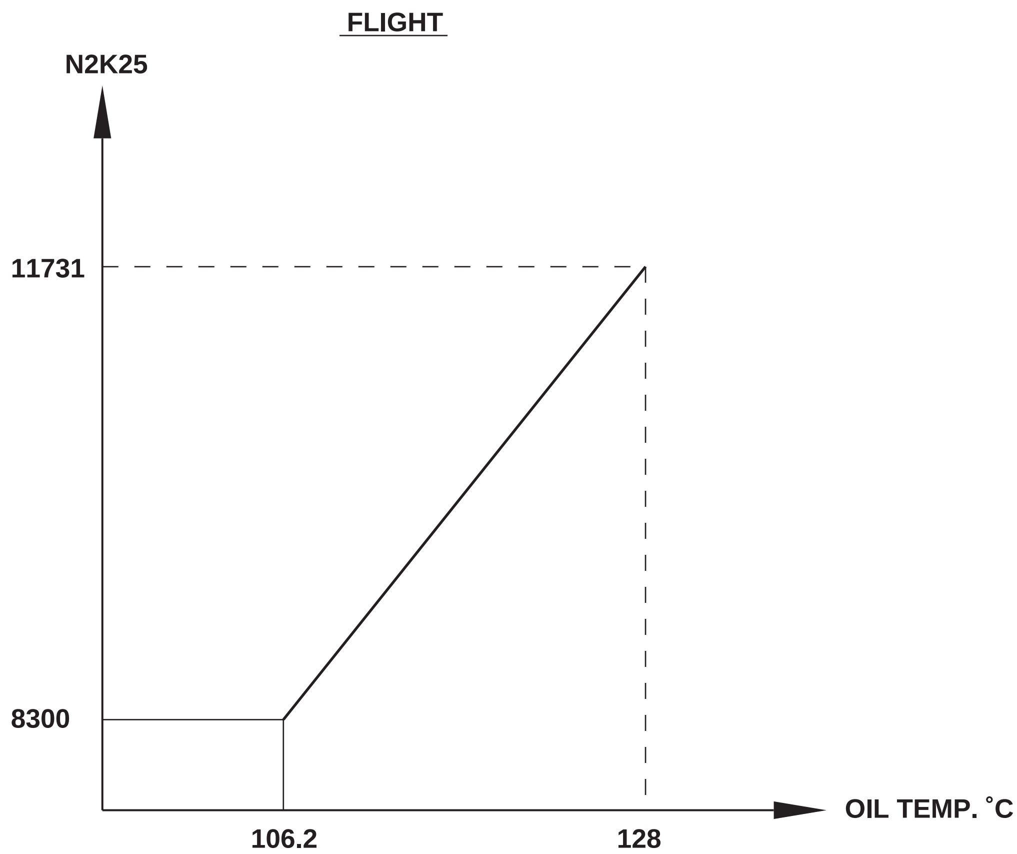
Therefore, the engine minimum idle speed may be increased to create a higher fuel flow, resulting in more effective oil cooling in the main oil/fuel heat exchanger.

The modulated idle operation depends upon the oil temperature and the A/C ground or flight condition.

On ground, no IDG modulated idle is required.

In flight, the modulated idle operation is set when the oil temperature reaches 223°F (106.2°C).

N2 speed then accelerates, according to a linear schedule, up to a maximum of 11731 rpm, which corresponds to an oil temperature of 262°F (128°C).



CTC-045-119-00

IDG OIL COOLING SYSTEM MODULATED IDLE

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VARIABLE GEOMETRY CONTROL SYSTEM

VARIABLE GEOMETRY CONTROL SYSTEM

The variable geometry control system is designed to maintain satisfactory compressor performance over a wide range of operation conditions.

The system consists of :

- a Variable Bleed Valve (VBV) system, located downstream from the booster.
- a Variable Stator Vane (VSV) system, located within the first stages of the HPC.

The compressor control system is commanded by the ECU and operated through HMU hydraulic signals.

At low speed, the LP compressor supplies a flow of air greater than the HP compressor can accept.

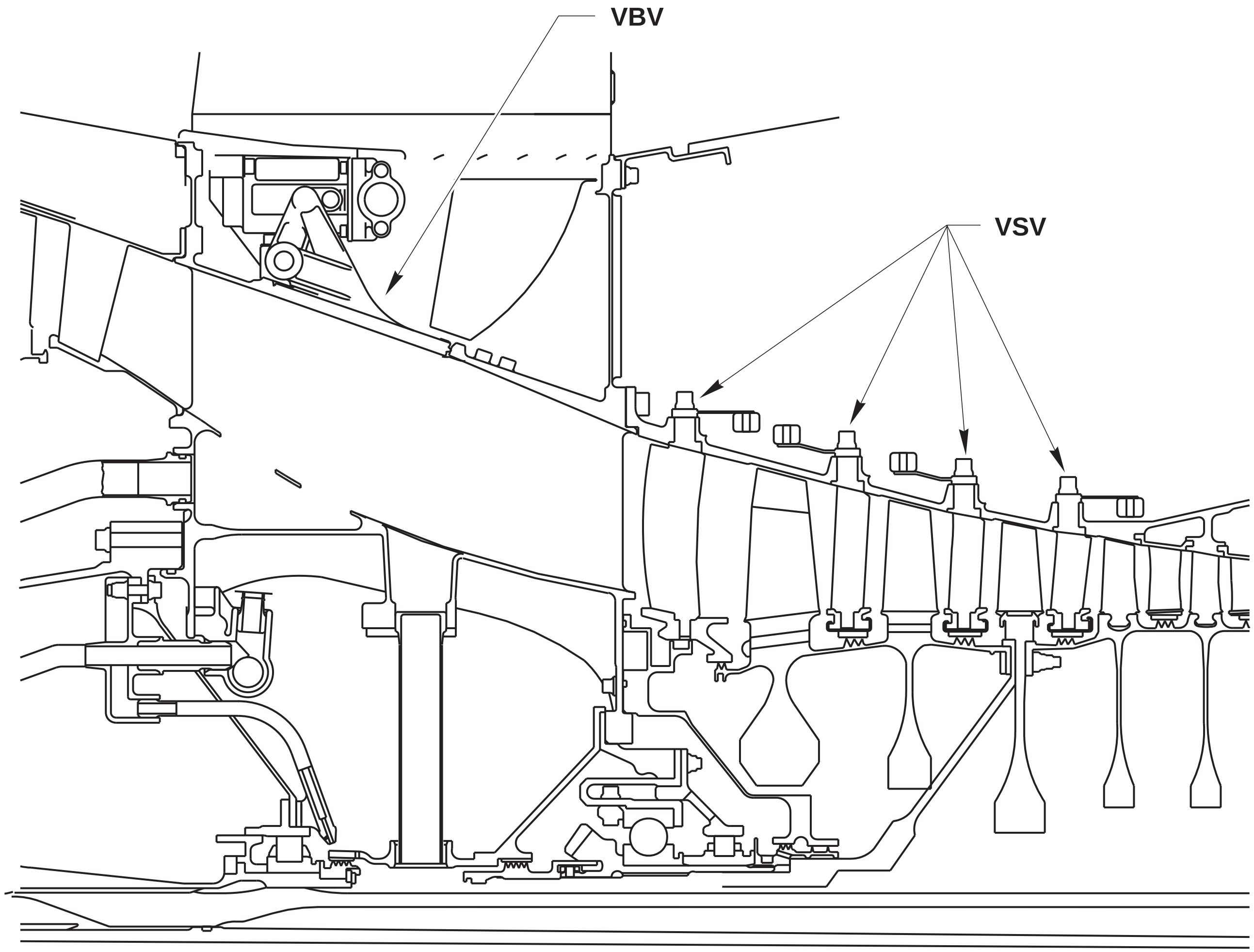
To establish a more suitable air flow, VBV's are installed on the contour of the primary airflow stream, between the booster and the HPC.

At low speed, they are fully open and reject part of the booster discharge air into the secondary airflow, preventing the LPC from stalling.

At high speed, the VBV's are closed.

The HPC is equipped with one Inlet Guide Vane (IGV) stage and three VSV stages.

An actuation system changes the orientation of the vanes to provide the correct angle of incidence to the air stream at the blades leading edge, improving HPC stall margins.



COMPRESSOR CONTROL DESIGN

CTC-045-120-00

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VARIABLE BLEED VALVE

VARIABLE BLEED VALVE

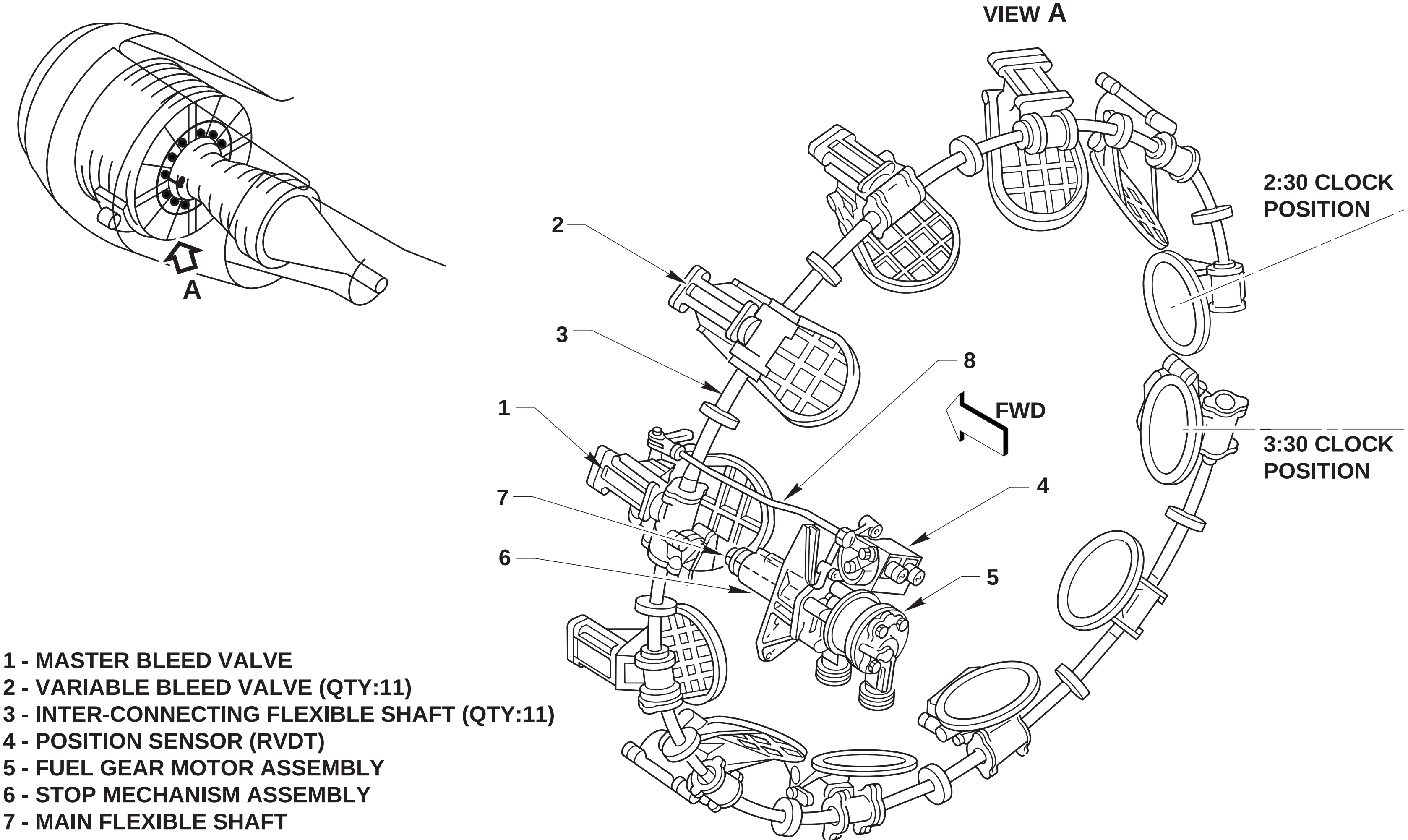
The purpose of the Variable Bleed Valve (VBV) system is to regulate the amount of air discharged from the booster into the inlet of the HPC.

To eliminate the risk of booster stall during low power conditions, the VBV system by-passes air from the primary airflow into the secondary.

It is located within the fan frame mid-box structure and consists of:

- a fuel gear motor.
- a stop mechanism.
- a master bleed valve.
- eleven variable bleed valves.
- flexible shafts.
- a feedback sensor (RVDT).

The ECU calculates the VBV position and the HMU provides the necessary fuel pressure to drive a fuel gear motor, through a dedicated servo valve.



1 - MASTER BLEED VALVE
2 - VARIABLE BLEED VALVE (QTY:11)
3 - INTER-CONNECTING FLEXIBLE SHAFT (QTY:11)
4 - POSITION SENSOR (RVDT)
5 - FUEL GEAR MOTOR ASSEMBLY
6 - STOP MECHANISM ASSEMBLY
7 - MAIN FLEXIBLE SHAFT
8 - FEEDBACK ROD

CTC-045-121-00

VBV SYSTEM

VARIABLE BLEED VALVE

Using engine parameters, the ECU calculates the VBV position, according to internal control laws.

An electrical signal is sent to the HMU torque motor to position a servo valve, which adjusts the fuel pressure necessary to drive a gear motor.

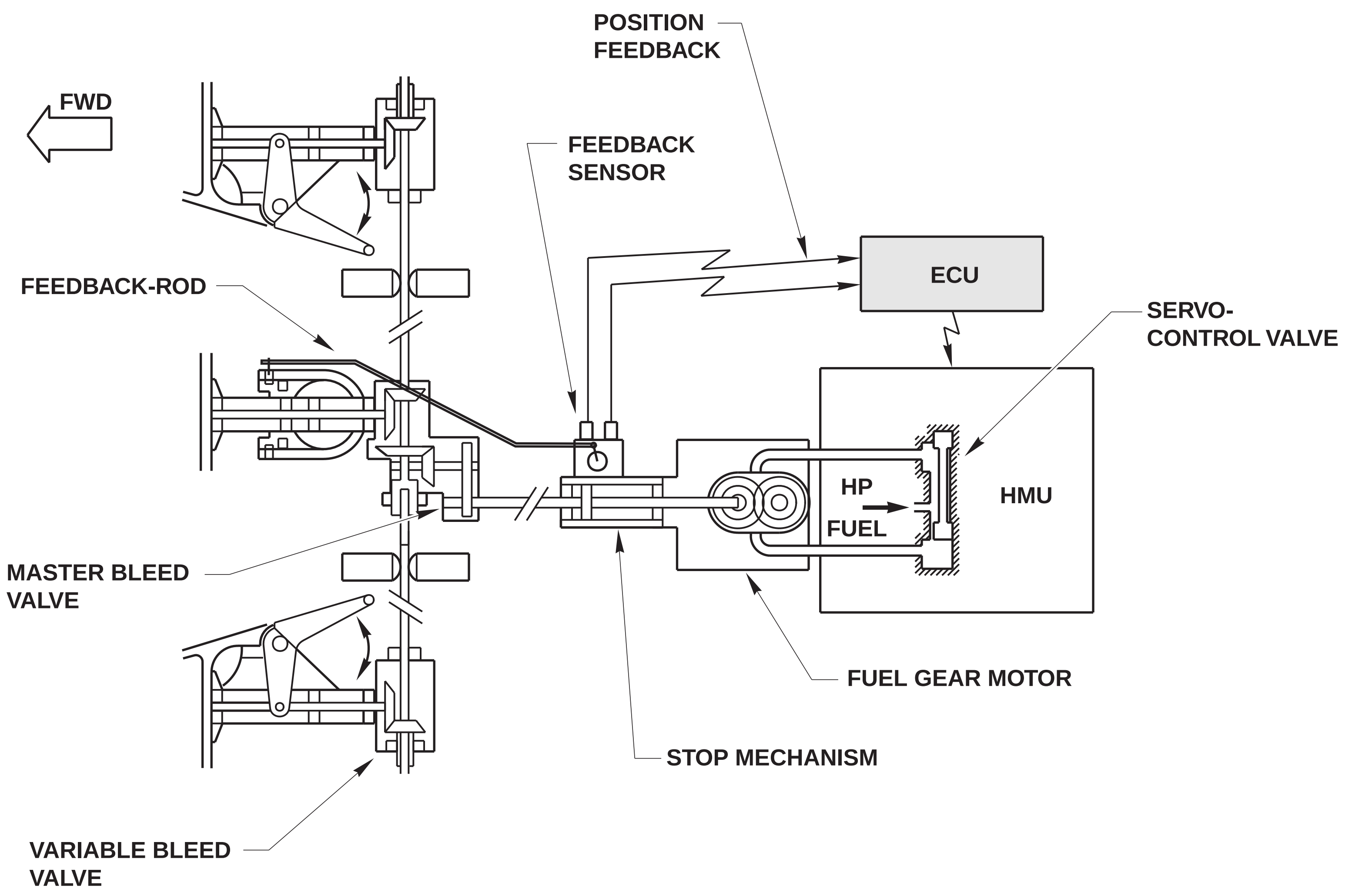
The gear motor transforms the fuel pressure into rotary torque to actuate a master bleed valve.

A stop mechanism mechanically limits the opening and closing of the master bleed valve.

The master bleed valve drives the 11 variable bleed valves, through a series of flexible shafts.

The flexible shafts ensure that the VBV's remain fully synchronized throughout their complete stroke.

A feedback rod is attached between the master bleed valve and a feedback transducer, which transforms the angular position of the master bleed valve into an electrical signal for the ECU.



CTC-045-122-00

VARIABLE BLEED VALVE SYSTEM OPERATION

Fuel gear motor.

The fuel gear motor transforms high pressure fuel flow into rotary driving power to position the master bleed valve, through a screw in the stop mechanism.

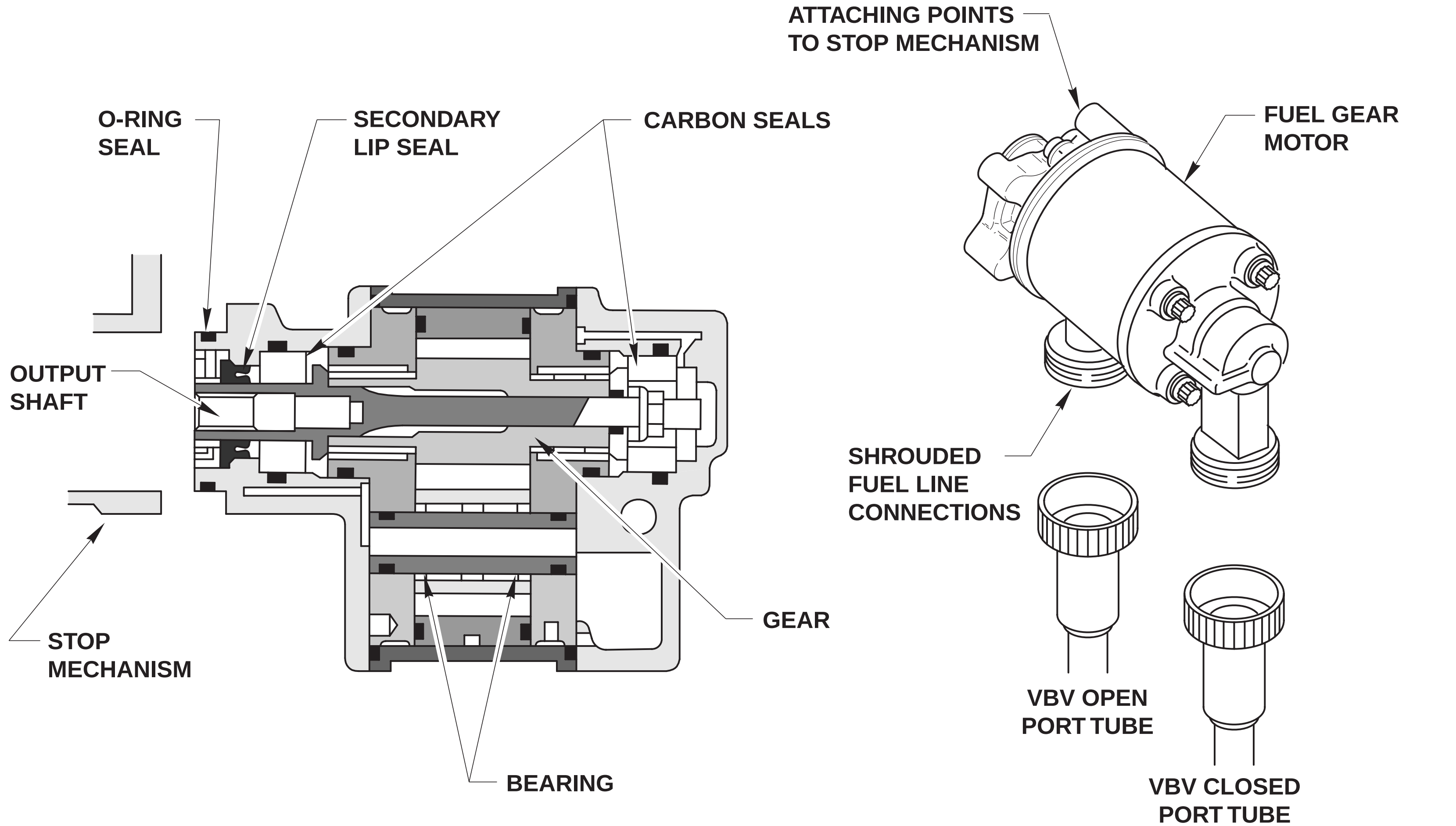
The fuel gear motor is a positive displacement gear motor secured on the stop mechanism rear flange.

It has 2 internal spur gears, supported by needle bearings.

Sealing of the drive gear shaft is provided by carbon seals.

A secondary lip seal is installed on the output shaft and a drain collects any internal fuel leaks which could occur.

The fuel flow sent to the gear motor is constantly controlled by the ECU, via the fuel control valve of the HMU.



CTC-045-123-00

FUEL GEAR MOTOR

Stop mechanism.

The stop mechanism limits the number of revolutions of the gear motor to the exact number required for a complete cycle (opening and closing) of the VBV doors.

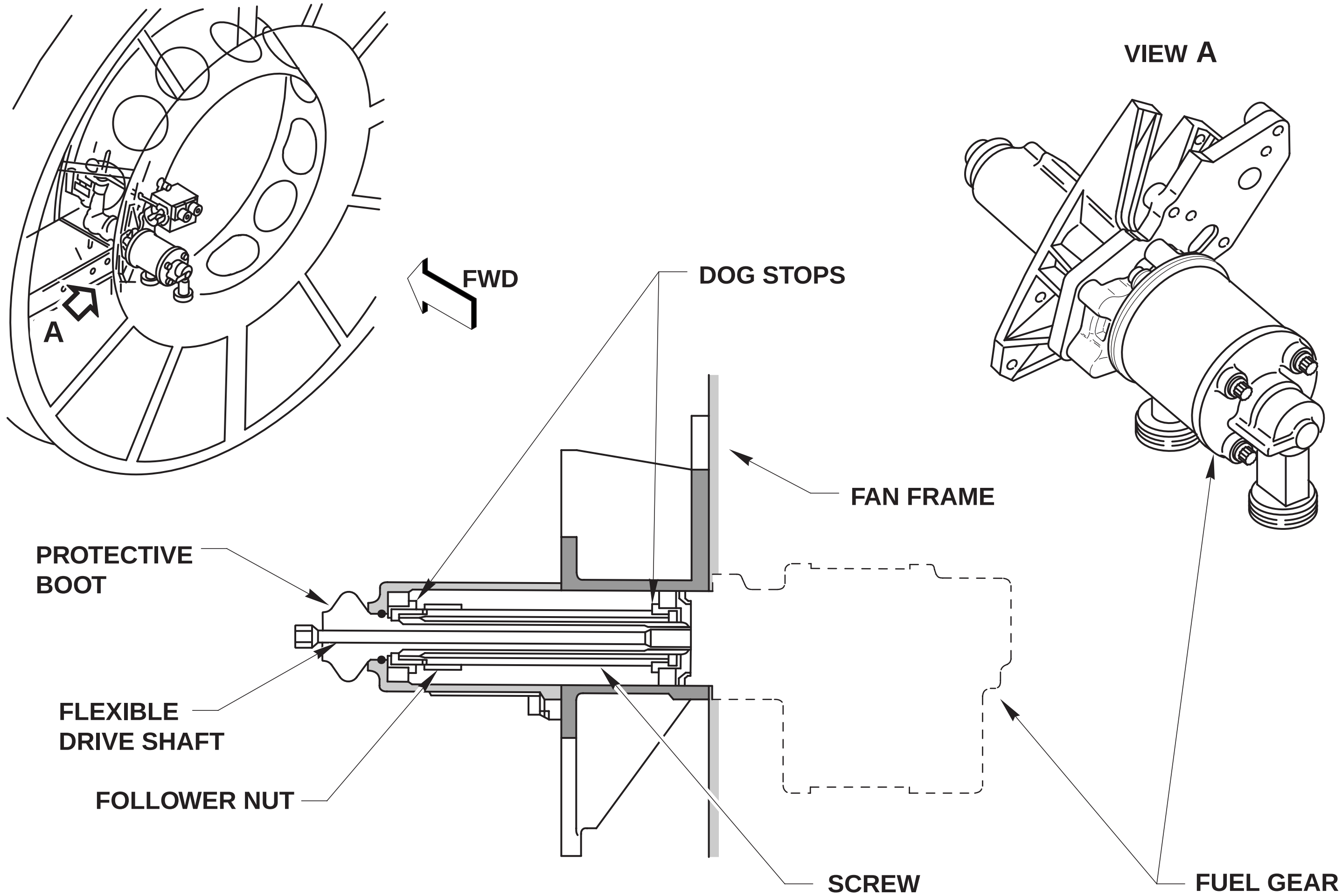
This function supplies the reference closed position to install and adjust the VBV system.

The stop mechanism is located between the gear motor and the master ball screw actuator.

Its main components are :

- a flexible drive shaft, which connects the gear motor to the master ballscrew actuator.
- a follower nut, which translates along a screw and stops the rotation of the gear motor when it comes into contact with "dog stops", installed on both ends of the screw.

A location is provided on its aft end for installation of a position sensor.



CTC-045-124-00

VBV STOP MECHANISM

Master bleed valve.

The master bleed valve and ballscrew actuator assembly is the unit which transmits the driving input from the gear motor to the 11 remaining variable bleed valves.

It is located between struts 10 and 11 in the fan frame mid-box structure.

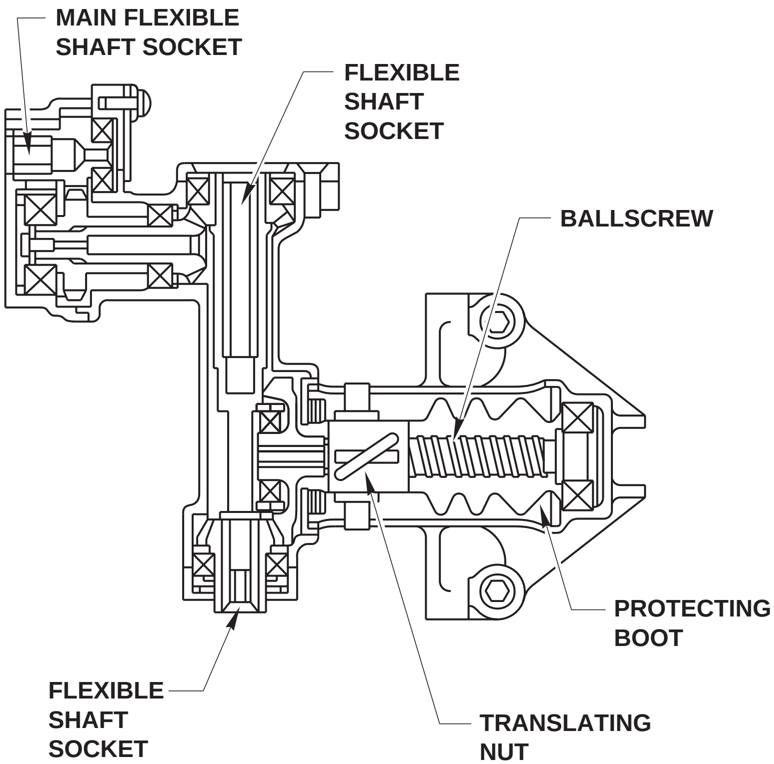
Its main components are :

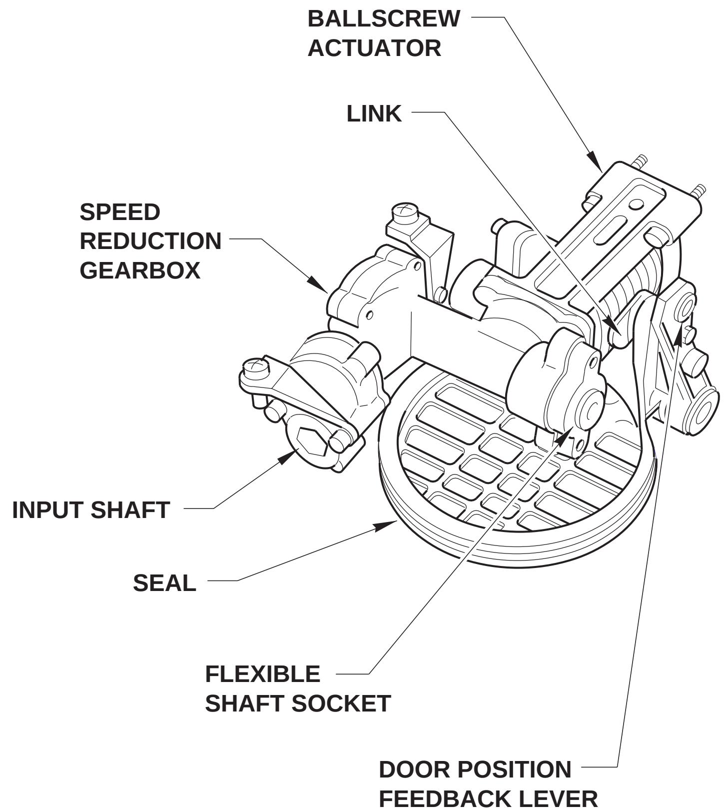
- a speed reduction gearbox.
- a ballscrew actuator, linked to a hinged door.

Speed is reduced through 1 pair of spur gears and by 2 pairs of bevel gears. The bevel gears drive the ballscrew.

Axial displacement of the ballscrew's translating nut is transmitted to the door by 2 links.

A lever, integral with the hinged door, is connected to a feedback rod which transmits the angular position of the door to a sensor (RVDT).





CTC-045-125-00

MASTER BLEED VALVE DESIGN

Variable Bleed valves.

The 11 variable bleed valves are located in the fan frame mid-box structure in between the fan frame struts.

They feature the same internal design as the master ballscrew assembly, but have only one reduction gear instead of two.

They operate in synchronization with the master ballscrew actuator, which provides the input through a flexible drive shaft linkage.

Main drive shaft.

The main drive shaft is a flexible and unshielded power core which has a hexagonal fitting on one end and a splined end fitting on the other.

A spring is attached to the splined end, to hold the shaft assembly in position during operation, and also help removal and installation of the shaft.

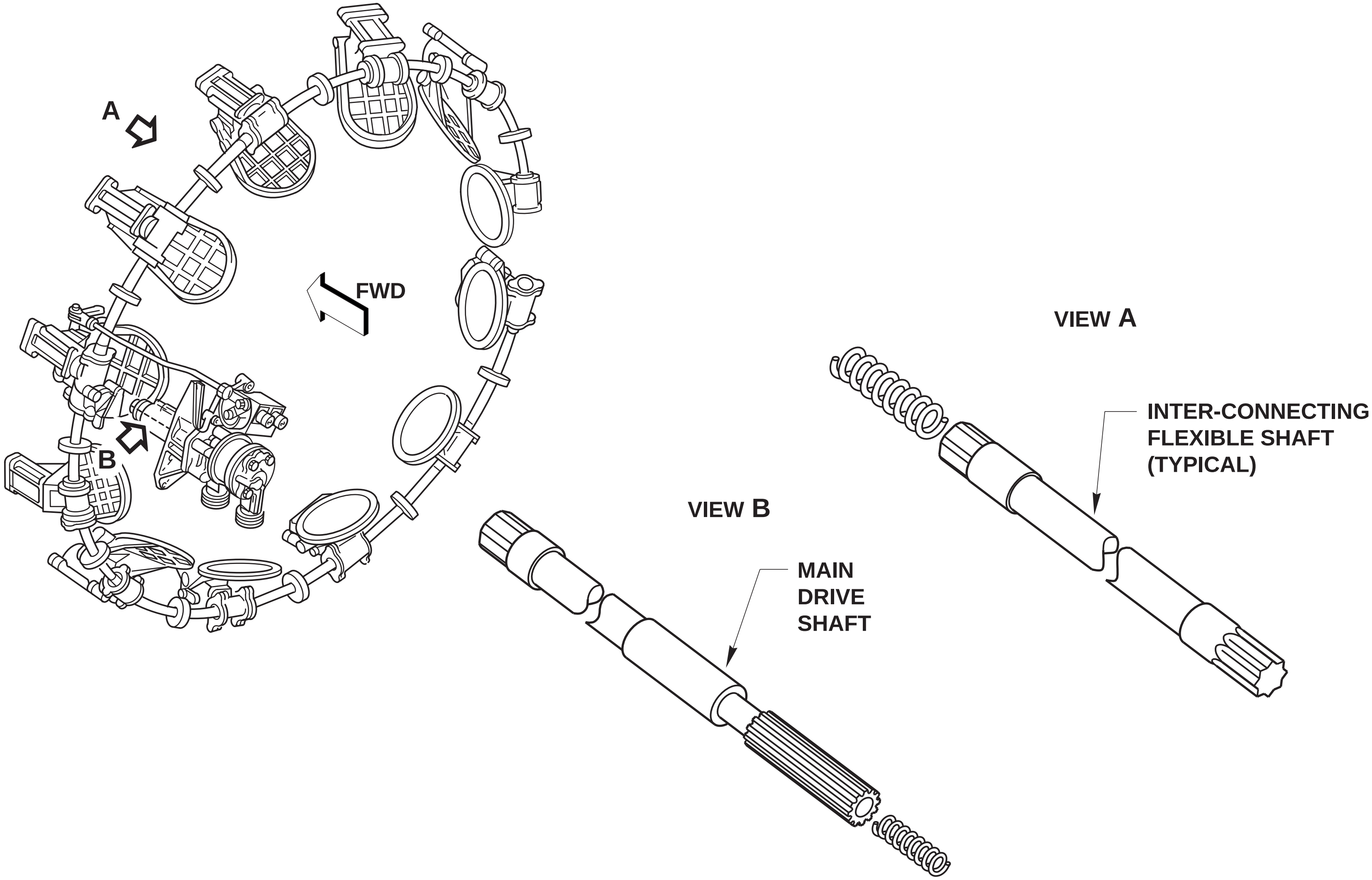
It is installed between the gear rotor, which drives it, and the master bleed valve.

Flexible shafts.

The flexible shafts are installed between the variable bleed valves and are unshielded power cores, which have a hexagonal fitting on one end and a double square fitting on the other.

A spring is attached to the hexagonal end, to hold the shaft assembly in position during operation, and also help shaft removal and installation.

Ferrules are installed in the struts of the engine fan frame to guide and support the flexible shafts during operation.



CTC-045-126-00

MAIN FLEXIBLE SHAFT AND INTER-CONNECTING FLEXIBLE SHAFT

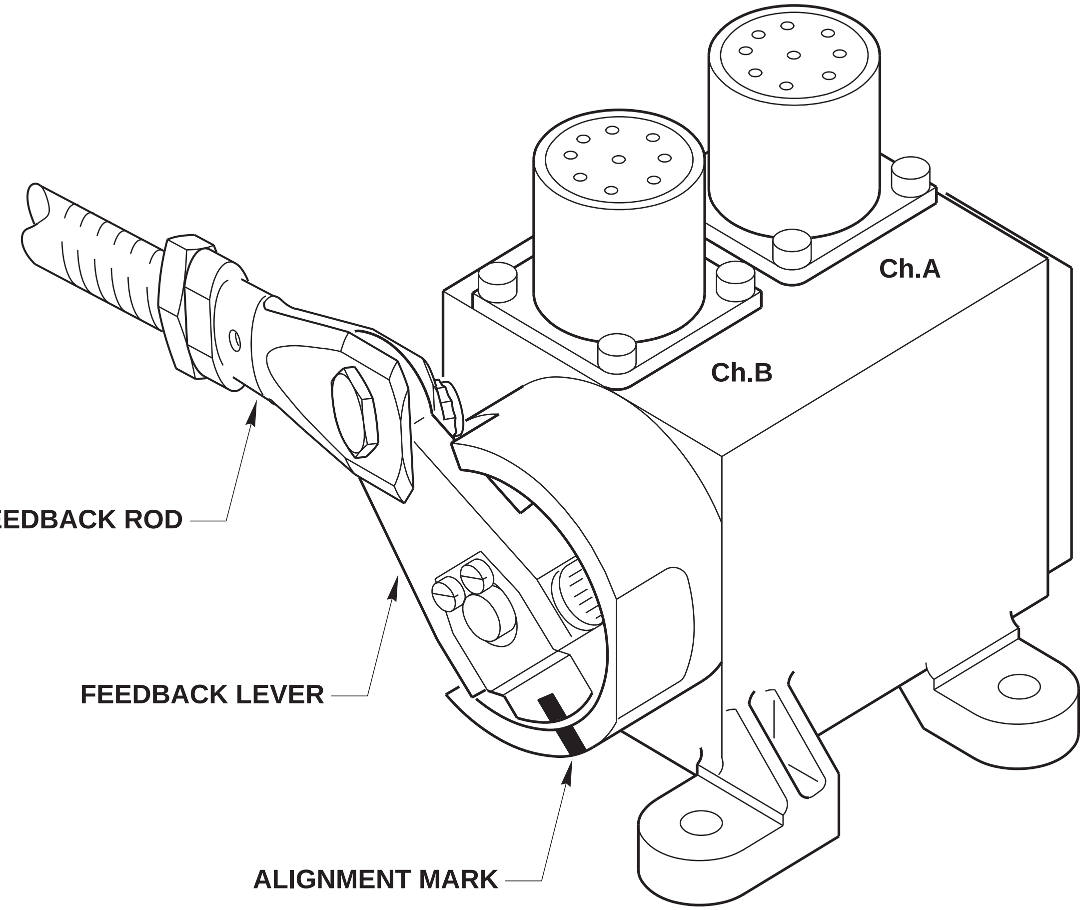
Bleed valve position sensor.

The bleed valve position sensor transmits the angular position of the VBV doors to the ECU by an electrical feedback signal.

It is a Rotary Variable Differential Transducer (RVDT), and is mounted onto the stop mechanism.

It has two marks which should be aligned when the system is adjusted to the reference closed position.

The adjustment is made through the feedback rod connecting the master bleed valve to the transducer’s feedback lever.



BLEED VALVE POSITION SENSOR

CTC-045-127-00

VBV system logic.

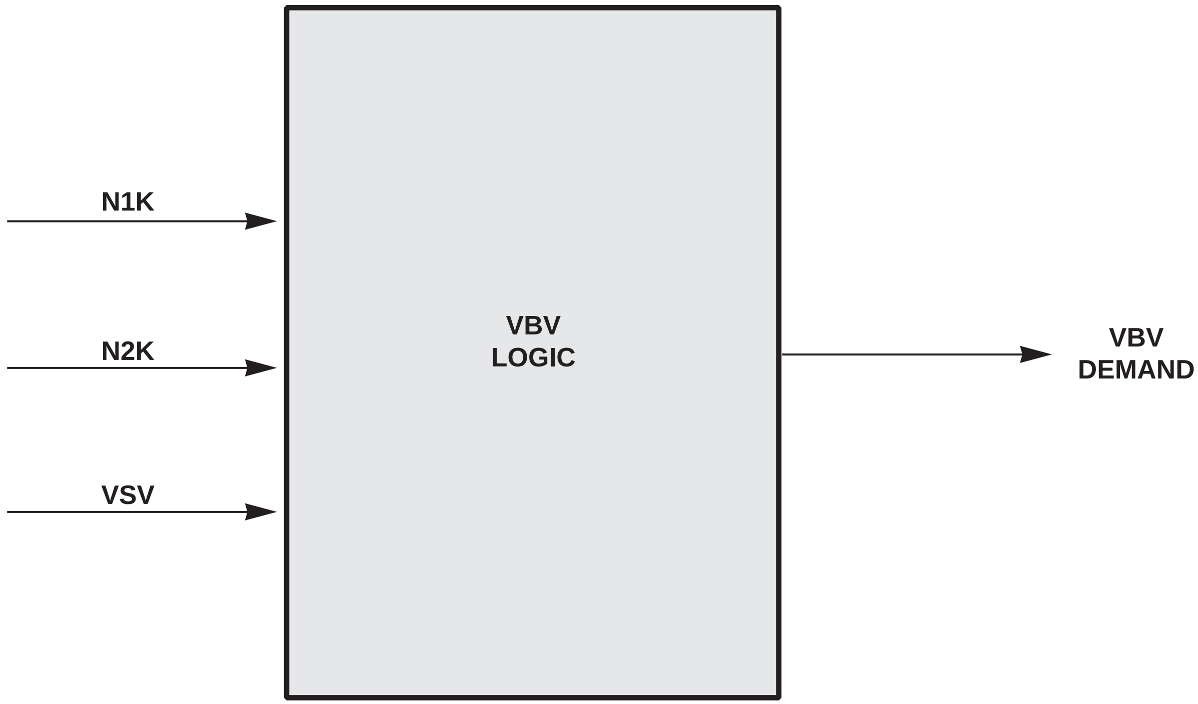
The ECU calculates the VBV demand-signal.

This calculation uses :

- a corrected fan speed (N1K).
- a corrected core speed (N2K).
- an N2-trim signal from the VSV.

The ECU calculates a basic VBV position, depending on N2 speed and the position of the VSV.

This position is then finely adjusted, according to the difference between the actual N1 speed and a calculated value.



CTC-045-128-00

VBV SYSTEM LOGIC

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VARIABLE STATOR VANE

VARIABLE STATOR VANE

The Variable Stator Vane (VSV) system positions the HPC stator vanes to the appropriate angle to optimize HPC efficiency. It also improves the stall margin during transient engine operations.

The VSV position is calculated by the ECU using various engine parameters, and the necessary fuel pressure is delivered by the HMU dedicated servo valve.

The VSV system is located at the front of the HP compressor.

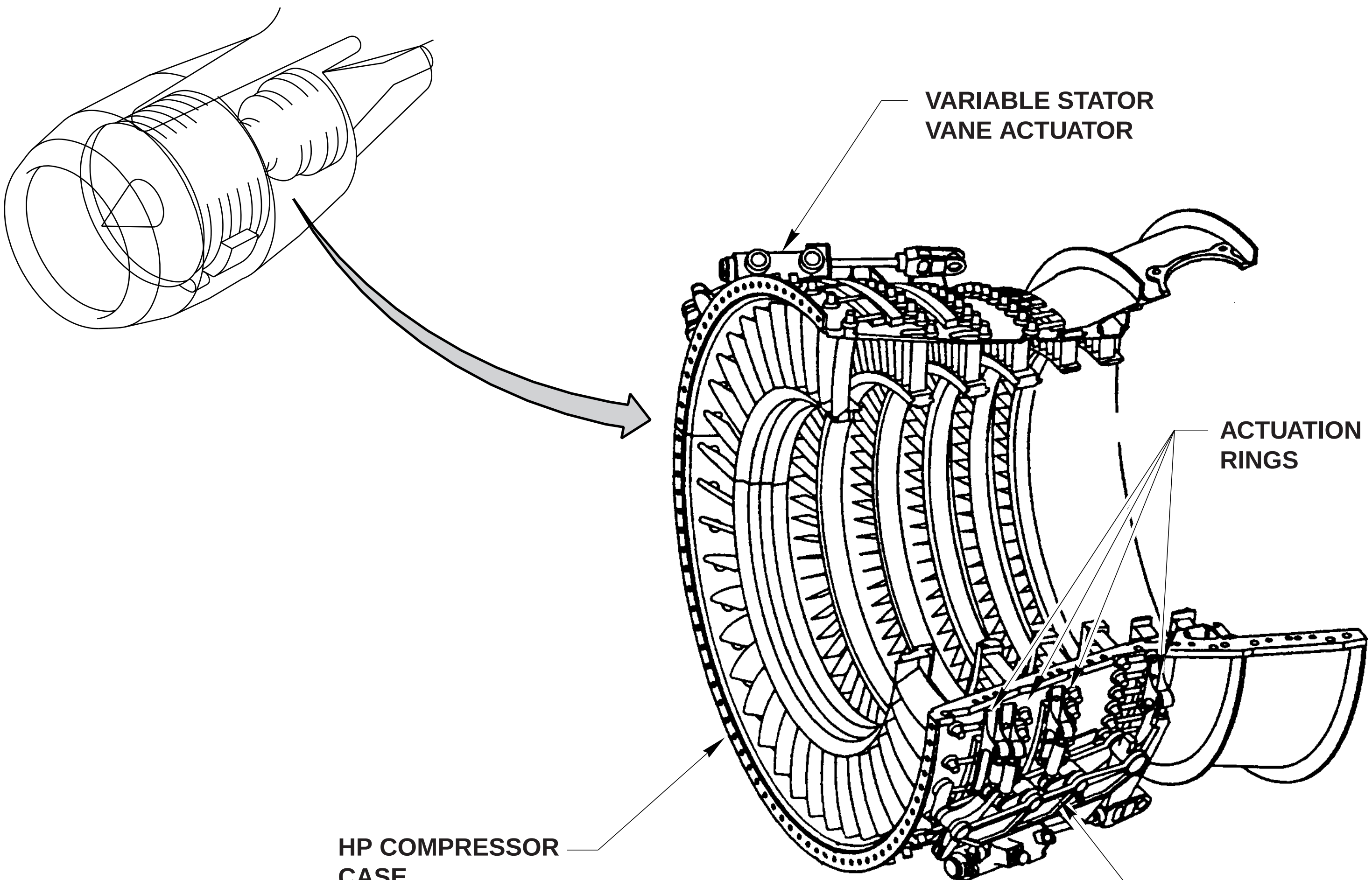
The system consists of :

A series of actuators and bellcrank assemblies, on both sides of the HPC case :

- two hydraulic actuators.
- two feedback sensors, installed in the actuators.
- two bellcrank assemblies.
- four actuation rings (made in 2 halves).

Variable stator stages, located inside the HPC case :

- Inlet Guide Vane (IGV)
- Variable Stator Vane (VSV) stages1-2-3.



VSV SYSTEM LOCATION

CTC-045-129-00

VARIABLE STATOR VANE

According to sensor signals, the ECU computes the appropriate VSV position.

Two actuators, located at the 2 and 8 o'clock positions on the HPC case, move the 4 actuation rings to change the angular position of the vanes.

Two electrical feedback sensors (LVDT), one per actuator, transmit the VSV position to the ECU to close the control loop.

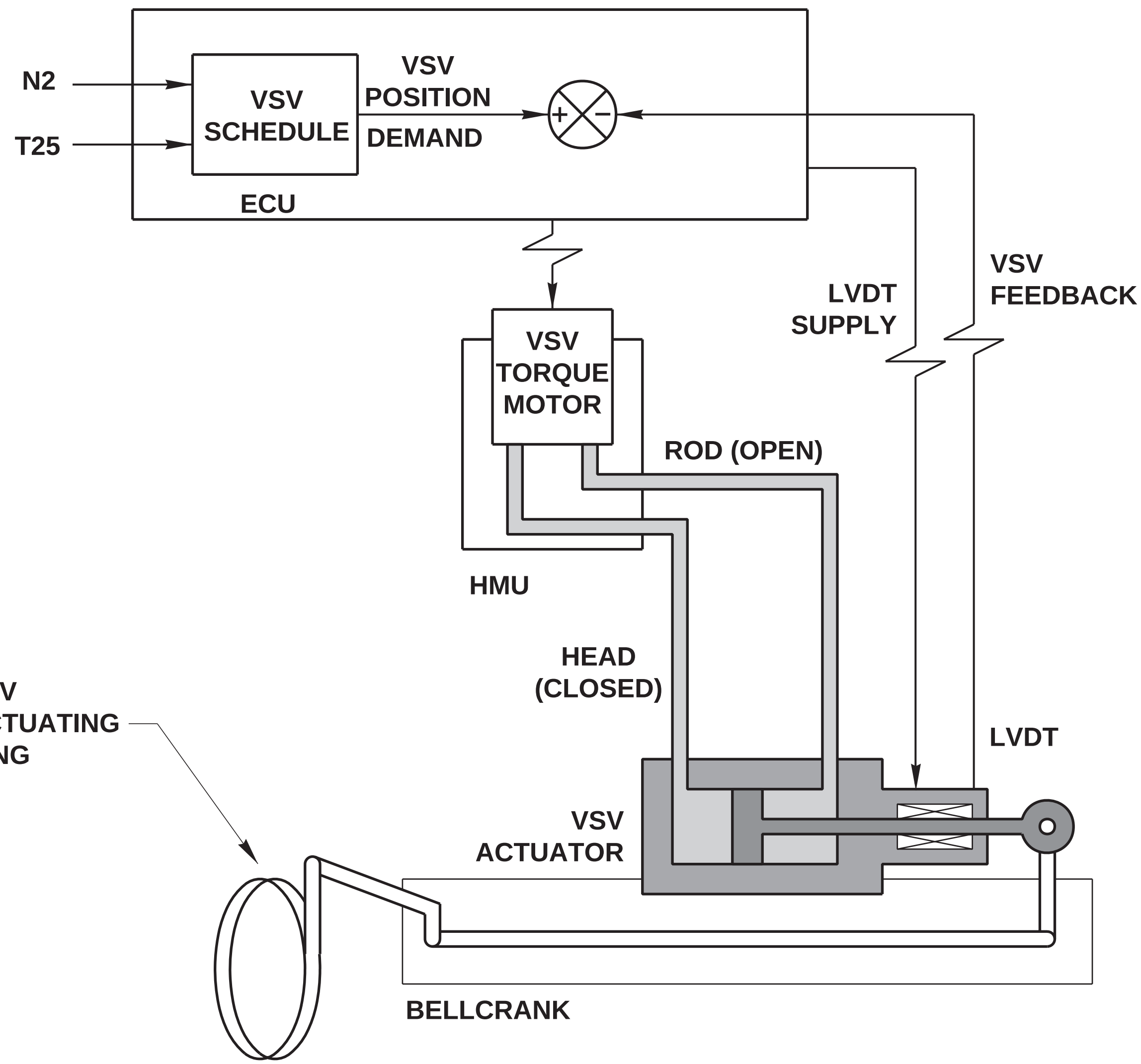
The left handside feedback sensor is connected to channel A and the right handside feedback sensor to channel B.

VSV position transducer.

The position sensors are Linear Variable Differential Transducers (LVDT) and consist of two windings, one stationary, one moveable.

The moveable winding translates with the actuator rod, and the resulting voltage is a function of actuator stroke/ VSV position.

Excitation is provided by the ECU.



VSV SYSTEM DESIGN

CTC-045-130-00

VSV actuators.

The actuators provide an output force and motion to the VSV system, in response to fuel pressure.

They are single ended, uncushioned, hydraulic cylinders, able to apply force in both directions.

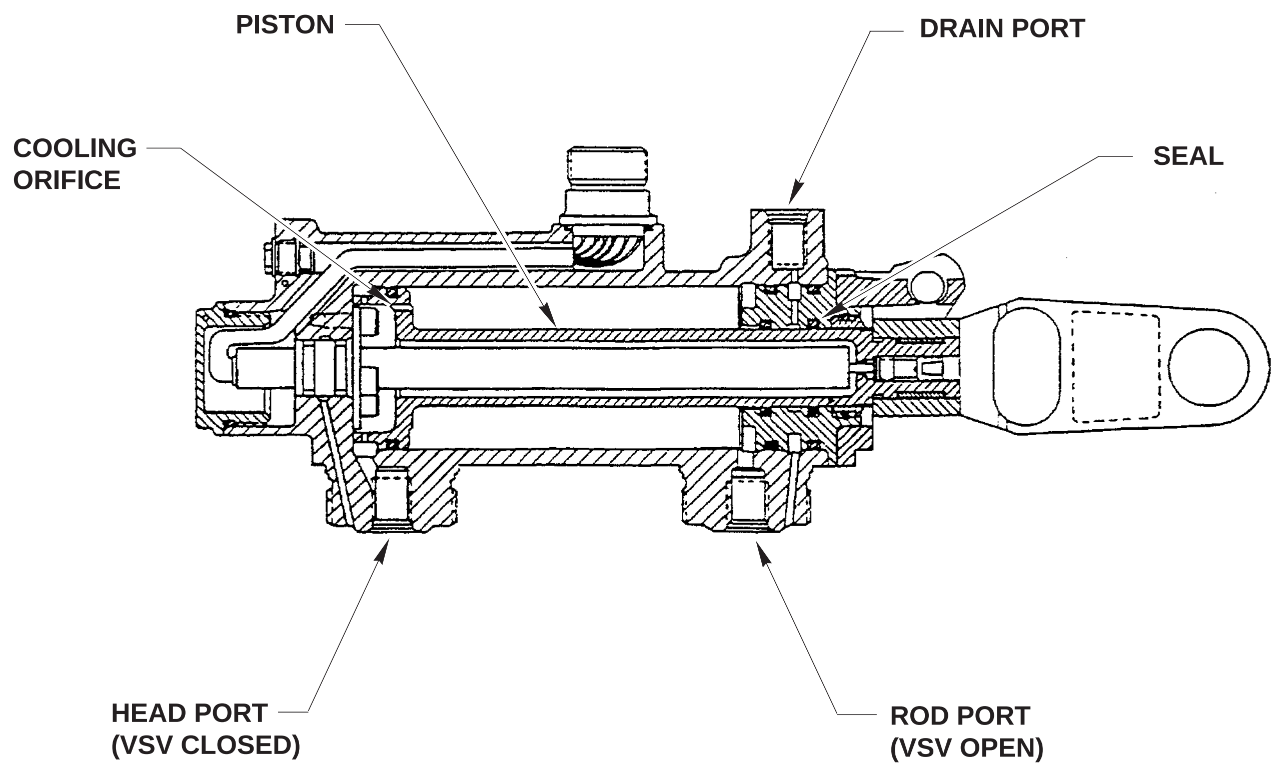
Piston stroke is controlled by internal stops.

The piston incorporates a capped, preformed packing to prevent cross-piston leakage and a wiper is provided to ensure the piston rod is dirt free.

The rod end features a dual-stage seal with a drain port and, at the end of the piston, there is an extension, which houses a bearing seat.

For cooling purposes, the head end of the piston has an orifice that allows the passage of fuel.

The VSV actuator is self-purging.



VSV ACTUATOR

CTC-045-131-00

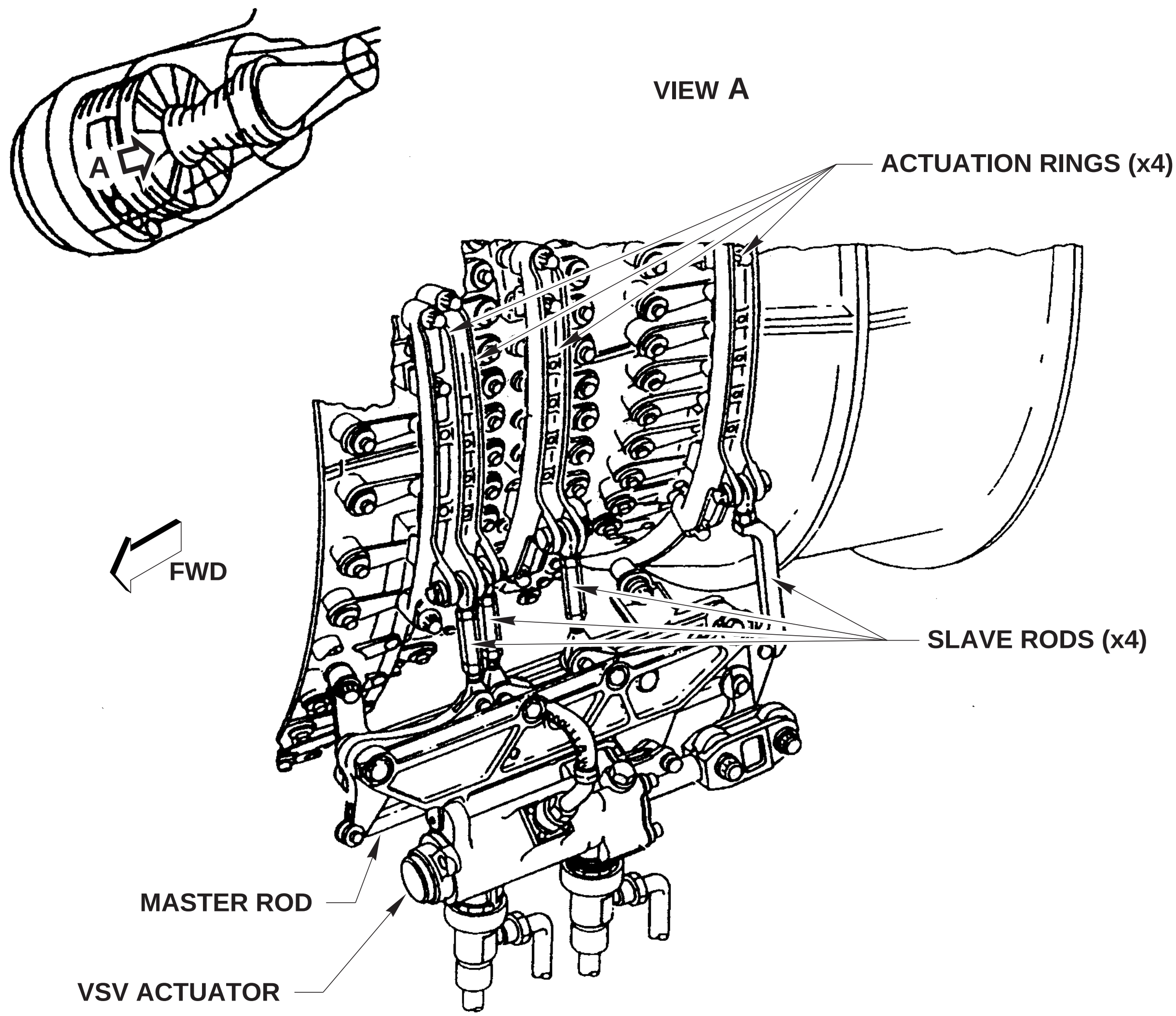
VSV linkage system.

Each VSV actuator is connected through a clevis link and a bellcrank assembly to a master rod.

The vane actuation rings are linked to the master rod in the bellcrank assembly, through slave rods.

The actuation ring halves, which are connected at the splitline of the compressor casing, rotate circumferentially about the horizontal axis of the compressor.

Movement of the rings is transmitted to the individual vanes, through vane actuating levers.



VSV LINKAGE SYSTEM

CTC-045-132-00

VSV system control.

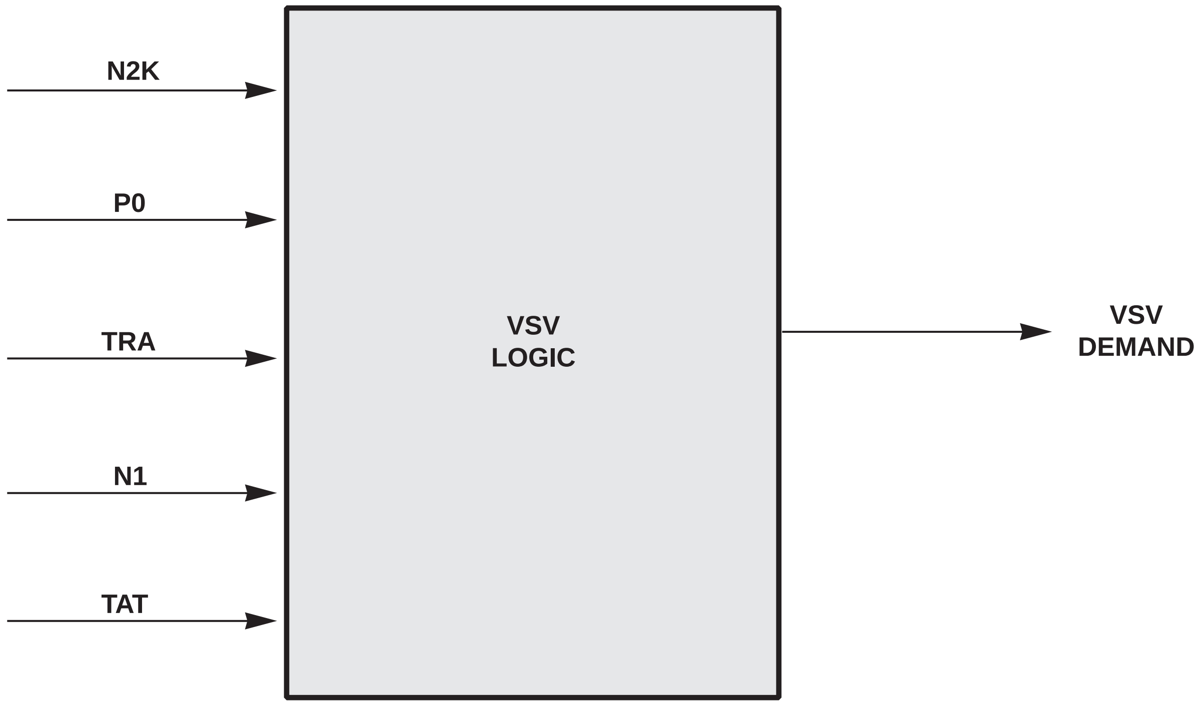
The ECU calculates the VSV demand signal using :

- Corrected N2 speed (N2K).
- Ambient pressure (P0) for Altitude.
- Throttle Resolver Angle (TRA).
- Fan speed (N1).
- Total Air Temperature (TAT).

It schedules the VSV position depending on corrected N2 speed and altitude.

Adjustments are applied, depending on the following :

- The bodie condition (rapid accel/decel).
- The steady state condition.
- The transient condition (slow accel/decel).
- Environmental icing condition.
- N1 and/or N2 overspeed condition.



VSV SYSTEM LOGIC

CTC-045-133-00

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HIGH PRESSURE TURBINE CLEARANCE CONTROL

HIGH PRESSURE TURBINE CLEARANCE CONTROL

The HPTCC system optimizes HPT efficiency through active clearance control between the turbine rotor and shroud and reduces compressor load during starting and transient engine conditions.

The HPTCC system uses bleed air from the 5th and 9th stages to cool down the HPT shroud support structure in order to:

- maximize turbine efficiency during cruise.
- minimize the peak EGT during throttle burst.

The system also includes a start bleed feature which provides a high level of 9th stage HPC bleed air for increased start stall margin.

The HPTCC valve is located on the engine core section at the 3 o'clock position.

This is a closed loop system, using the valve position status as feedback.

The ECU uses various engine and aircraft sensor information to take into account the engine operating range and establish a schedule.

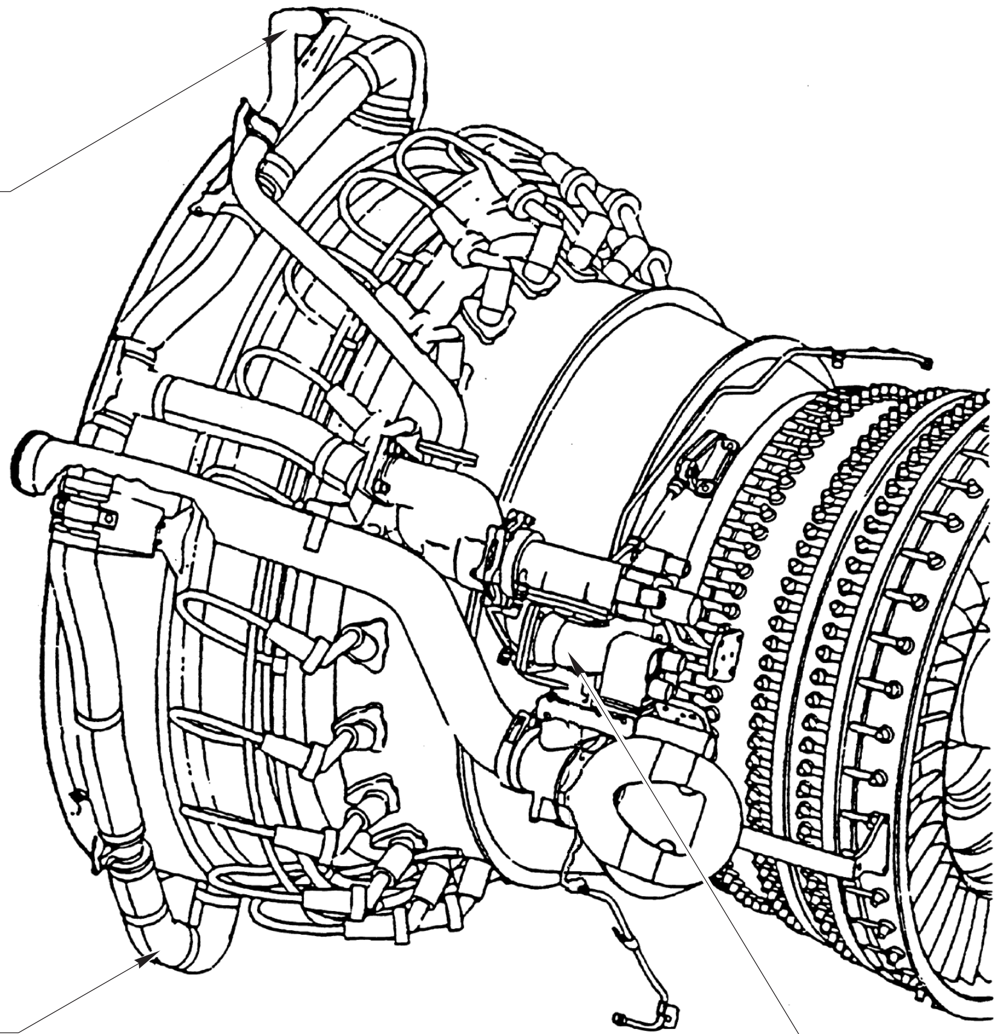
A thermocouple, located on the right hand side of the HPT shroud support structure, provides the ECU with temperature information.

To control the temperature of the shroud at the desired level, the ECU calculates a valve position schedule.

This valve position is then sent by the ECU active channel as torque motor current to the HPTCC servo valve, within the HMU.

The servo valve modulates the fuel pressure sent to command the HPTCC valve.

Two sensors (LVDT), connected to the actuator, provide the ECU with position feedback signals and the ECU changes the valve position until the feedback matches the schedule demand.



HPTCC SYSTEM

CTC-045-134-00

HIGH PRESSURE TURBINE CLEARANCE CONTROL

5th and 9th stage compressor bleed air enters the HPTCC valve, where the two airflows are mixed.

The fuel pressure command from the HMU, Pc, enters the valve at the Turbine Clearance Control (TCC) supply port.

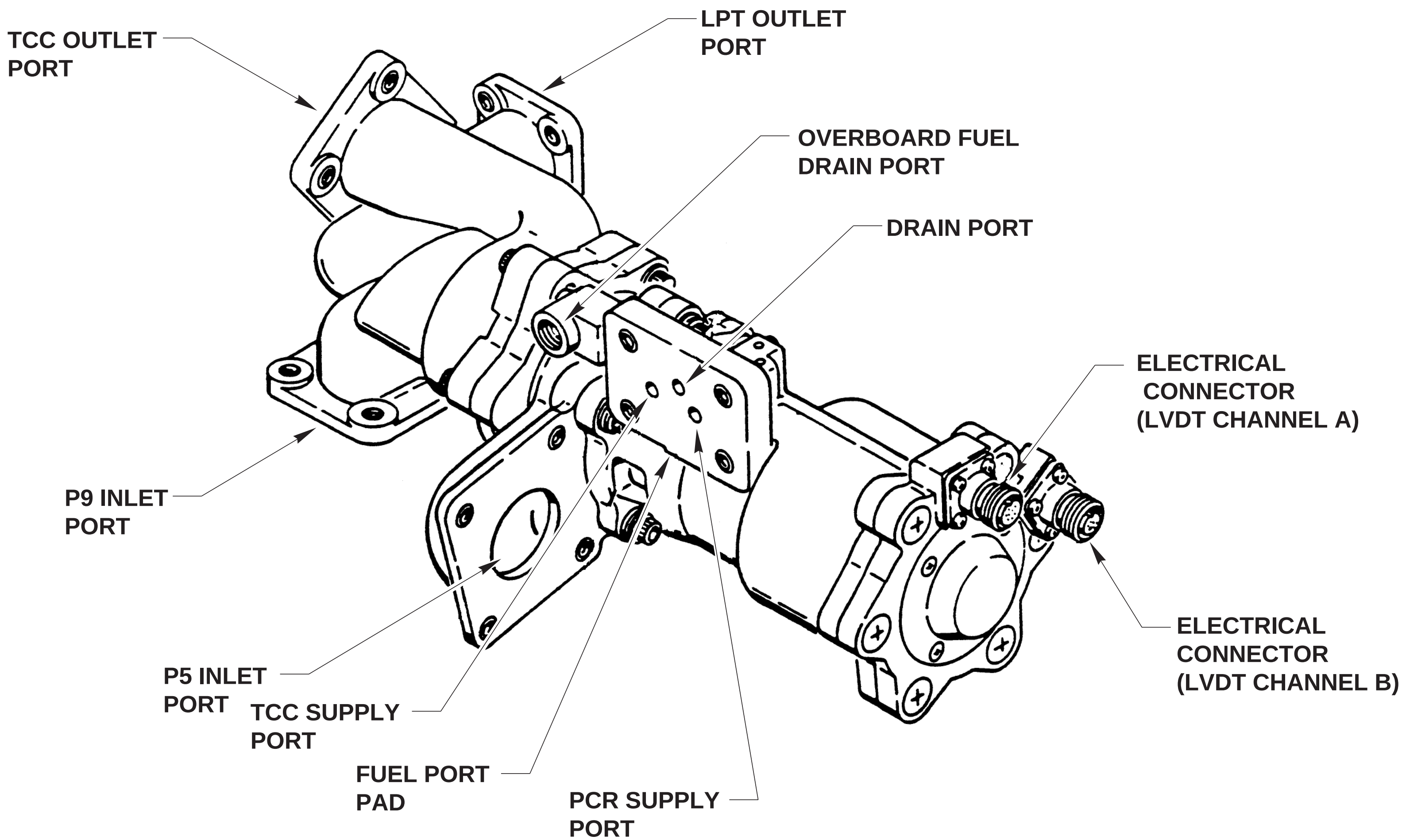
An intermediate pressure, Pcr, is applied on the opposite side of the hydraulic piston within the valve.

The difference between these two pressures actuates the piston, which varies the position of a poppet valve.

This position variation determines the mixture of 5th and 9th stage air to be ported to the HPT shroud support through the impingement manifold at 12 and 6 o'clock, and to the LPT stage 1 nozzle support cavity.

The valve position is sensed by a dual LVDT and sent to both channels of the ECU, for close loop control.

A drain port on the valve directs any fuel leaks towards the draining system.



HPTCC VALVE

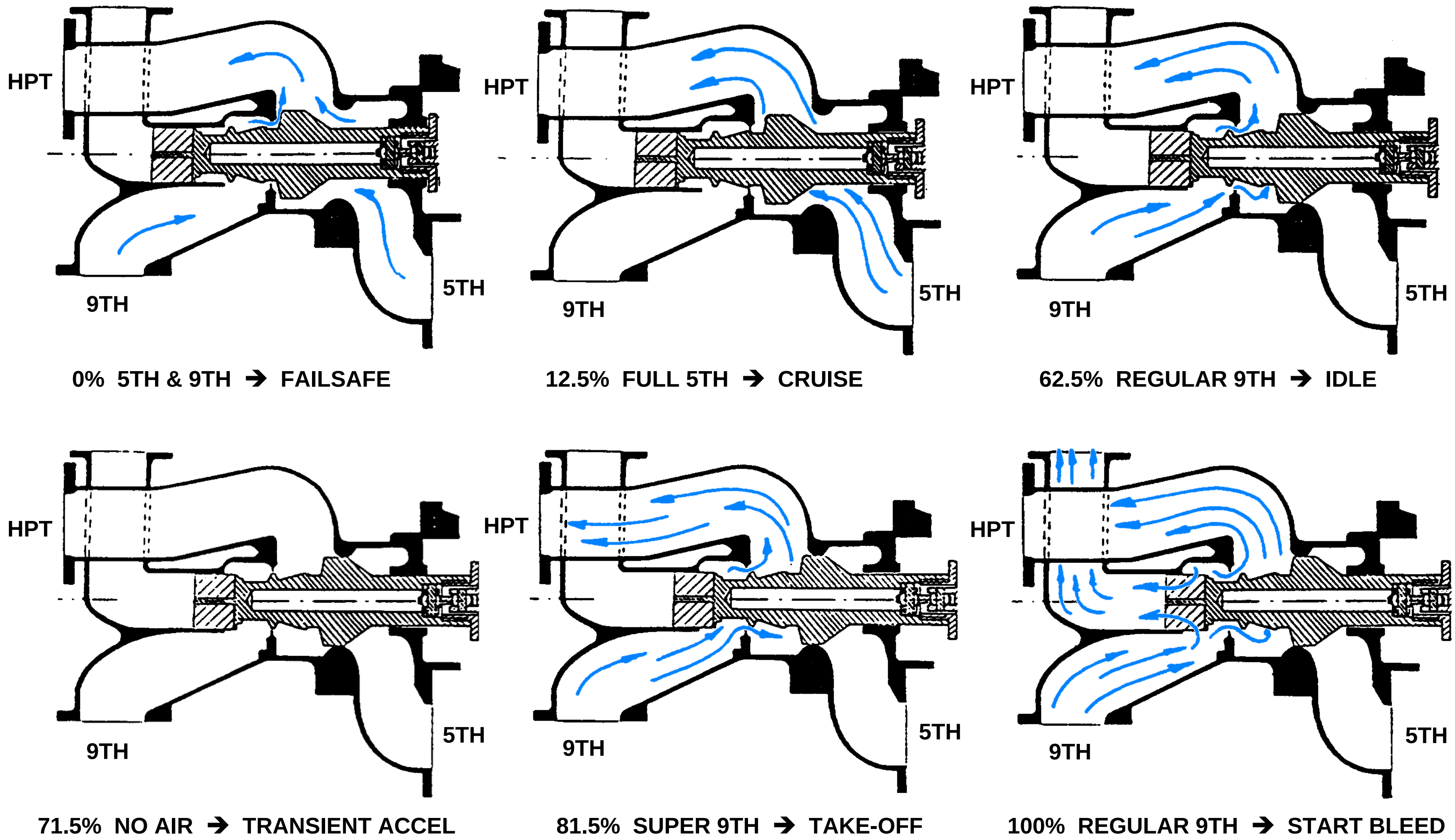
CTC-045-135-00

HIGH PRESSURE TURBINE CLEARANCE CONTROL

From various parameters, such as N2, TC, T3, the ECU calculates the HPTCC valve position and sends electrical signals to the torque motor, within the HMU, to move the valve.

The main modes of the HPTCC valve depend on the piston stroke and various air configurations :

- Mixed 5th and 9th, 0% stroke (failsafe position).
- Full 5th, 12.5% stroke (cruise).
- Regular 9th, 62.5% stroke (idle).
- No air, 71.5% stroke (transient accel).
- Super 9th, 81.5% stroke (take-off).
- Regular 9th, 100% stroke (start bleed).
- Mixed 9th and 5th, stroke modulated from full 9th to full 5th (climb).



CTC-045-136-00

HPTCC AIR CONFIGURATIONS

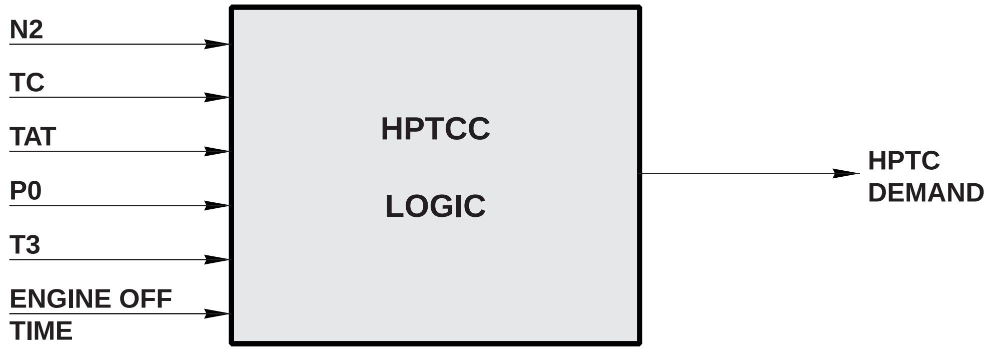
The ECU calculates the HPTC demand, using:

- N2 (core aerothermo-dynamics and speed)
- TC (case temperature)
- TAT (Total Air Temperature)
- P0 (ambient pressure)
- T3 (CDP temperature)
- Engine off time (Time between Master Lever OFF and Master Lever ON)

The ECU determines the thermal state of the HPC rotor and the air available in the primary flow, using N2, TAT.

It sets a theoretical demand and clearance adjustment for thermal expansion according to P0, N2, T3.

It establishes the valve position using N2, T3, TC and engine off time.



HPTCC LOGIC

CTC-045-137-00

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LOW PRESSURE TURBINE CLEARANCE CONTROL

LOW PRESSURE TURBINE CLEARANCE CONTROL

The LPTCC system uses fan discharge air to cool the LPT case during engine operation, in order to control the LPT rotor to stator clearances.

It also protects the turbine case from over-temperature by monitoring the EGT.

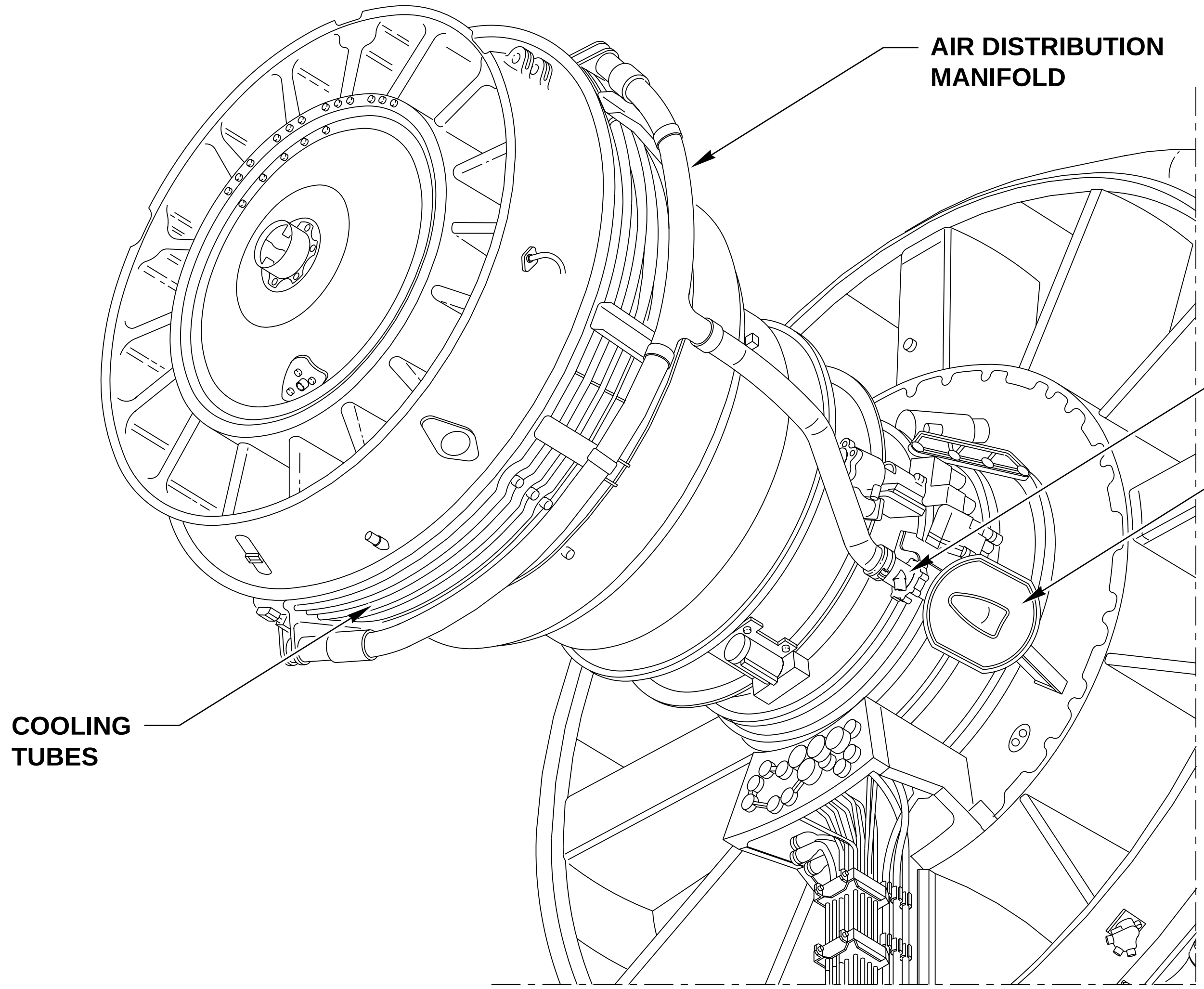
This ensures the best performance of the LPT at all engine ratings.

The LPTCC system is a closed loop system, which regulates the cooling airflow sent to the LPT case, through a valve and a manifold.

The LPTCC valve is located on the engine core section between the 4 and 5 o'clock positions.

The LPTCC system consists of:

- -an air scoop
- -the LPTCC valve.
- -an air distribution manifold.
- -six LPT case cooling tubes.



CTC-045-138-00

LPTCC SYSTEM LOCATION

LOW PRESSURE TURBINE CLEARANCE CONTROL

According to a schedule from the ECU, an electrical order, proportional to a valve position demand, is first sent to a servo valve within the HMU.

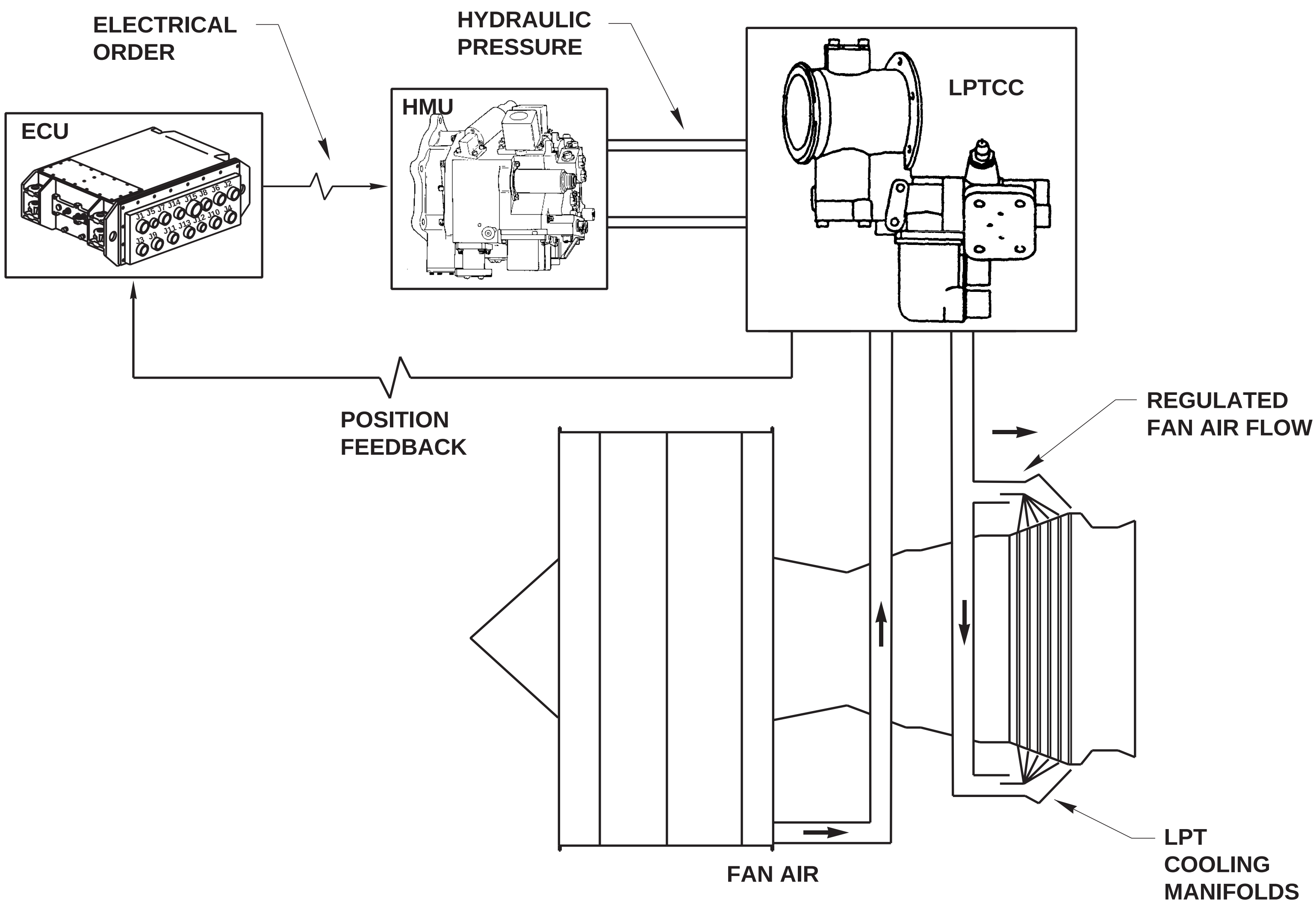
The servo valve changes the electrical information into fuel pressure and sends it to the LPTCC valve.

Within the LPTCC valve, an actuator drives a butterfly, installed in the airflow.

The butterfly valve position determines the amount of fan discharge air entering the manifold and cooling tube assembly.

Sensors (RVDT), built in the valve, send the valve position to the ECU as feedback, to be compared with the position demand.

If the valve position does not match the demand, the ECU sends an order, through the HMU, to change the valve state until both terms are equal.



LPTCC

CTC-045-139-00

LOW PRESSURE TURBINE CLEARANCE CONTROL

LPTCC valve.

The LPTCC valve includes a linear actuator with a gear section, which rotates a butterfly valve shaft.

The actuator is attached to a control plate, which has three holes.

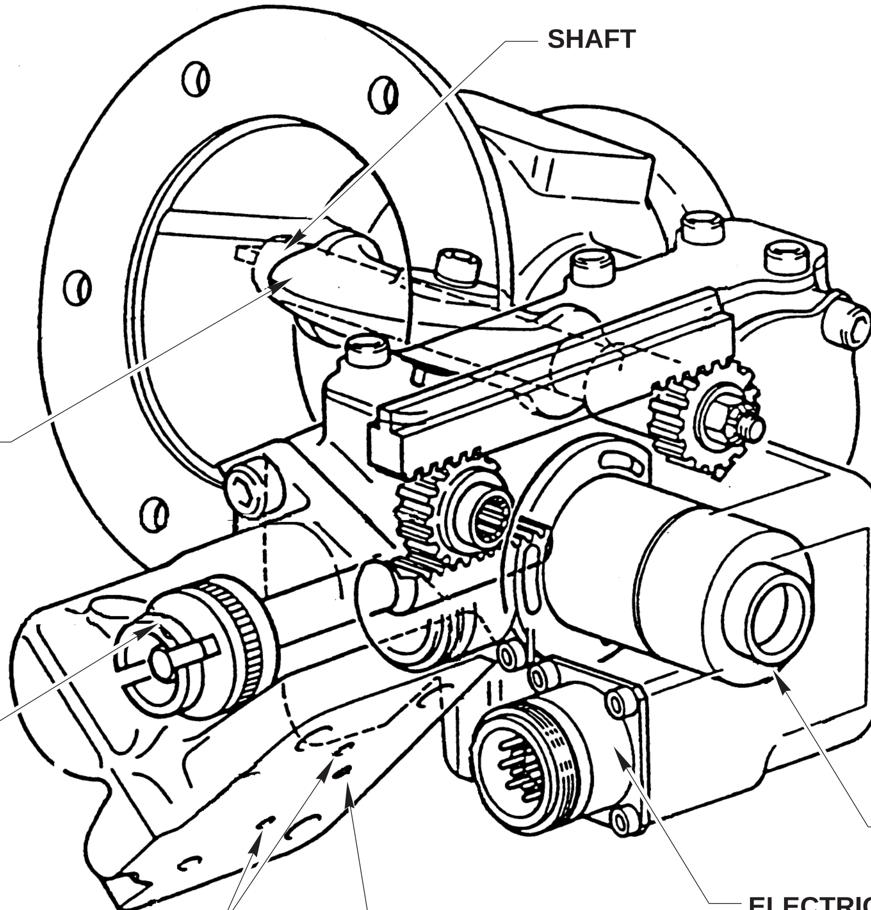
Two of these holes are used for valve actuation :
- One hole ports modulated pressure from the servo valve to one side of the actuator.
- The second hole ports Pcr pressure to the other side of the actuator.

The modulated pressure is either greater, or smaller, than Pcr and determines the direction of the actuator motion.

The third hole is a drain port designed to collect leakage from the actuator and direct it to the draining system.

An RVDT sensor is fitted at one end of the buttterfly valve shaft and supplies an electrical signal proportional to the valve position.

The valve butterfly operates from 80°, full open position, to 45°, closed position. In case of failure, the valve goes to a failsafe full open position.



CTC-045-140-00

LTP ACTIVE CLEARANCE CONTROL VALVE

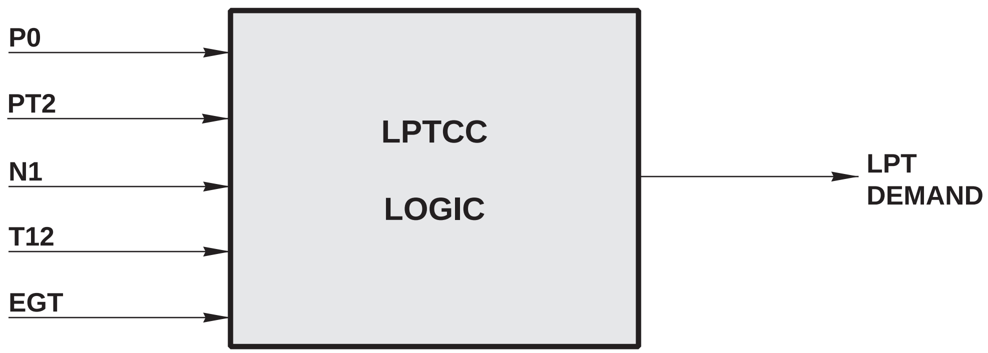
Control logic.

In the ECU, the LPTCC calculation block establishes the valve position demand.

The airflow demand calculation is based on various parameters such as :

- P0 (ambient pressure).
- PT (total pressure).
- N1 state (fan aerothermo-dynamics and speed).
- T12 (Fan inlet temperature).
- EGT(Exhaust Gas Temperature).

From these parameters, the ECU calculates the required airflow and valve position for clearance control and protects the turbine case from over temperature by monitoring the EGT.



LPTCC LOGIC

CTC-045-141-00

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OIL GENERAL

Sump philosophy

The engine has 2 sumps; the forward and aft.

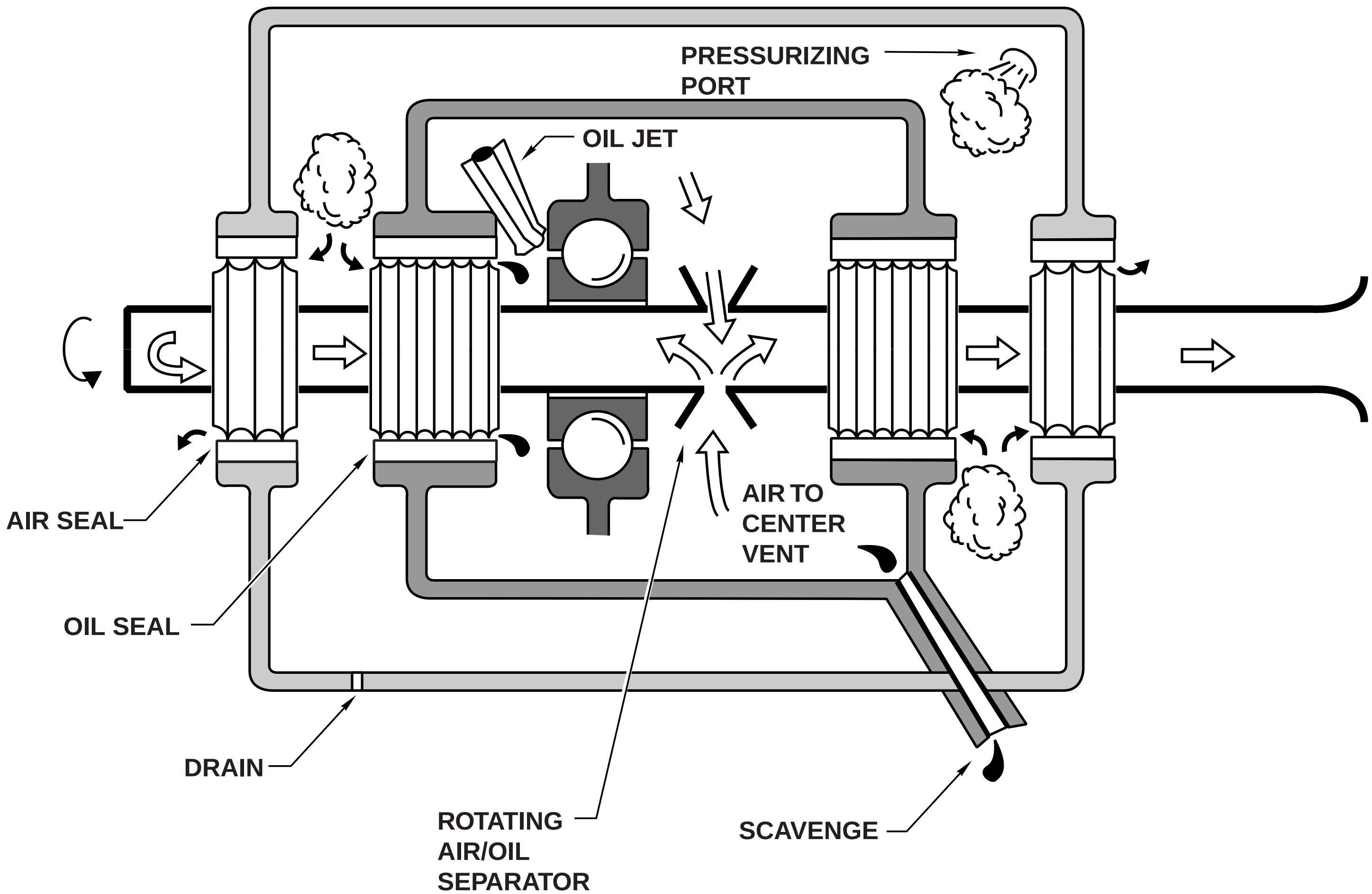
The forward sump is located in the cavity provided by the fan frame and the aft sump is located in the cavity provided by the turbine frame.

The sumps are sealed with labyrinth type oil seals, which must be pressurized in order to ensure that the oil is retained within the oil circuit and, therefore, minimize oil consumption.

Pressurization air is extracted from the primary airflow (booster discharge) and injected between the two labyrinth seals. The air, looking for the path with the least resistance, flows across the oil seal, thus preventing oil from escaping.

Any oil that might cross the oil seal is collected in a cavity between the two seals and routed to drain pipes.

Once inside the oil sump cavity, the pressurization air becomes vent air and is directed to an air/oil rotating separator and then, out of the engine through the center vent tube, the rear extension duct and the flame arrestor.



CTC-045-142-00

SEALS PRESSURIZATION PRINCIPLE

OIL GENERAL

The purpose of the oil system is to provide lubrication and cooling for gears and bearings located in the engine sumps and gearboxes.

It includes the following major components :

- an oil tank, located on the left handside of the fan case.
- an antisiphon device, close to the oil tank cover, on the left hand side of the tank.
- a lubrication unit assembly, installed on the accessory gearbox.
- a main oil/fuel heat exchanger, secured on the engine fuel pump.

The oil system is self contained and may be split into the different circuits listed below :

- Oil supply circuit.
- Oil scavenge circuit.
- Oil circuit venting.

<u>Oil supply circuit.</u>

The oil is drawn from the oil tank, through an antisiphon device, by a pressure pump within the lube unit. The pressure pump is powered through a drive shaft driven by the AGB.

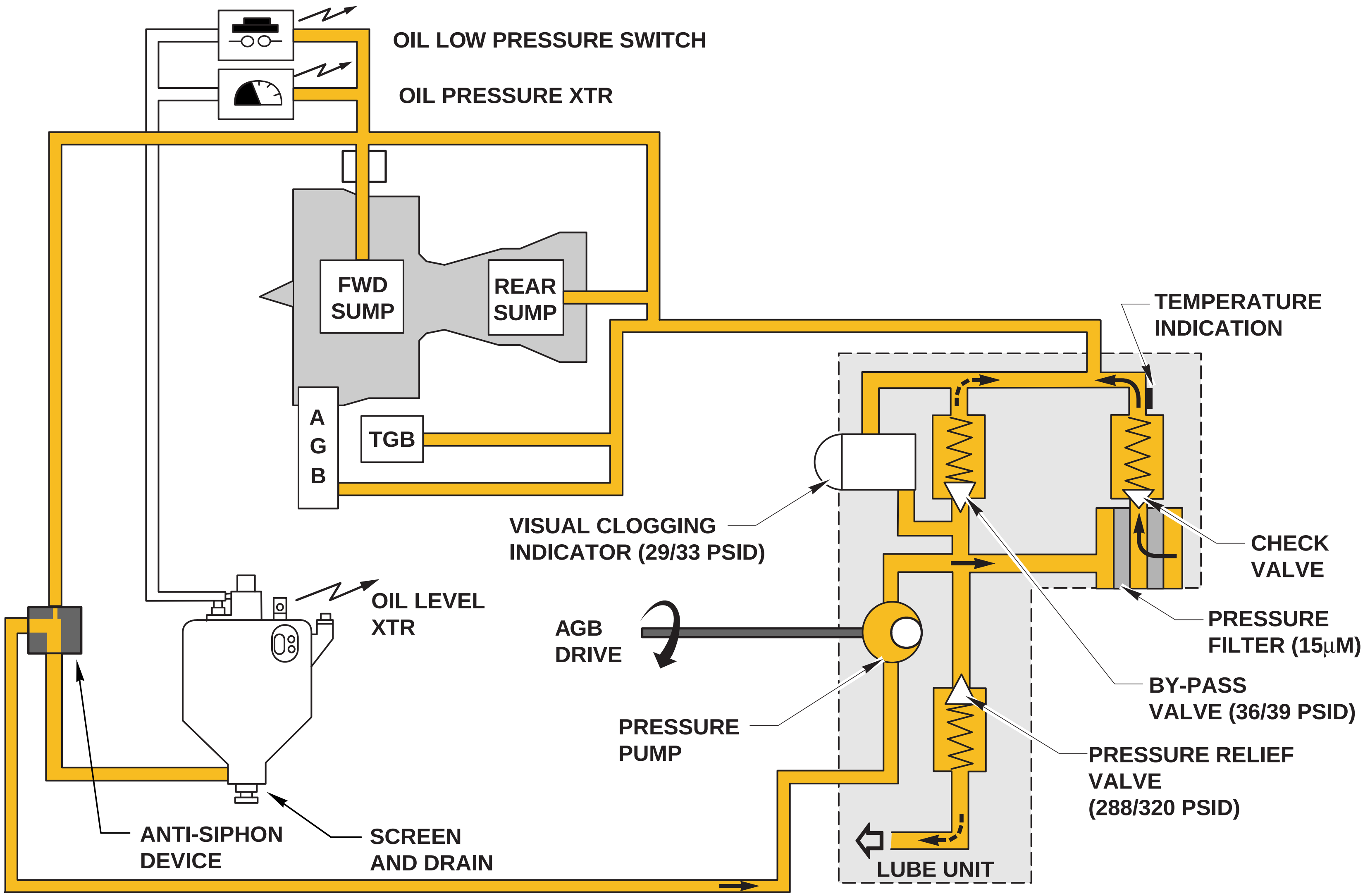
The oil then passes through the main filter and check valve, to be distributed to the engine sumps and gearboxes. The check valve prevents any oil spillage during filter replacement.

A bypass valve installed in parallel to the filter, opens in case of filter clogging, which triggers a ‘pop out’ indicator.

A pressure relief valve bypasses part of the flow to the AGB scavenge pump to protect the supply pump against abnormal output pressure buildup.

The following parameters are used for aircraft indicating purposes :

- Oil pressure (delta P between oil supply pressure and sump pressure).
- Oil temperature.
- Main filter clogging.



OIL SUPPLY CIRCUIT

CTC-045-143-00

Oil scavenge circuit.

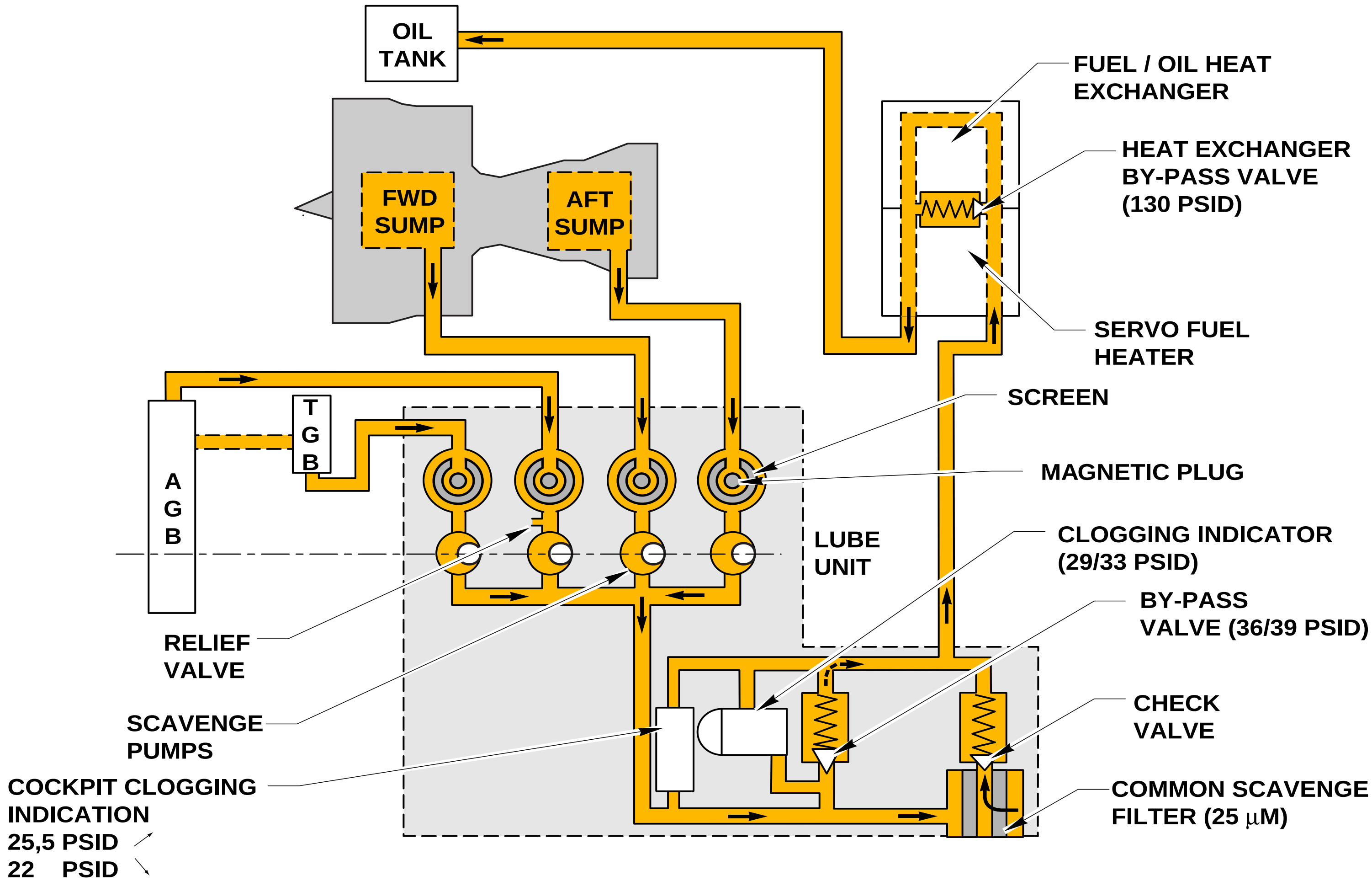
The oil is drawn from the forward and aft sumps, the AGB and the TGB, by 4 individual scavenge pumps, installed within the lube unit.

The oil passes through magnetic chip detectors and scavenge screens within the lubrication unit.

The magnetic chip detectors enable maintenance staff to identify a particular scavenge circuit that may have particles in suspension in the oil.

Then, the oil goes through a common scavenge filter to the servo fuel heater and main oil/fuel heat exchanger to be cooled, before returning to the oil tank.

A bypass valve installed in parallel opens in case of filter clogging and a sensor sends clogging indication to the cockpit. At the same time, a pop-out indicator is triggered to give maintenance staff a visual warning.



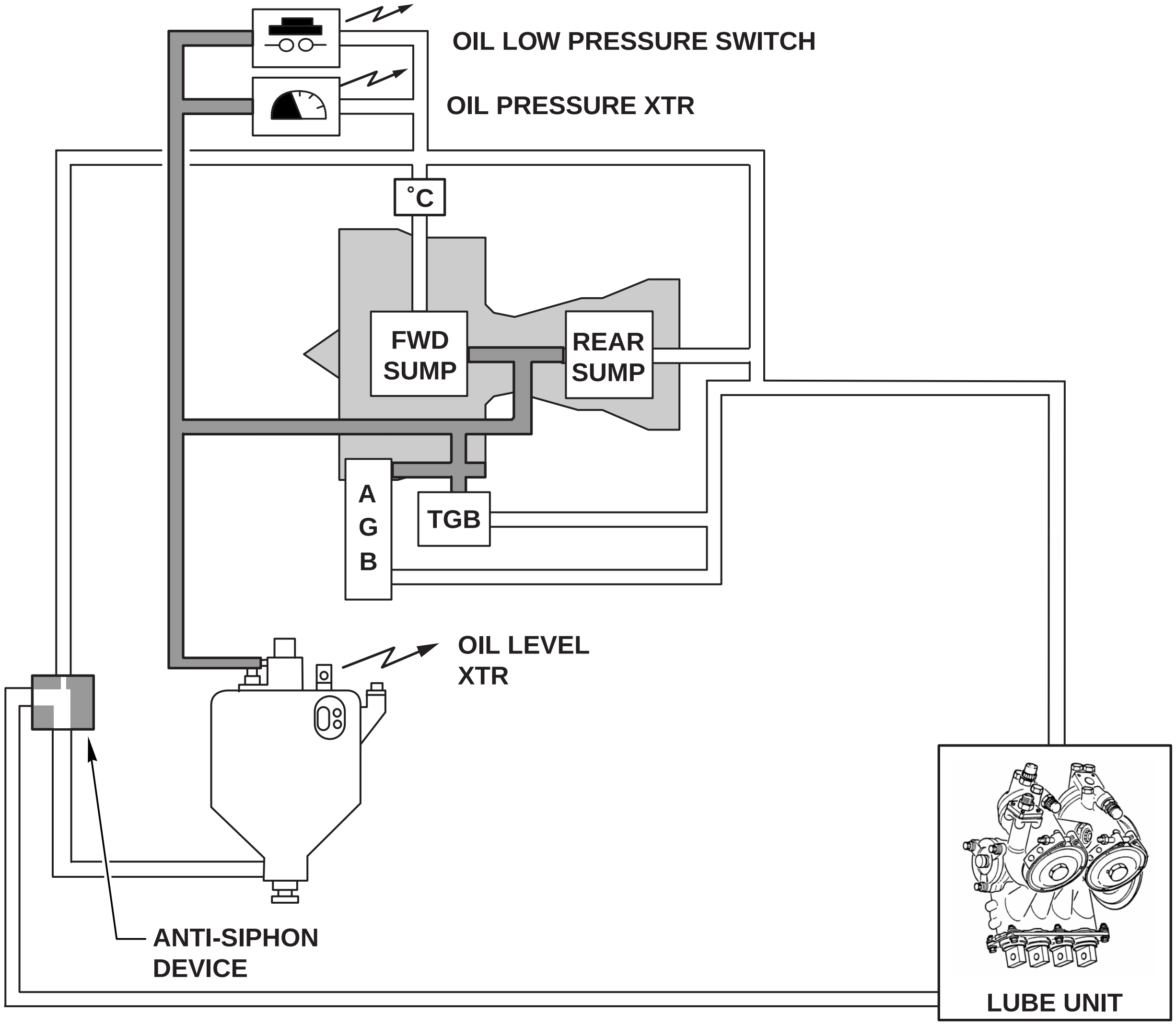
OIL SCAVENGE CIRCUIT

CTC-045-144-00

Oil circuit venting.

A venting system links the oil tank, the engine sumps and the gearboxes, in order to vent the air from the scavenge pumps and balance pressures between the different areas.

A dedicated pipe connects the forward and aft sumps for oil vapor collection and sumps pressure balancing.



OIL CIRCUIT VENTING

CTC-045-145-00

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OIL TANK

OIL TANK

The oil tank stores the engine oil and is installed on the fan case, at the 8 o'clock position, on one upper and two lower mounts with shock absorbers.

The tank body is made of light alloy and covered with a flame resistant coating to meet fireproof requirements. Five inner bulkheads add strength and reduce oil sloshing.

The cover is a light alloy casting, bolted on the oil tank body.

The tank has an oil inlet tube from the exchanger, an oil outlet to the lubrication unit and a vent tube.

To replenish the oil tank, there are a gravity filling port, a remote filling port and an overflow port.

A scupper drain ducts any oil spillage to the drain mast and a plug is provided for draining purposes.

The tank has a pressure tapping connected to a low oil pressure switch and oil pressure transmitter, that are used in cockpit indicating.

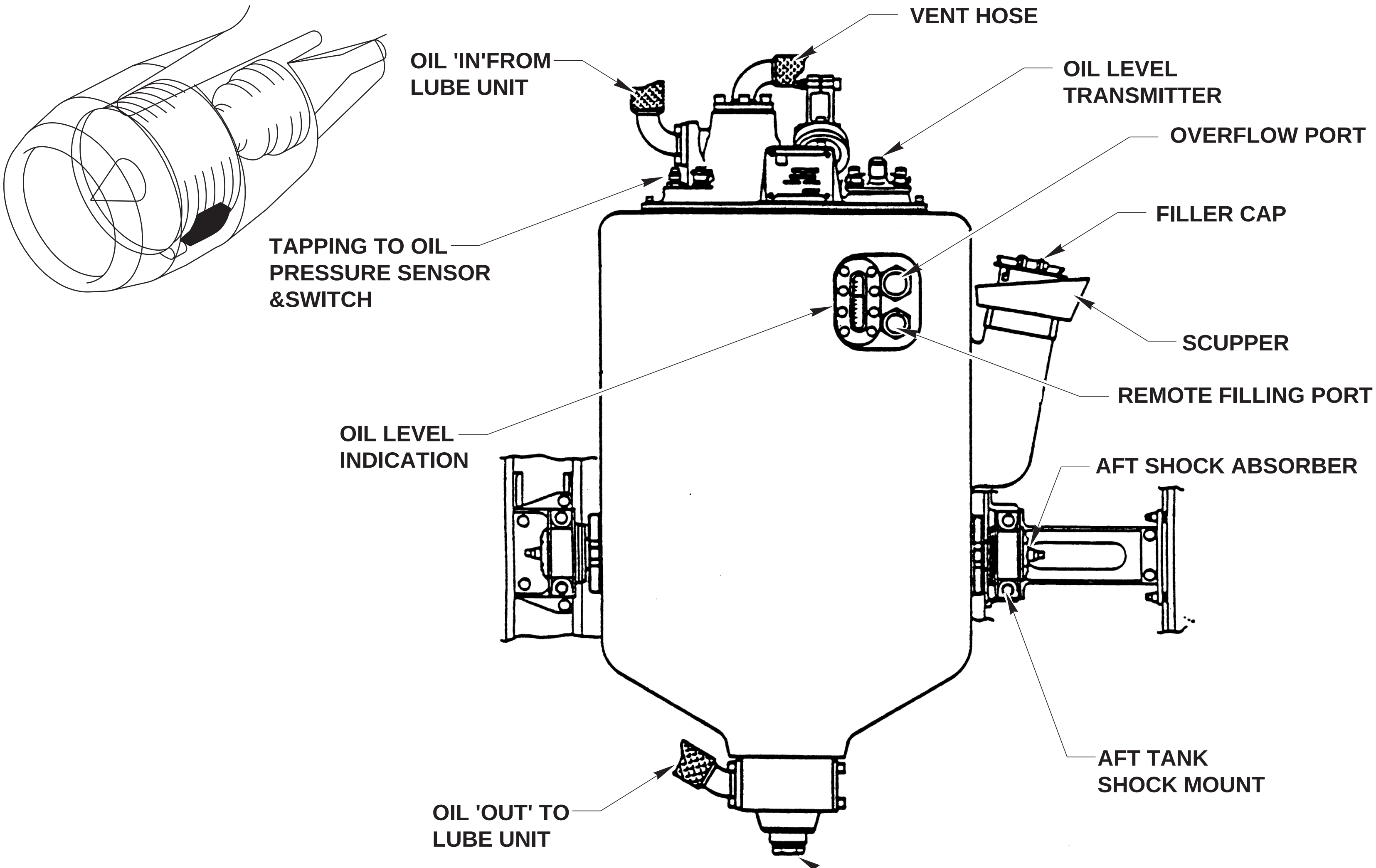
Between engine start and running conditions, the oil level drops, due to the gulping effect.

Oil level checks must be done within five to thirty minutes, after engine shutdown, due to oil volume changes.

To avoid serious injury, the oil filler cap must not be opened until a minimum of 5 minutes has elapsed after engine shutdown.

Oil tank characteristics :

	U.S. GALLONS	LITERS
Total tank volume	6	23
Oil capacity	5.2	19.6
Available oil capacity	5	19



OIL TANK

CTC-045-146-00

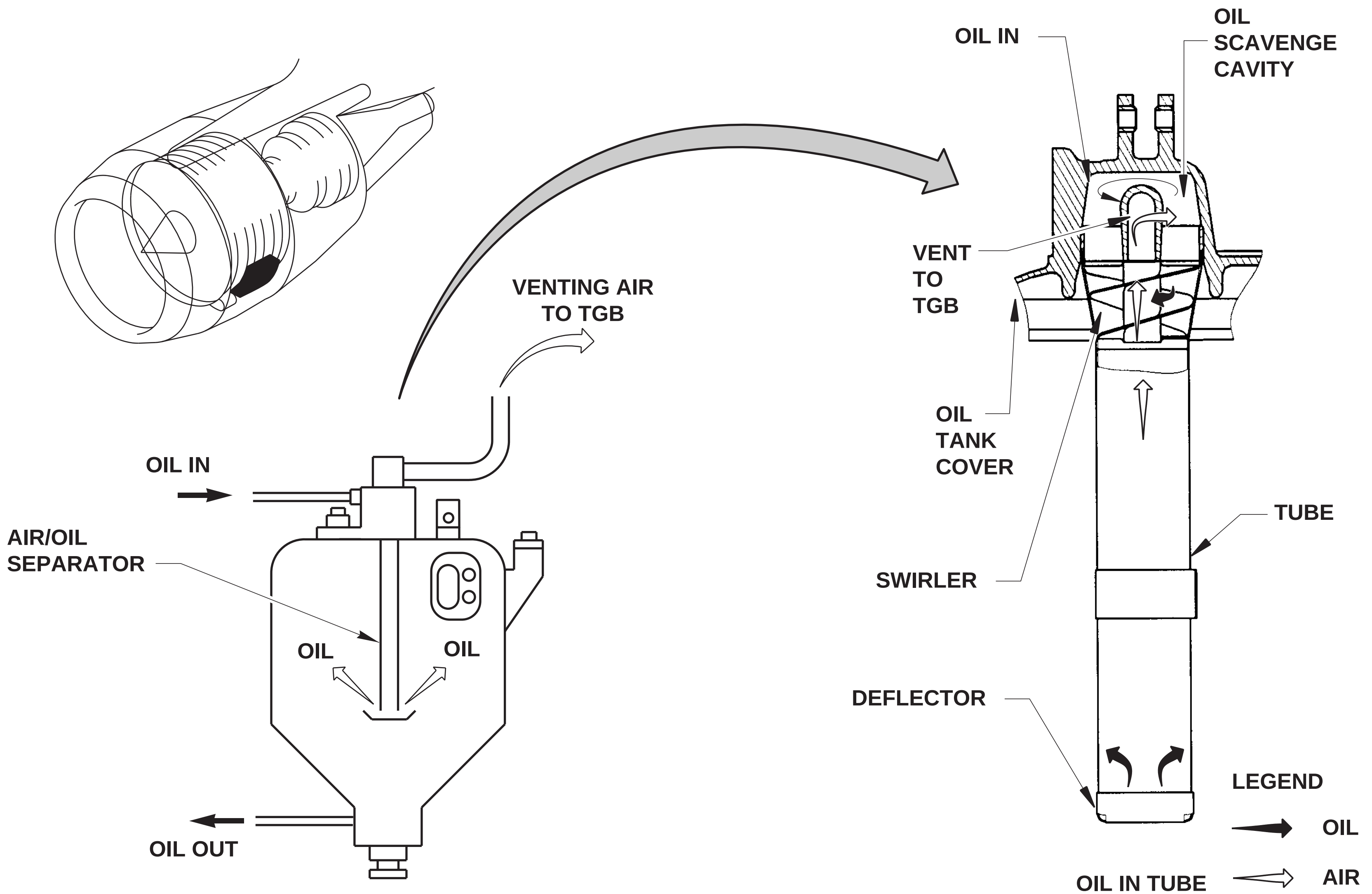
OIL TANK

The tank is vented through a duct connected to the transfer gearbox. During engine running operation, the oil is routed to the lubrication unit from an outlet port, located in the lower section of the tank to ensure constant oil availability.

A scavenge tube brings the air/oil mixture back to a cavity in the tank cover. Installed in the cavity, there is a tube with a swirler, which acts a static air/oil separator to centrifuge the oil for air extraction.

The other end of the tube has a deflector to prevent disturbances near the suction port. The tube length and the deflector prevent oil from going to the vent port, during excessive negative G flight conditions.

An electrical transmitter provides the aircraft indicating system with the oil level and a sight gauge, installed on the oil tank, can be used for visual level checks during ground maintenance tasks.



OIL STORAGE OPERATION

CTC-045-147-00

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ANTI-SIPHON

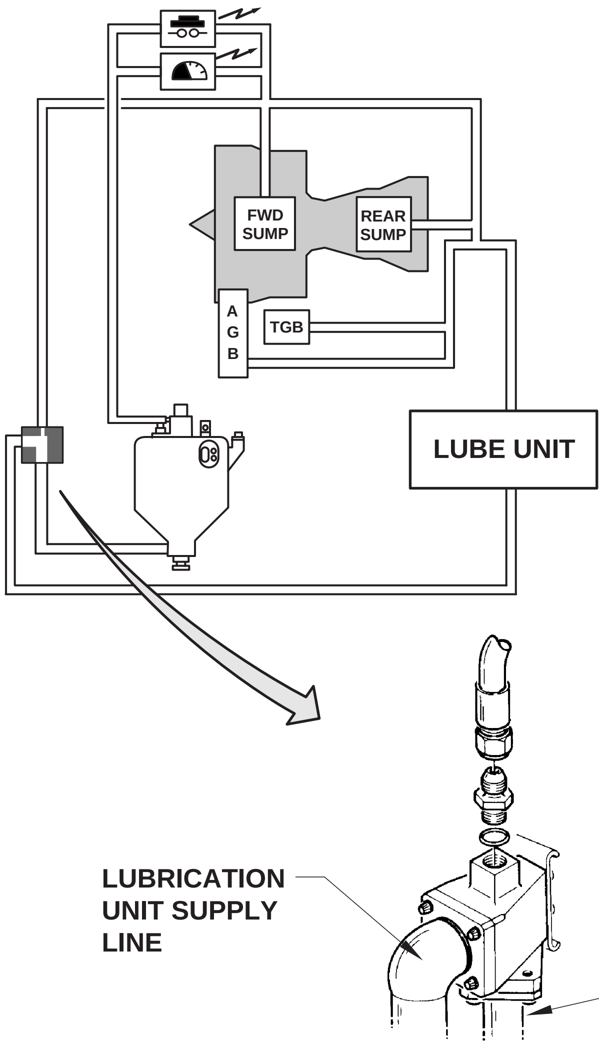
ANTI-SIPHON

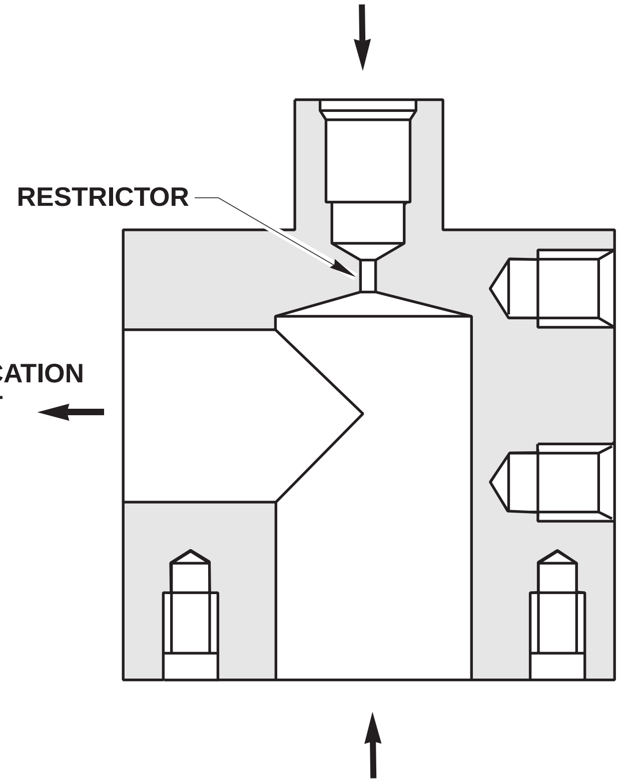
The anti-siphon device prevents oil from the oil tank being siphoned into the accessory gearbox, during engine shutdown.

Oil from the oil tank flows across the anti-siphon device, through its main orifice.

During engine operation, the downstream oil pressure from the supply pump enters the anti-siphon device, through a restrictor.

During engine shutdown, sump air pressure is able to enter the anti-siphon device and inhibit the oil supply flow.





ANTI SIPHON

CTC-045-148-00

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LUBRICATION UNIT

LUBRICATION UNIT

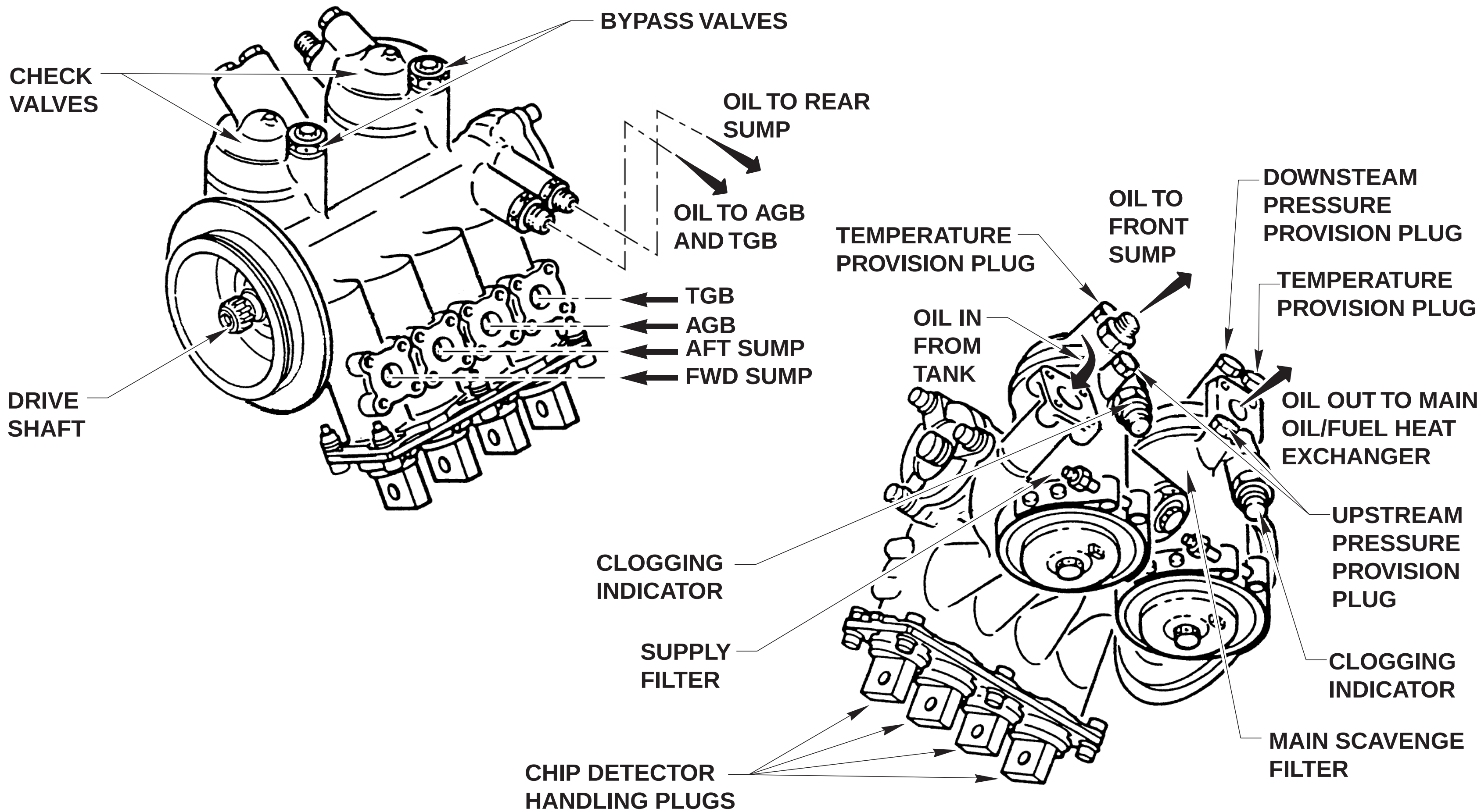
The lubrication unit provides:

- the required oil flows for engine component lubrication and cooling.
- engine oil sumps scavenge.
- oil filtering.
- oil circulation through the servo fuel heater and heat exchanger.

It is installed on the left hand side of the AGB front face.

It features a one-piece cast housing that contains:

- five positive displacement pumps (one supply, four scavenge), driven by the AGB through a single shaft
- a pressure relief valve
- an oil supply filter
- four magnetic chip detectors
- a common scavenge filter
- two filter clogging indicators
- two filter bypass valves



LUBRICATION UNIT

CTC-045-149-00

Oil filtering.

Oil filtering is done by an oil supply filter, four magnetic chip detector screens and a main scavenge filter.

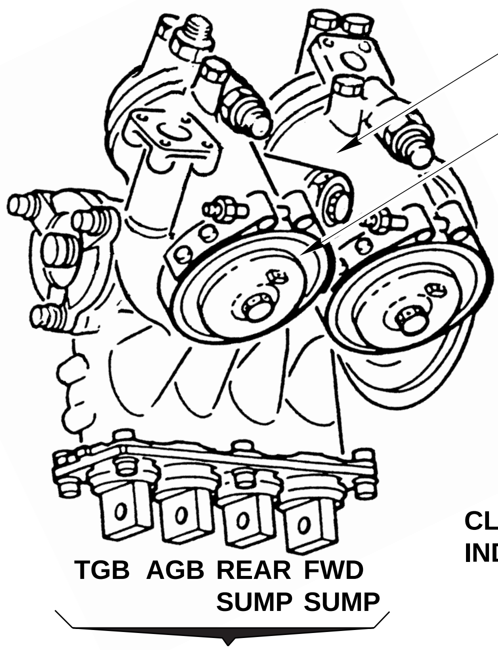
After leaving the common scavenge filter, the scavenged oil is cooled in the servo fuel heater and the oil/fuel heat exchanger, before being returned to the oil tank.

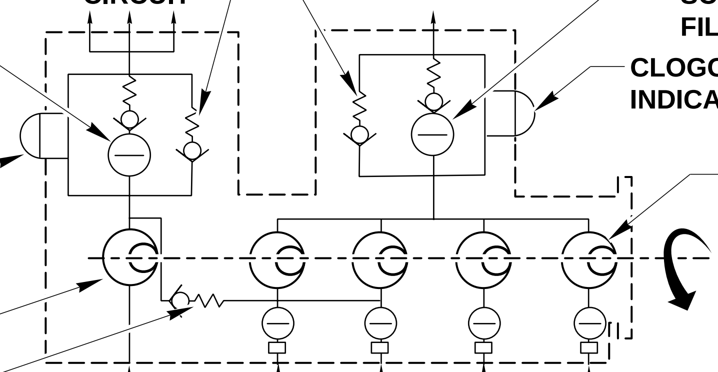
Both supply and scavenge filter cartridges are discardable.

The filtering capacity is 15 microns for the supply filter and 25 to 32 microns for the scavenge filter.

The filter bypass valves ensure a continuous oil flow in case of filter clogging.

The filter inlet and outlet pressures are applied on a spring-loaded piston valve. When the differential pressure exceeds the spring force, the valve opens.





OIL FILTERING

CTC-045-150-00

Clogging indicators.

The purpose of the pop-out indicators is to give indication of imminent filter clogging.

As the filters become dirtier, the difference between the inlet and outlet pressures increases, releasing a plunger which 'pops-out'.

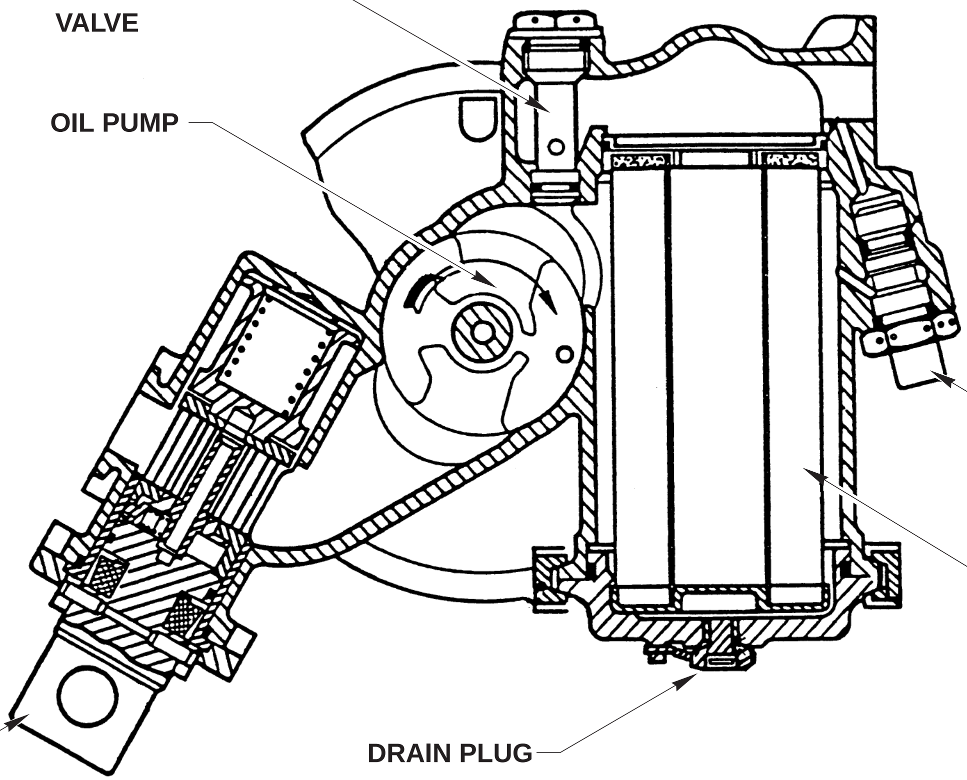
The differential pressure that activates the indicator is set at 29 psid for both filters. This is below the differential pressure needed to open the filter bypass valve.

The pop-out indicators must be reset manually.

Pressure relief valve.

The pressure relief valve protects the supply pump and circuit against abnormal output pressure buildup.

It bypasses oil from the supply circuit to the AGB scavenge circuit if the oil pressure between the two circuits exceeds 300 psid.



CTC-045-151-00

LUBRICATION UNIT

Magnetic chip detectors.

The four chip detectors consist of:

- a magnetic plug assembly.
- a sleeve.
- a spring-loaded sealing spool.

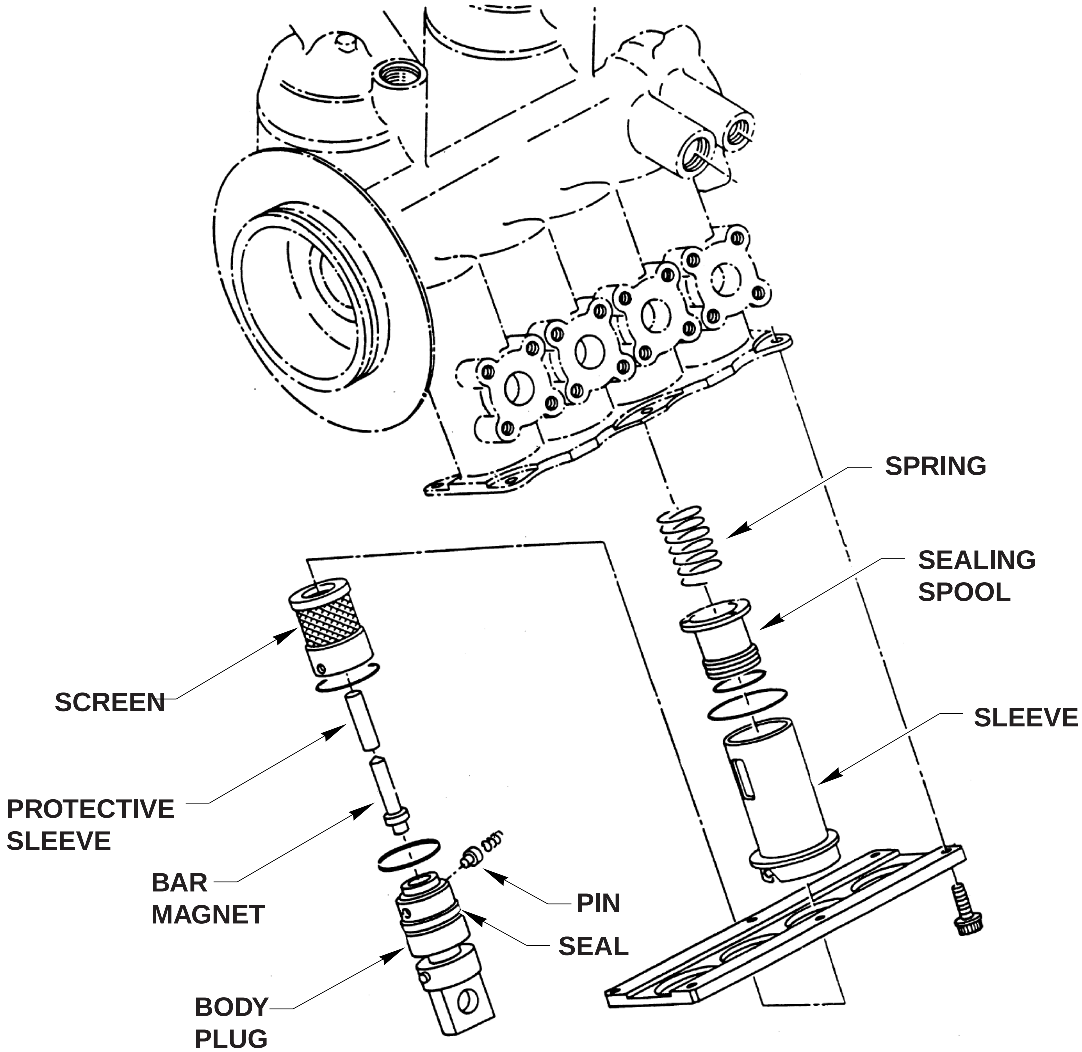
The plug assembly features a metal mesh screen, a spring-loaded pin to lock the screen in position, a magnet bar to attract magnetic particles, oil seals and a handle with bayonet-type locking pins.

The sleeve is installed in the lubrication unit housing and has a bayonet-type cut-out. Two holes allow scavenge oil flow when the magnetic plug is installed.

The spring-loaded spool is installed in a bore of the lubrication unit housing. When the magnetic plug assembly is removed, a spring pushes the sealing spool into the sleeve.

This provides positive sealing of the oil circuit, minimizes oil spillage during plug inspection and prevents contamination of the oil circuit.

When the plug is re-installed, it pushes back the sealing spool and re-opens the scavenge circuit.



MAGNETIC CHIP DETECTOR

CTC-045-152-00

Pump design principle.

The five pumps are positive displacement pumps, powered by a single shaft.

Their design consists of two rotor gears rotating in an eccentric ring.

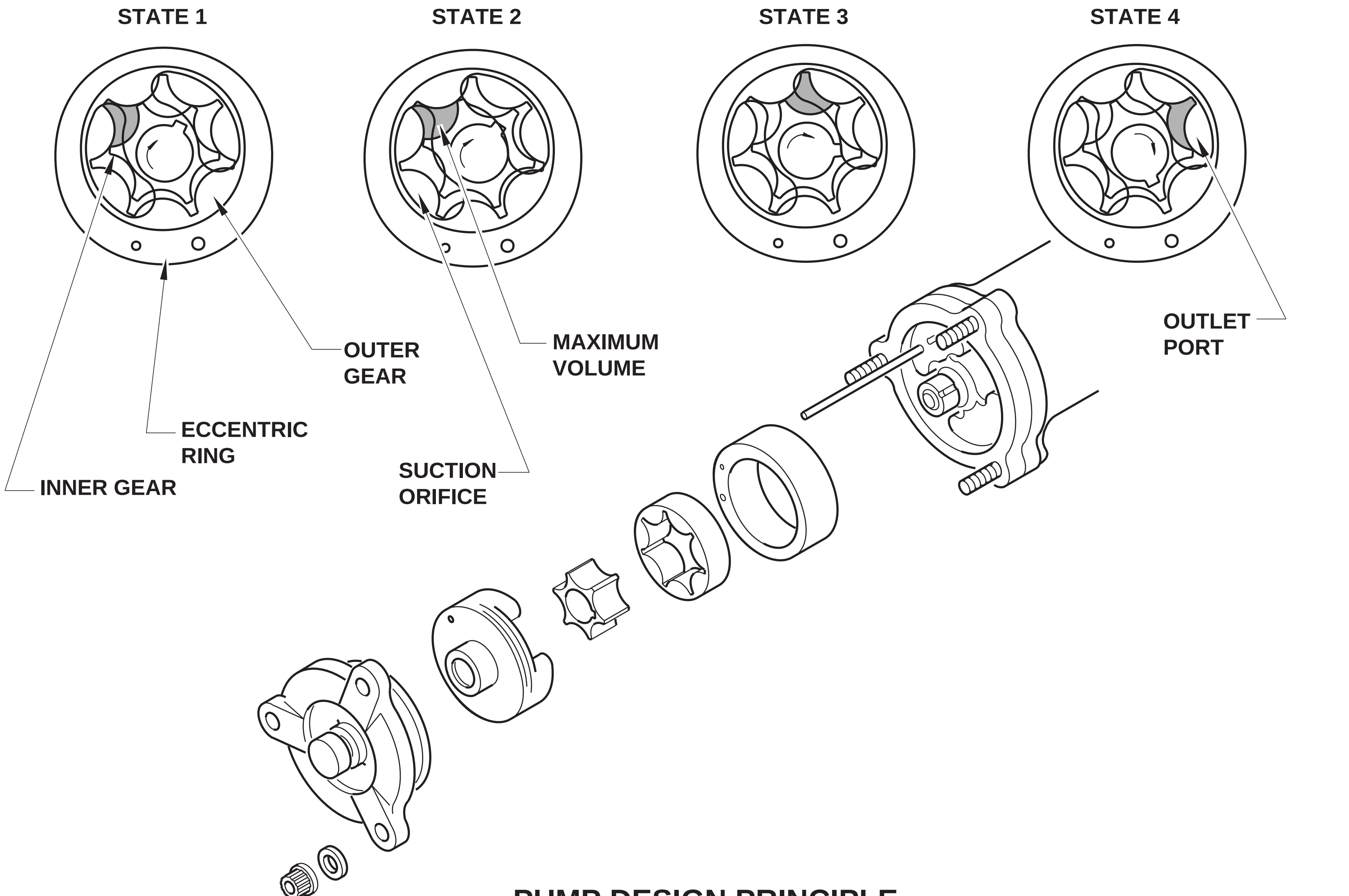
The outer gear (driven gear) has one tooth more than the inner gear (driver gear). The gears rotate in the same direction, but with different angular speeds.

The volume corresponding to the missing tooth is, therefore, displaced from the inlet to the outlet.

Since the two gears rotational axes are offset, the area between two teeth profiles increases up to a maximum volume during half a turn.

During this first half cycle, the increased volume creates a vacuum and pumps in the oil from the inlet orifice.

During the second half cycle, the volume decreases between the teeth, causing the oil to be discharged through the outlet port.



CTC-045-153-00

PUMP DESIGN PRINCIPLE

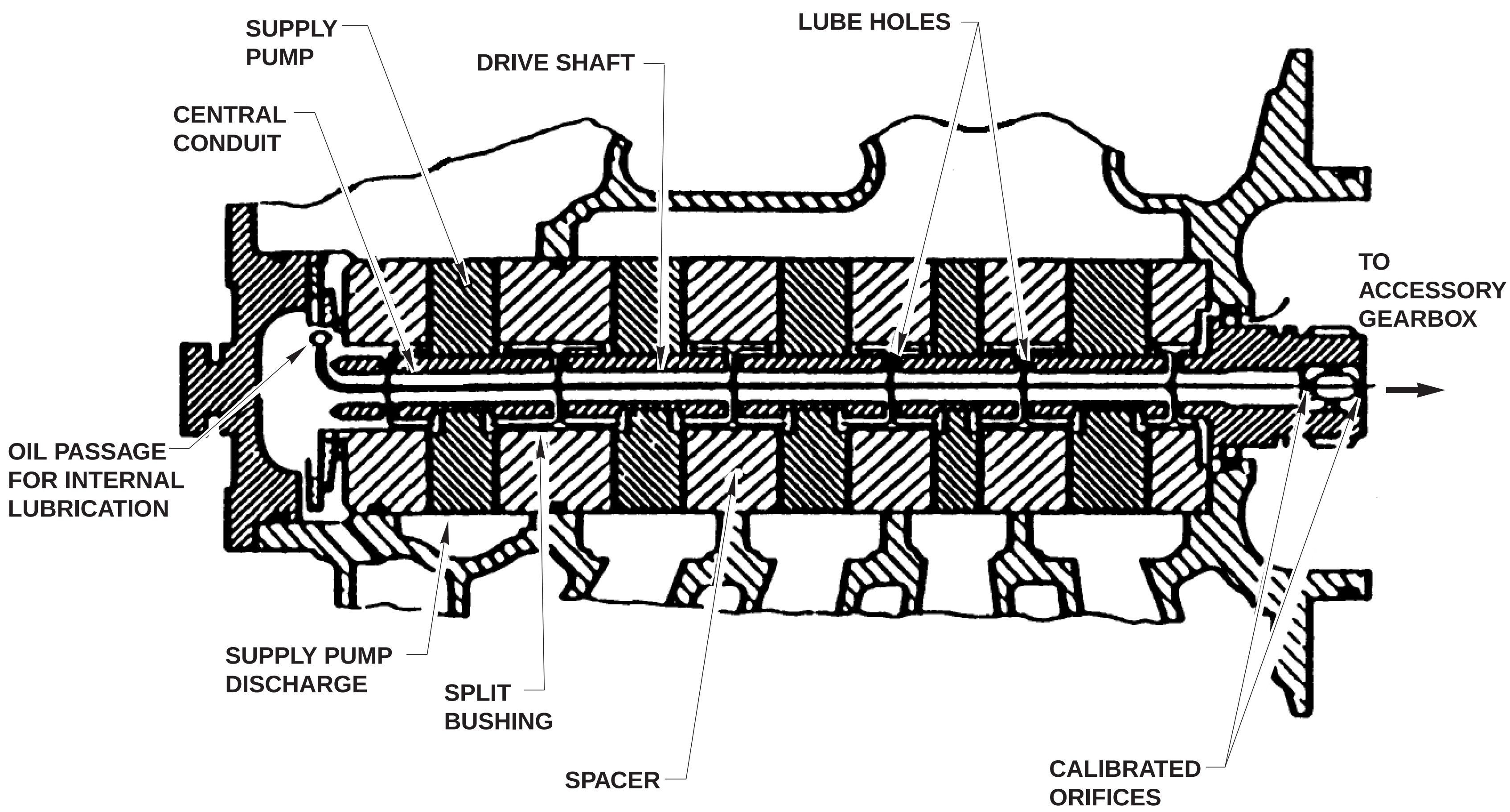
Lube unit internal lubrication.

Internally, the lube unit is lubricated with supply pump outlet oil, which flows within the drive shaft of the unit.

The oil flow lubricates the external splines of the shaft aft end, via two calibrated holes, and then circulates towards the AGB.

The AGB mounting pad has no carbon seal.

The lube unit has an O-ring for sealing purposes.



LUBE UNIT INTERNAL LUBRICATION

CTC-045-154-00

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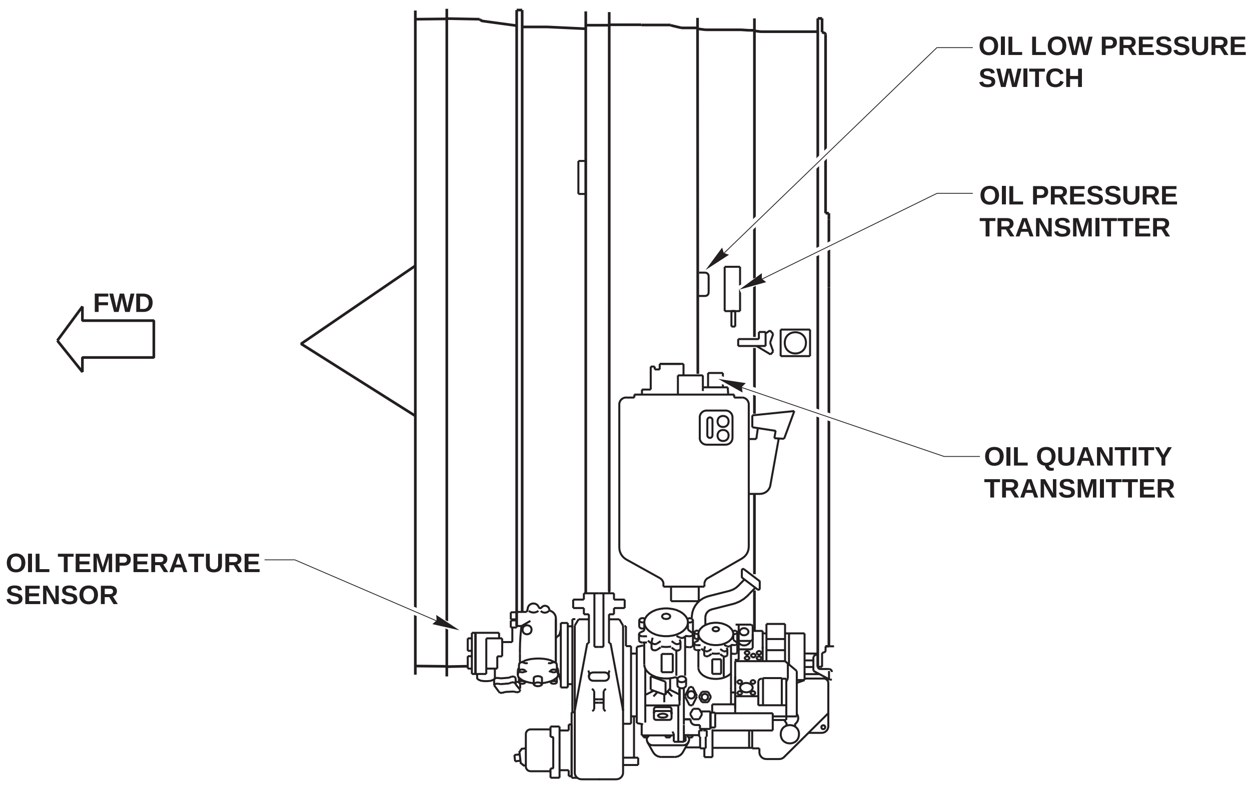
OIL INDICATING COMPONENTS

OIL INDICATING COMPONENTS

The purpose of the indicating components is to provide oil system parameters information to the aircraft systems, for cockpit indication and, if necessary, warning.

The system includes mainly :

- an oil quantity transmitter.
- an oil temperature sensor.
- an oil pressure transmitter.
- an oil low pressure switch.



CTC-045-155-00

INDICATING COMPONENTS

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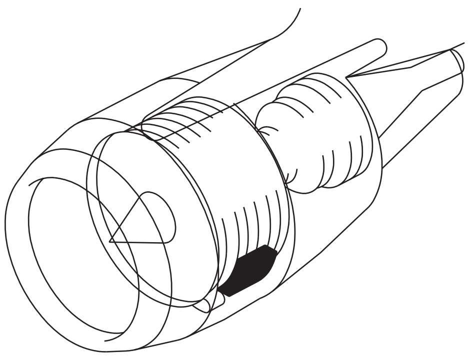
OIL QUANTITY TRANSMITTER

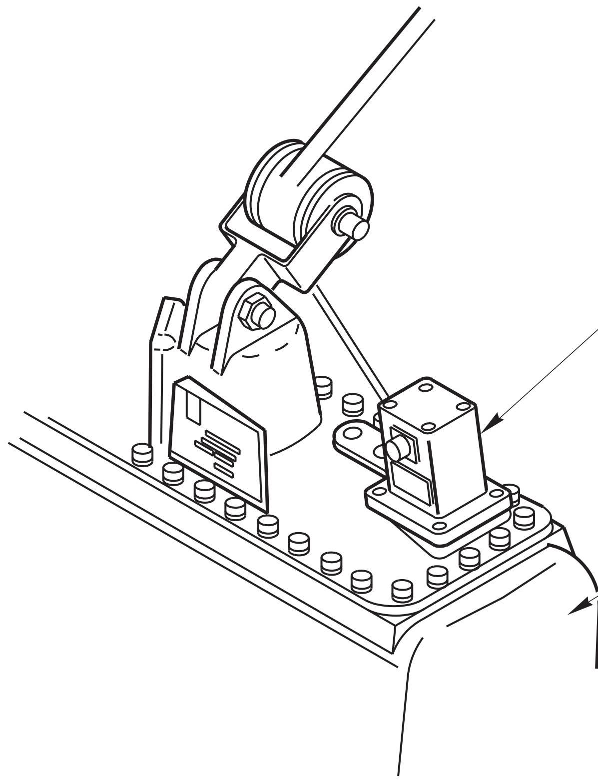
OIL QUANTITY TRANSMITTER

The oil quantity transmitter provides indication of the oil level to the cockpit, for oil system monitoring.

The transmitter is installed on the top of the engine oil tank and has an electrical connection to the aircraft EIU.

The lower section of the oil quantity transmitter is enclosed in the tank. Within this section is a device which transforms the oil level into a proportional electrical signal.





CTC-045-156-00

OIL QUANTITY TRANSMITTER

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OIL TEMPERATURE SENSOR

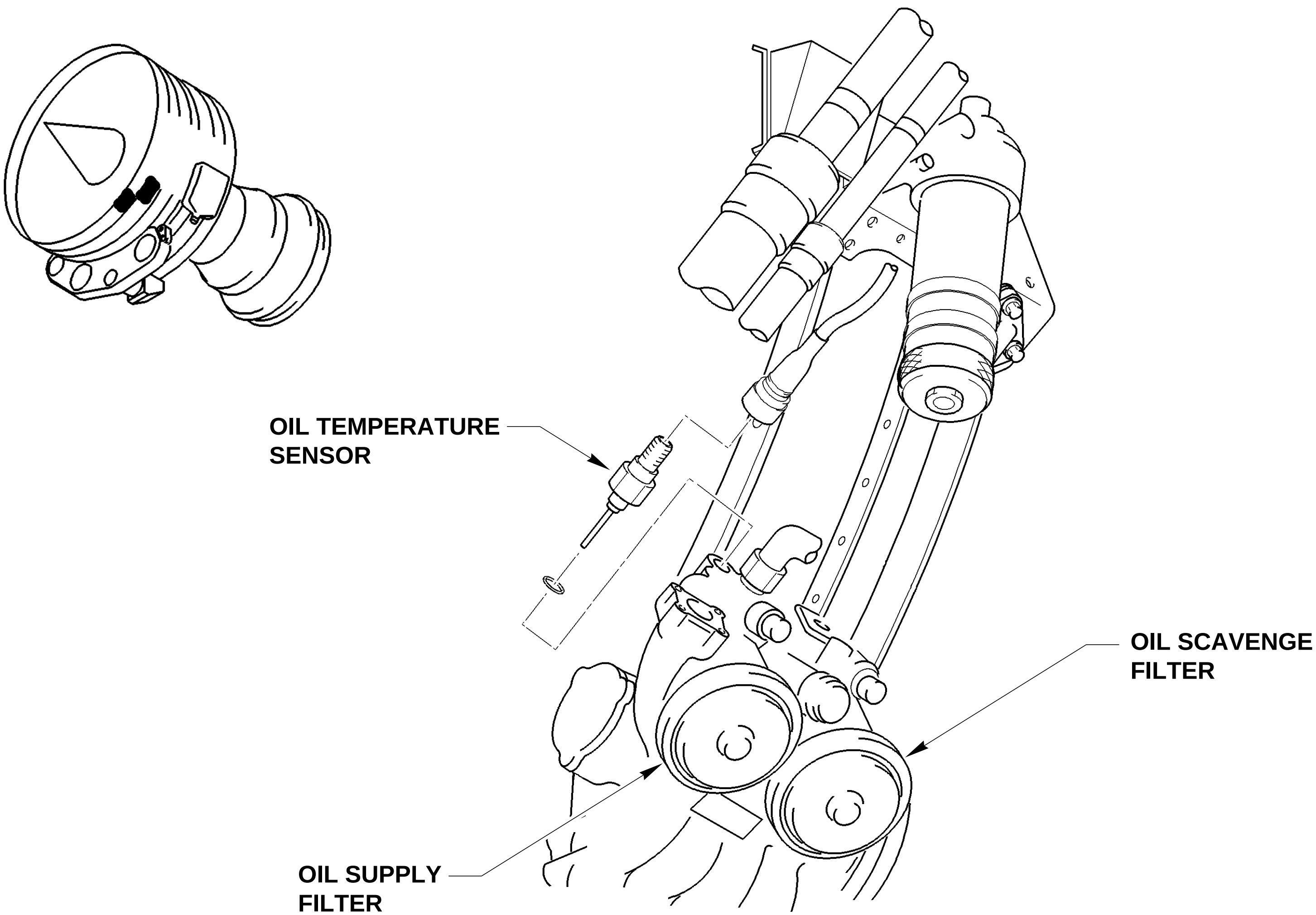
OIL TEMPERATURE SENSOR

The oil temperature sensor transmits the engine oil temperature to the aircraft indicating system and is installed on the engine lubrication unit.

A sensing probe transforms the oil temperature into an electrical signal, routed through a connector.

This connection links the probe to the aircraft indicating system and the cockpit, where the information is displayed.

In case of a problem with this oil temperature sensor, the A/C system is able to use information from the TEO sensor as a backup signal. The opposite is not possible.



CTC-045-157-00

OIL TEMPERATURE SENSOR

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OIL PRESSURE TRANSMITTER AND OIL LOW PRESSURE SWITCH

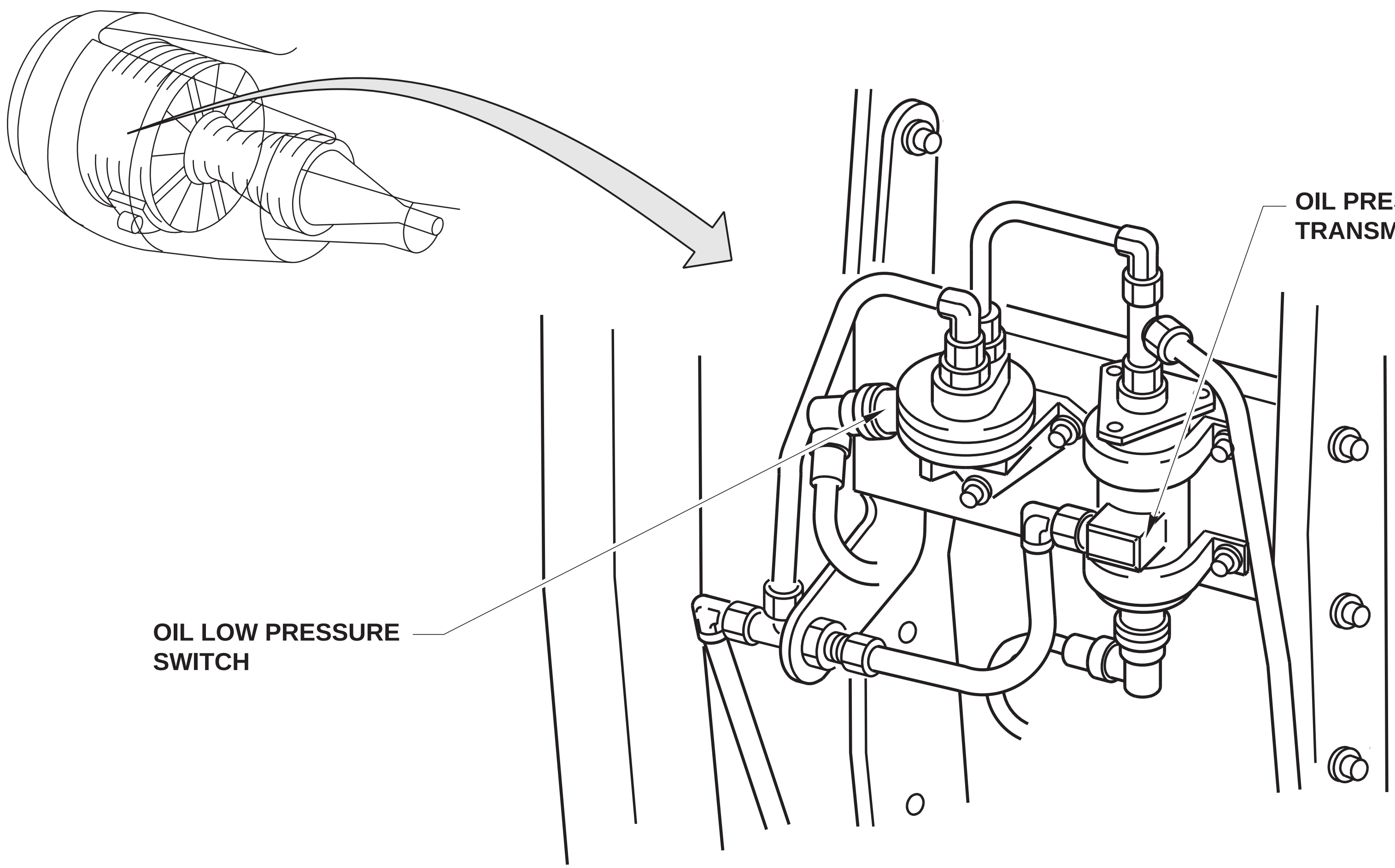
OIL PRESSURE TRANSMITTER AND OIL LOW PRESSURE SWITCH

The oil pressure transmitter and oil low pressure switch transmit information to the aircraft systems for cockpit indication and oil system monitoring.

They are installed on the left handside of the engine fan case, above the oil tank, at about the 9 o'clock position.

They have 2 connecting tubes and 2 electrical connections :

- one tube to the forward sump oil supply line
- one tube to the vent circuit, through the oil tank
- one connection to the aircraft indicating systems
- one connection to the Flight Warning Computer (FWC).



CTC-045-158-00

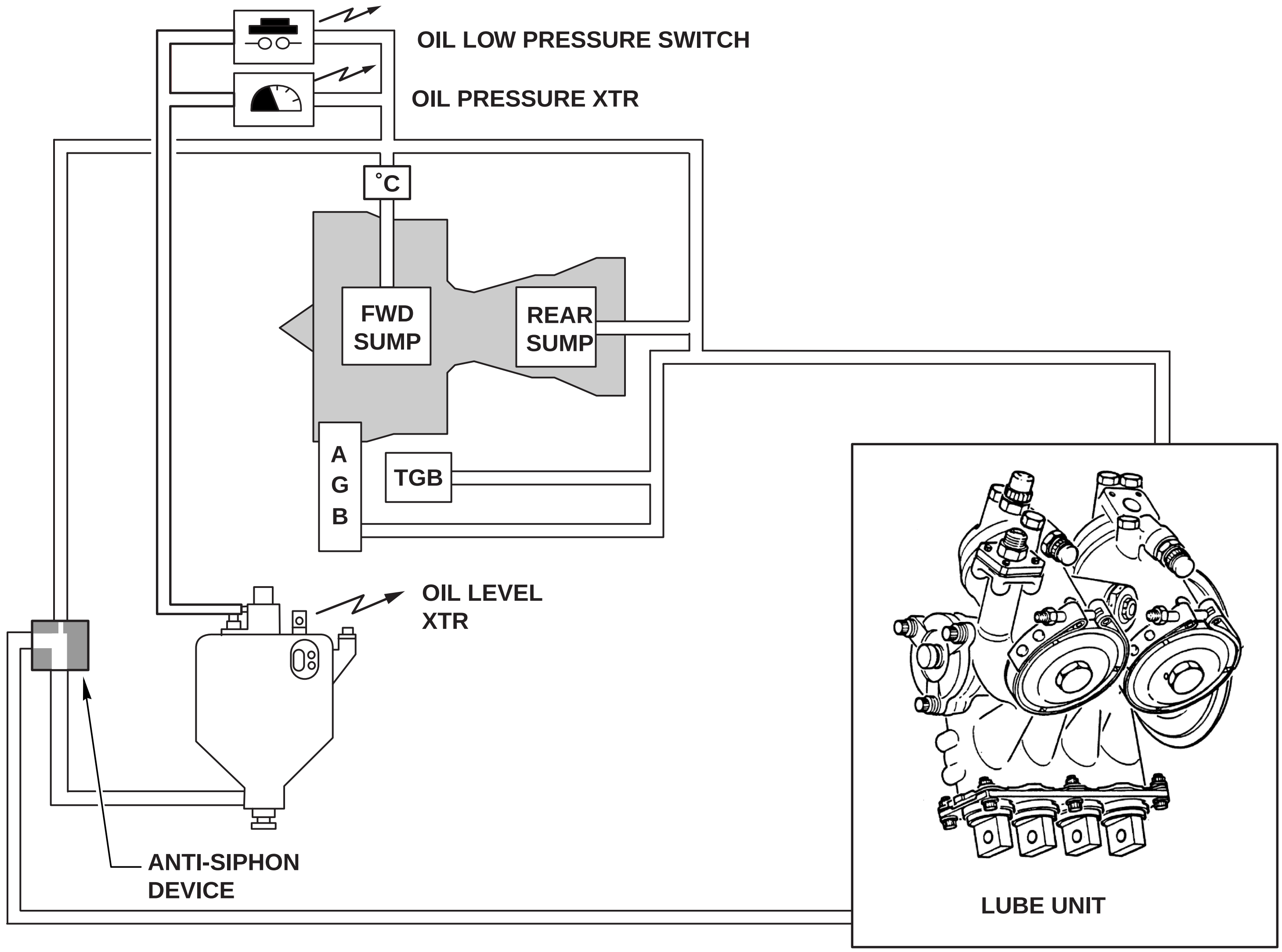
OIL PRESSURE TRANSMITTER AND LOW PRESSURE SWITCH

OIL PRESSURE TRANSMITTER AND OIL LOW PRESSURE SWITCH

An oil pressure signal, from the forward sump supply line, is applied on one side of the transmitter, and vent circuit pressure from the oil tank is applied on the other side.

This differential pressure, applied to a transducer, is transformed into a proportional electrical signal.

The electrical information is then sent to the aircraft indicating system which transforms and transmits the signal for final indication in the cockpit.



OIL PRESSURE TRANSMITTER

CTC-045-159-00

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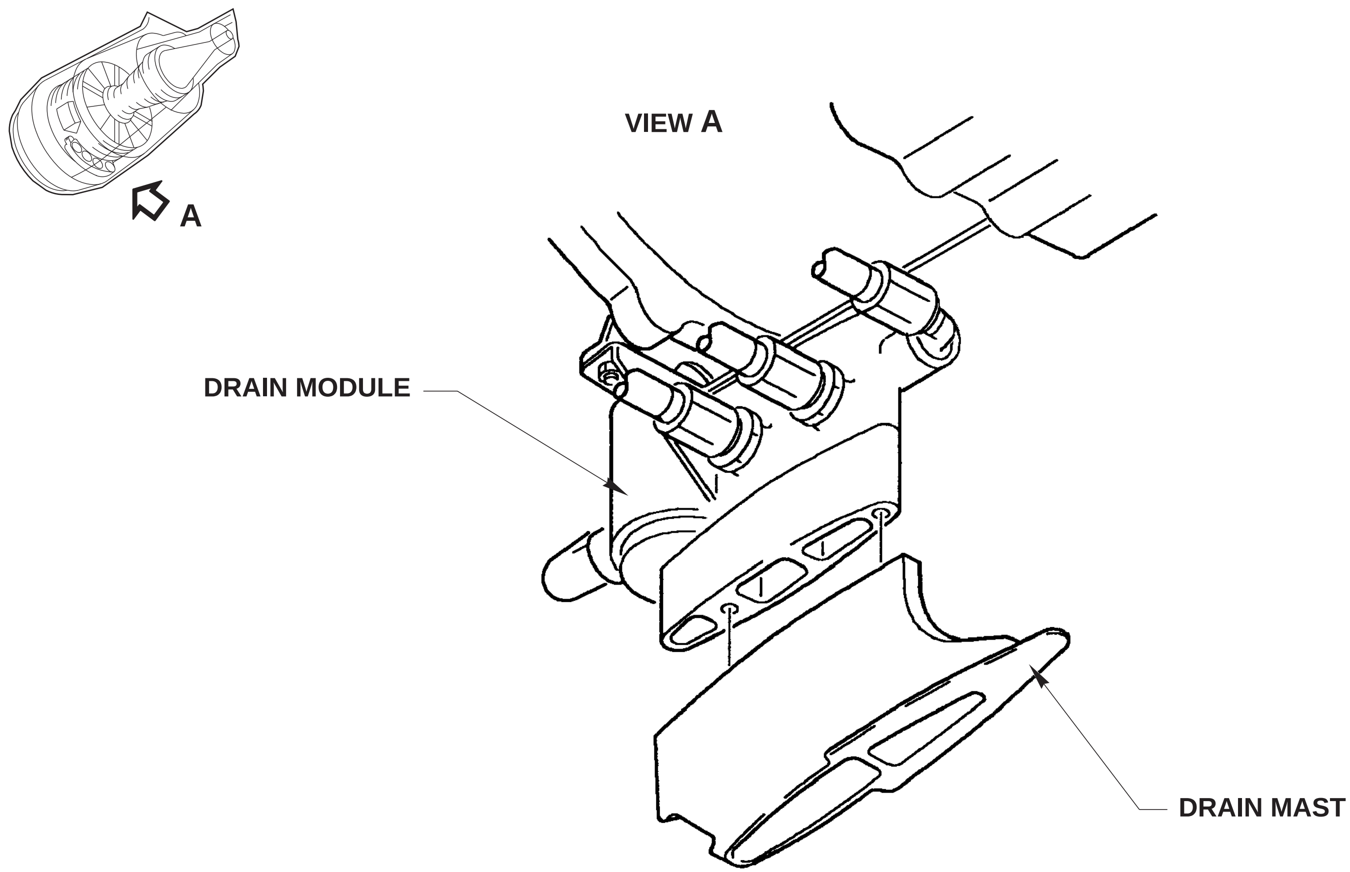
POWER PLANT DRAINS

POWER PLANT DRAINS

Lines are provided on the engine to collect waste fluids and vapours that come from engine systems and accessories and drain them overboard.

The system consists of a drain collector assembly (not shown), a drain module and a drain mast.



CTC-045-160-00

DRAIN MAST

POWER PLANT DRAINS (CONTINUED)

Drain collector assembly

The drain collector assembly is attached to the aft side of the engine gearbox.

It is composed of 4 drain collectors with manual drain valves and 2 holding tanks.

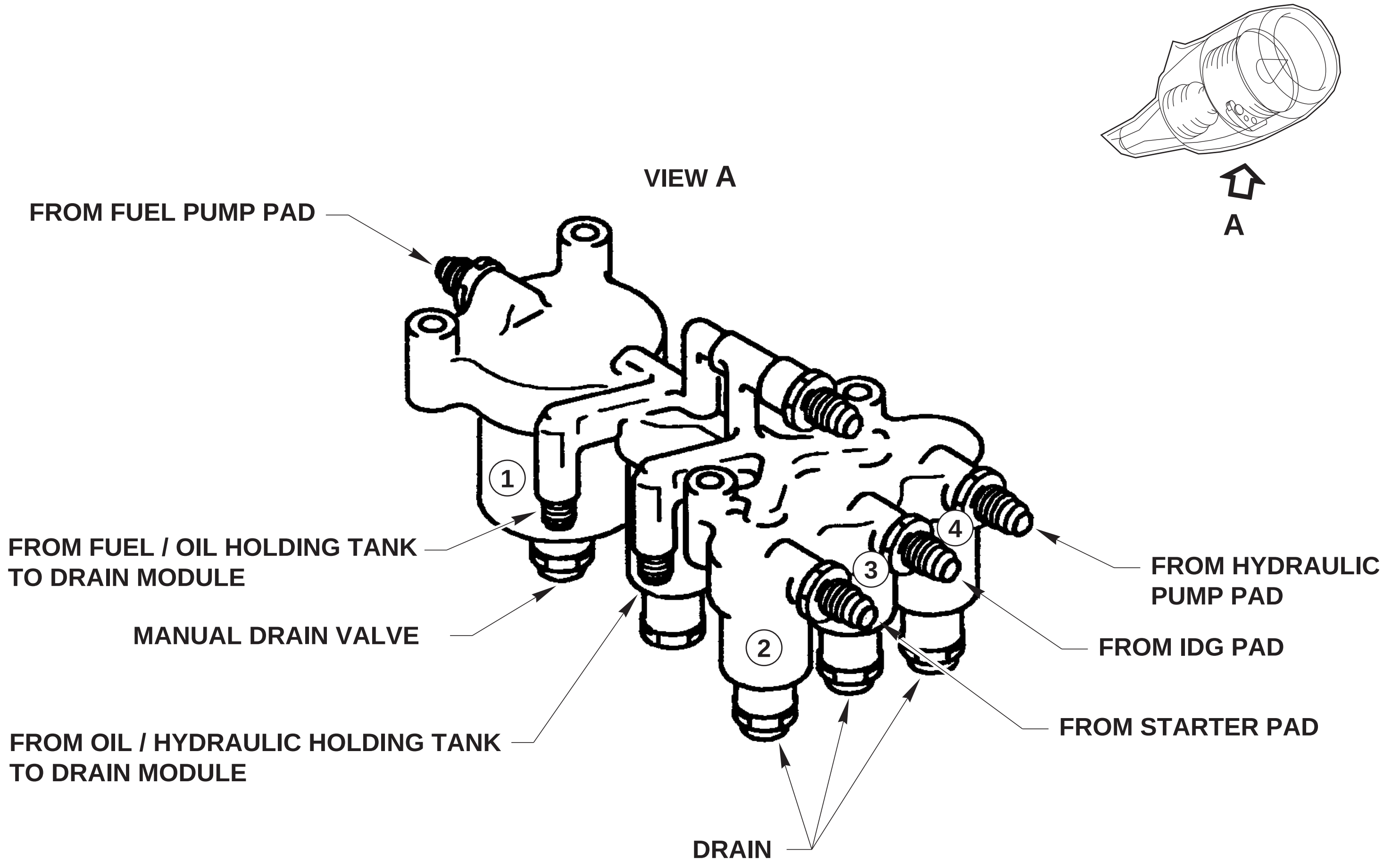
The drain collectors enable leakages to be collected separately from 4 seals :

- fuel pump
- IDG
- starter
- hydraulic pump

Each collector is identified with the accessory seal pad to which it is connected.

The manual drain valves are installed at the bottom of each collector, enabling the source of leakages to be found during troubleshooting.

The collector retains fluids until it is full, then the overflow goes to 2 tanks, called the fuel/oil holding tank and the oil/hydraulic holding tank. The first receives the fuel pump overflow and the second receives the IDG, starter and hydraulic pump overflows.



CTC-045-161-00

DRAIN COLLECTOR ASSEMBLY

POWER PLANT DRAINS (CONTINUED)

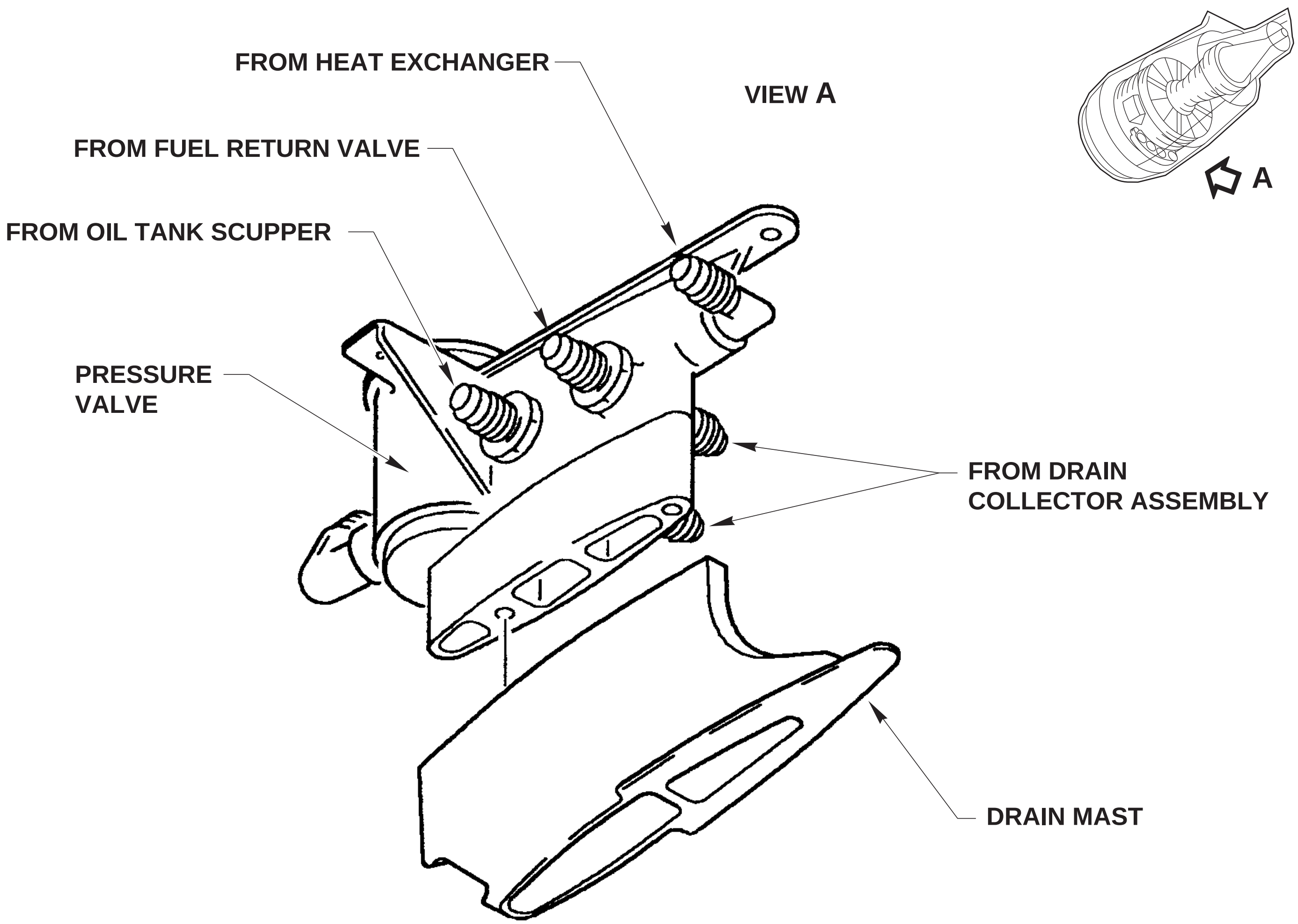
Drain module

The drain module is directly attached to the aft side of the engine gearbox and supports the drain mast.

It receives the overflow from the drain collector assembly. A valve pressurizes the holding tanks and enables fluid to be discharged overboard through the drain mast.

It also receives fluids that are discharged directly overboard through the drain mast :

- the oil tank scupper
- the forward sump
- the fan case
- the oil/fuel heat exchanger
- the VBV
- the VSV
- the turbine clearance control
- the aft sump
- the 6 o'clock fire shield
- FRV



CTC-045-162-00

DRAIN AND DRAIN MAST

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THRUST REVERSER

THRUST REVERSER

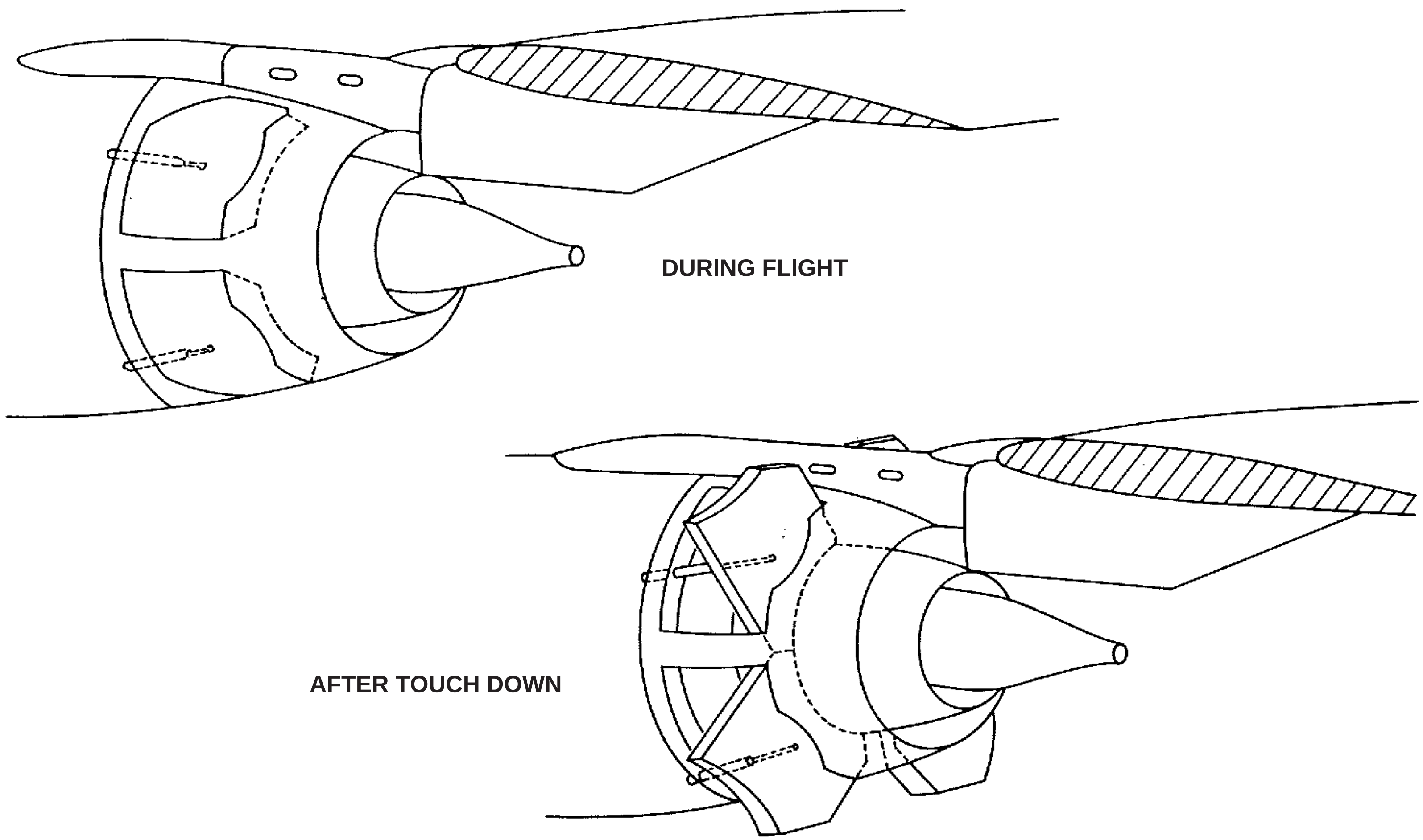
The Thrust Reverser (T/R) system provides additional aerodynamic breaking during aircraft landing.

It can only be operated on ground, with the engines at idle speed and the throttle lever in the reverse position.

The fan thrust reverser is part of the exhaust system and is located just downstream of the fan frame. It consists of blocker doors opening on cockpit order.

In direct thrust configuration, during flight, the cowlings mask the blocker doors, thus providing fan flow ducting.

In reverse thrust configuration, after landing, the blocker doors are deployed in order to obstruct the fan duct. The fan flow is then rejected laterally with a forward velocity.



THRUST REVERSER OPERATION

CTC-045-163-00

The T/R system is fully controlled by the ECU, and consists of:

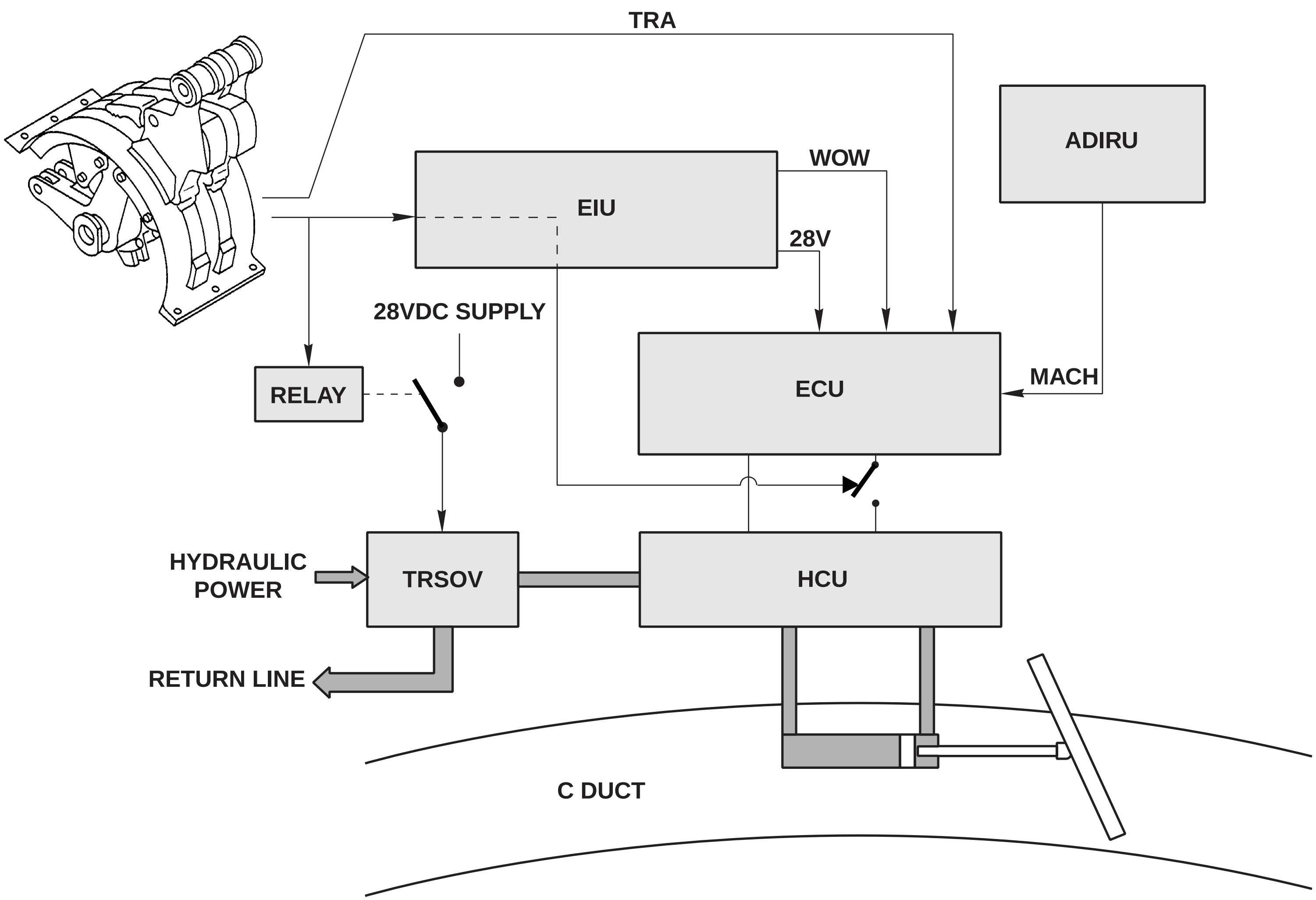
- the cockpit throttle assembly.

- the Engine Interface Unit (EIU) which supplies both channels of the ECU with 28 VDC for the T/R solenoid valves, and with the Weight On Wheel (WOW) aircraft parameter.

- the Air Data and Inertial Reference Unit (ADIRU), which provides Mach number to the ECU.

- the Hydraulic system, including the Thrust Reverser Shut-Off Valve (TRSOV) and the Hydraulic Control Unit (HCU).

- the C-ducts and blocker doors with their related actuators and deploy and stow switches.



T/R SYSTEM

CTC-045-164-00

Thrust reverser position.

The blocker doors are monitored in the open or closed positions by a series of deploy and stow switches.

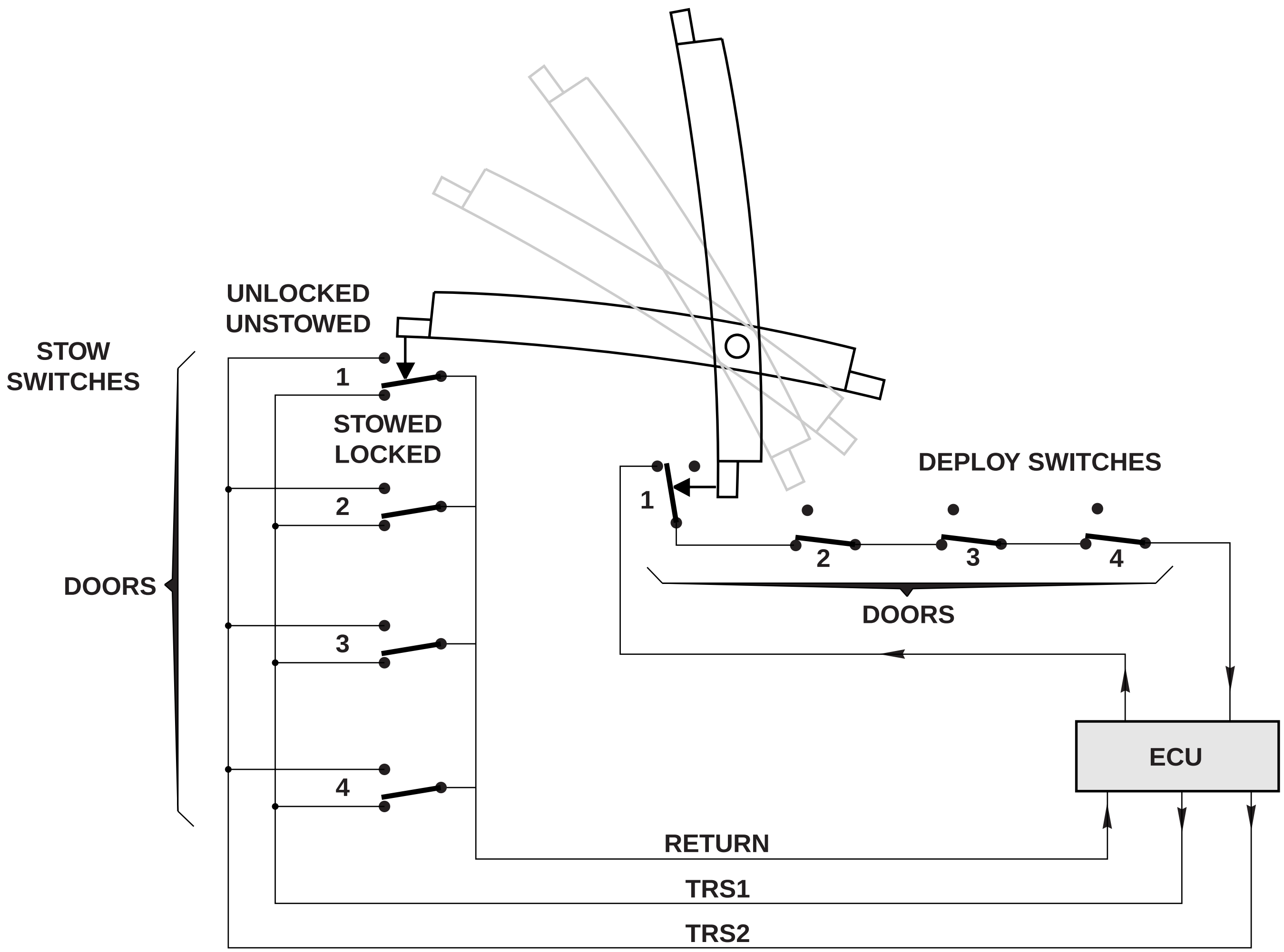
These switches provide the ECU with T/R door positioning:

Stow switches.

TRS1
All switches open = 4 doors unstowed
One switch closed = at least one door stowed
TRS2
All switches open = 4 doors stowed
One switch closed = at least one door unstowed

Deploy switches.

Any switch open = at least one door not deployed
All switches closed = all doors deployed



CTC-045-165-00

STOW/DEPLOY SWITCHES

Thrust reverser logic.

Based upon the T/R status, the ECU will apply full reverse thrust only if:

- the four doors are detected open.
- the engine is running.
- the aircraft is on ground.

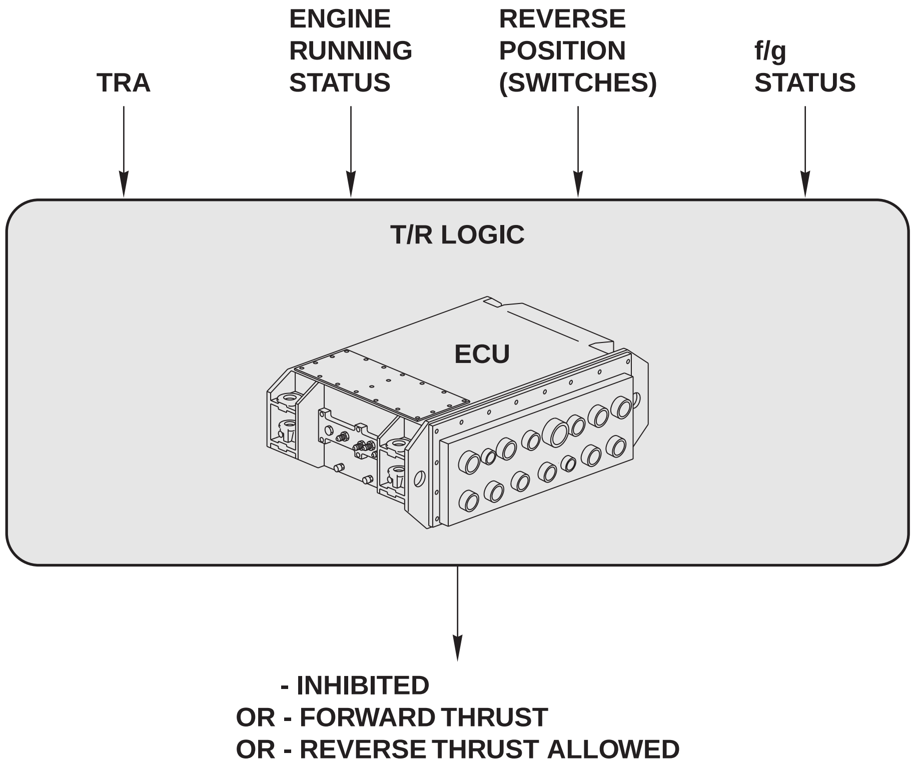
In transient, idle speed is selected.

The ECU receives signals from aircraft and engine systems, such as the TRA position, flight/ground status and position of the stow and deploy switches. Depending on these inputs, the T/R logic within ECU will either:

- inhibit the thrust reverser, or
- allow forward thrust, or
- allow reverse thrust.

A test is available through the MCDU menus, to check some T/R components. To perform this test, the conditions are:

- aircraft on ground.
- engine not running.



T/R LOGIC

CTC-045-166-00

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INDICATING SYSTEM

Engine indicating systems.

The engine is equipped with sensors that monitor :

- temperature
- pressure
- speed
- vibration
- fuel flow

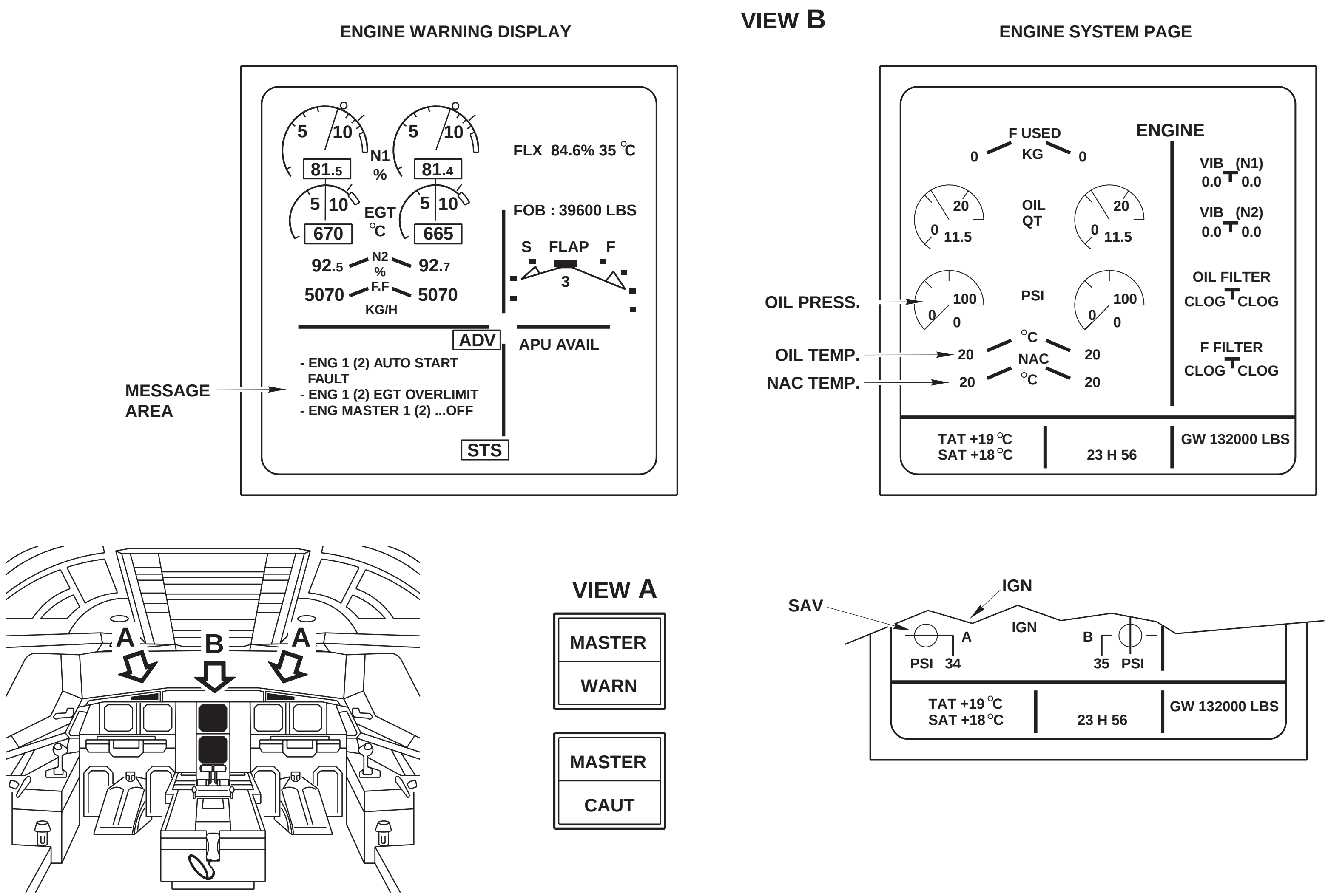
It also has switches that provide indication for :

- oil, fuel clogging.
- thrust reverser hydraulic pressure.
- position (SAV, T/R, Overspeed governor, etc.…).

Depending on the data transmitted, messages are generated on the following devices :

- Upper ECAM : Engine Warning Display (EWD).
- Lower ECAM : Systems Display (SD).
- Master caution, master warning.
- Audible chimes and oral warning.

These messages are used to run the engine under normal conditions throughout the operating range, or to provide warning messages to the crew and maintenance personnel.
The master caution and warning are located in front of the pilot on the glareshield panel.



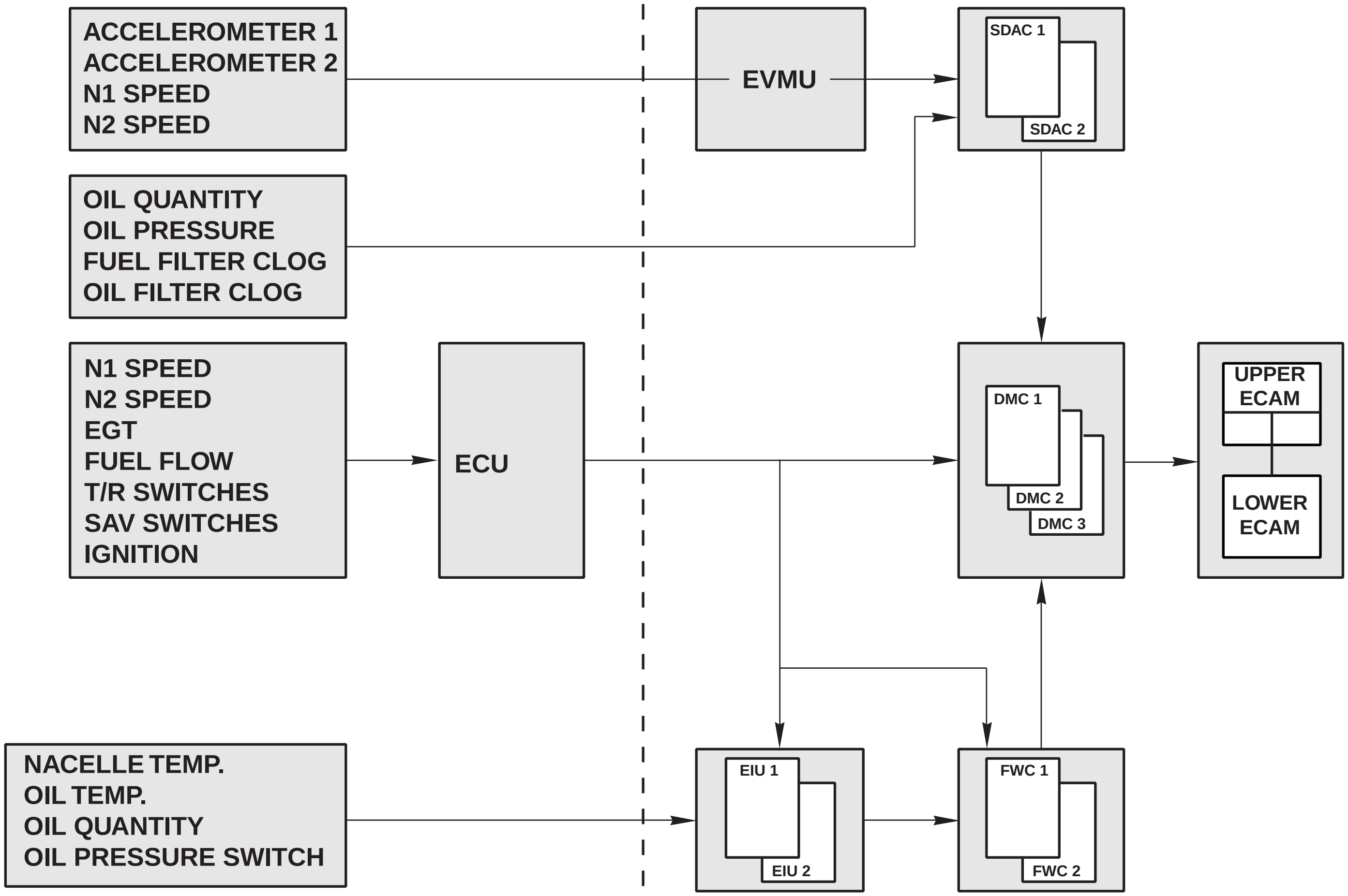
CTC-045-167-00

ENGINE INDICATING SYSTEM

Aircraft computers.

The aircraft computers that are linked to the engine are :

- 2 System Data Acquisition Concentrators (SDAC).
- 3 Display Monitoring Computers (DMC).
- 2 Flight Warning Computers (FWC).
- 2 Engine Interface Units (EIU).
- 1 Engine Vibration Monitoring Unit (EVMU) .



CTC-045-168-00

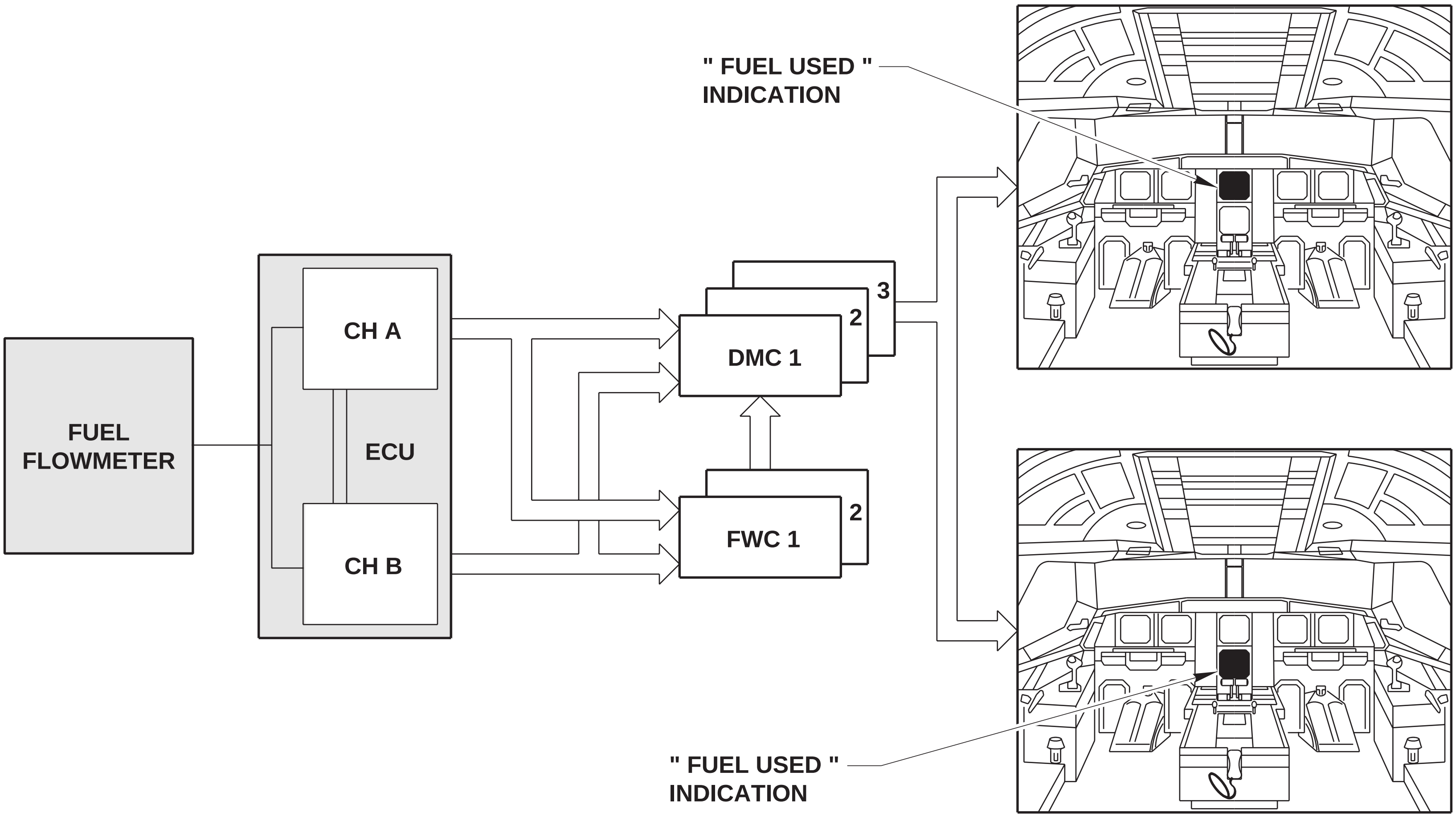
ENGINE INDICATING SYSTEM DESCRIPTION

Fuel indicating

The fuel flow transmitter sends electrical analog signals to the ECU channels A and B.

These signals are then digitized inside the ECU and sent through ARINC 429 for 'fuel flow' and 'fuel used' indication, as follows :

- through the DMC's N° 1, 2, and 3, for display on the ECAM.
- through the FWC,s N° 1 and 2, for warning activation and display on the ECAM.



FUEL INDICATING

CTC-045-169-00

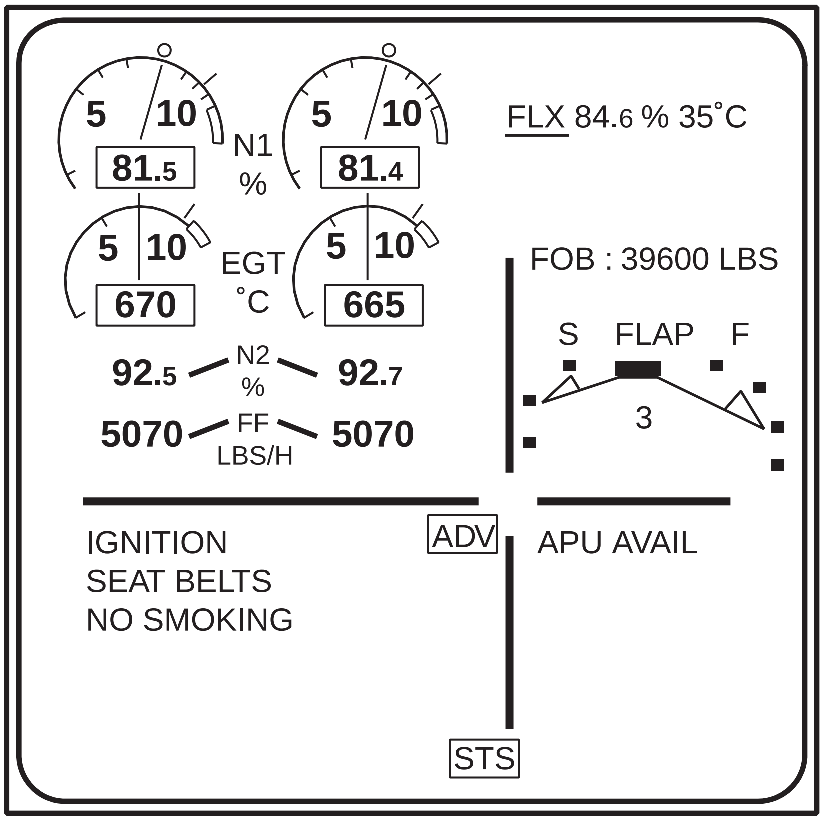
Fuel flow

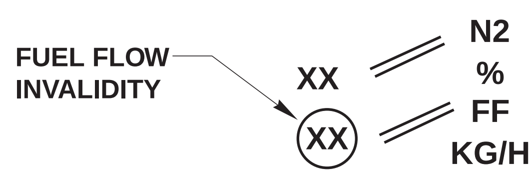
'Fuel flow' information is always indicated on the upper ECAM, Engine/Warning Display (E/WD).

It is displayed in a green color.

In case of invalid fuel flow information, the digital indication is replaced by two amber crosses.

This lack of valid data happens when the ECU power is off. This is the case on the ground, five minutes after the last engine shut down.





FUEL INDICATING

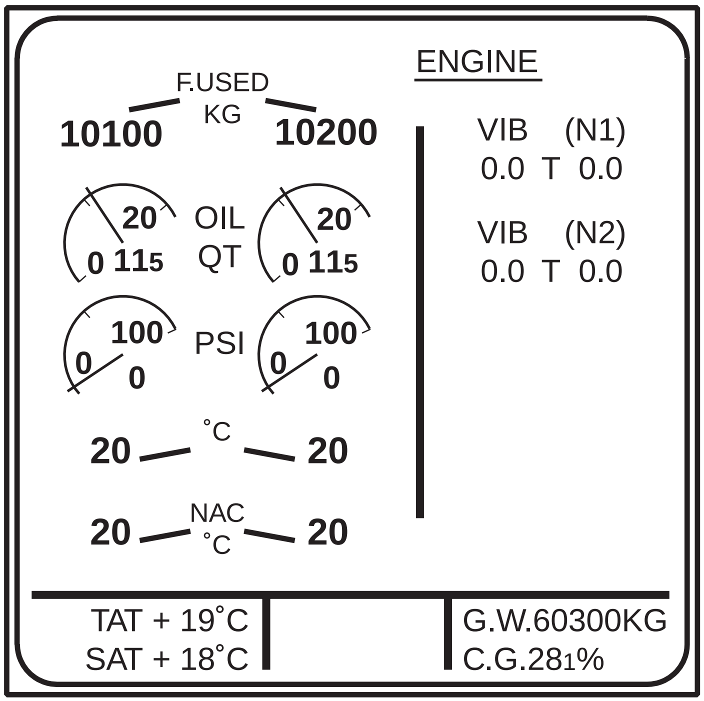
Fuel used

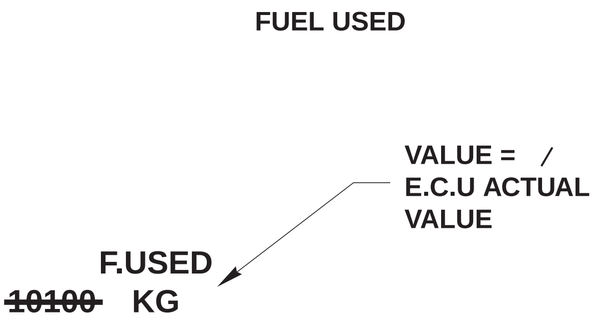
‘Fuel used’ information is indicated on the lower ECAM System Display (SD), during start and cruise conditions.

The fuel used is computed by the ECU from engine start to engine shut-down and automatically reset at the next engine start.

It is displayed in a green color.

The indication is amber-dashed if the value from the A/C computers does not correspond to the value sent by the ECU.





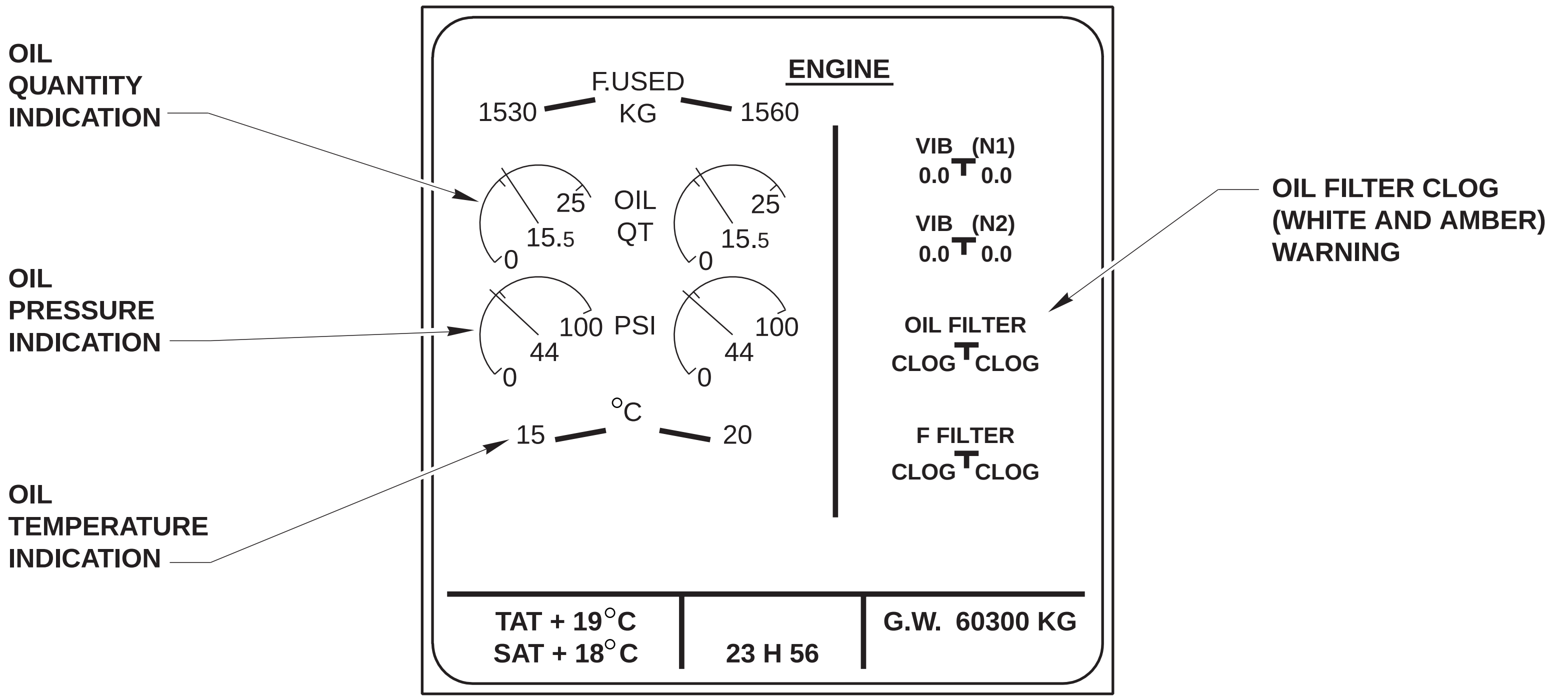
CTC-045-171-00

FUEL INDICATING

Oil indicating.

Major parameters for monitoring the oil system are provided to the aircraft system such as :

- quantity
- temperature
- pressure
- low pressure warning
- filter clogging.



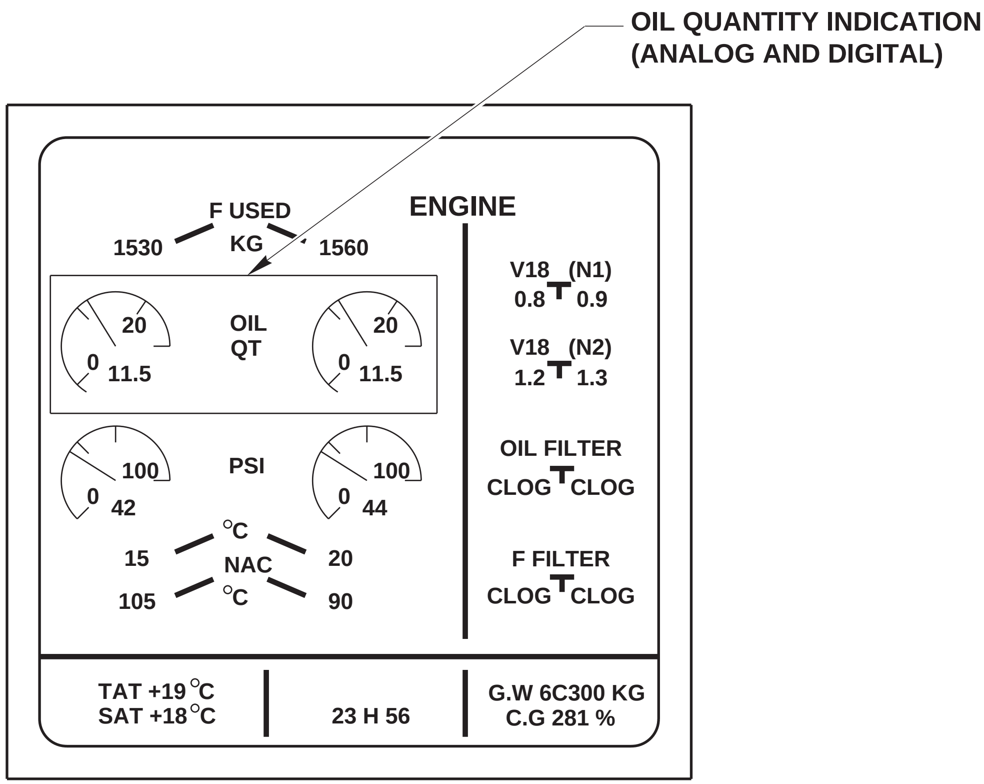
CTC-045-172-00

OIL GENERAL INDICATING

Oil quantity

During engine operation, the oil quantity is shown in green on the lower ECAM System Display in the cockpit.

If the oil quantity drops below 1.8 quarts, the indication flashes green. This indication corresponds to 3 flight hours at the maximum consumption rate.



LOWER ECAM

CTC-045-173-00

OIL QUANTITY DISPLAY

Oil temperature .

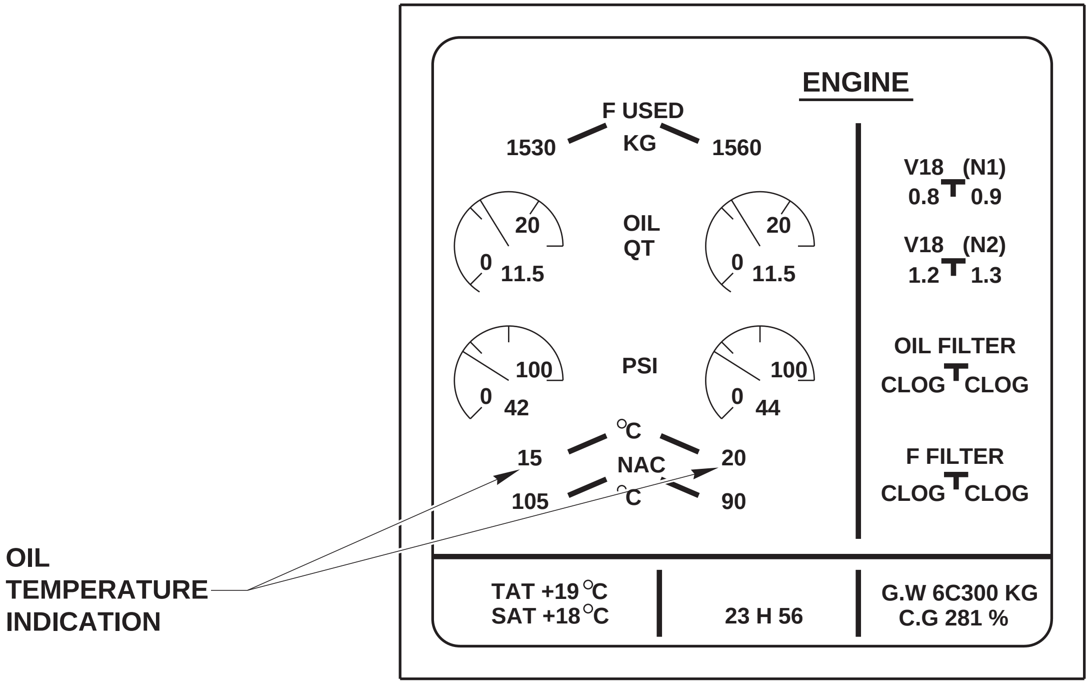
During engine operation, various warnings are given in the cockpit if the oil temperature reaches specified exceedance thresholds.

If the oil temperature exceeds 140°C for more than 15 minutes, or exceeds 155°C, the following occurs :

- Oil temperature value flashes in amber color.
- Caution message OIL HI TEMP is displayed.
- MASTER CAUT (amber) lights up with an Audio warning (single chime).

If the oil temperature is lower than -10°C, the following occurs :

- Caution message OIL LO TEMP is displayed.
- MASTER CAUT (amber) lights up with an Audio warning (single chime).



CTC-045-174-00

OIL TEMPERATURE INDICATION

Oil pressure indication.

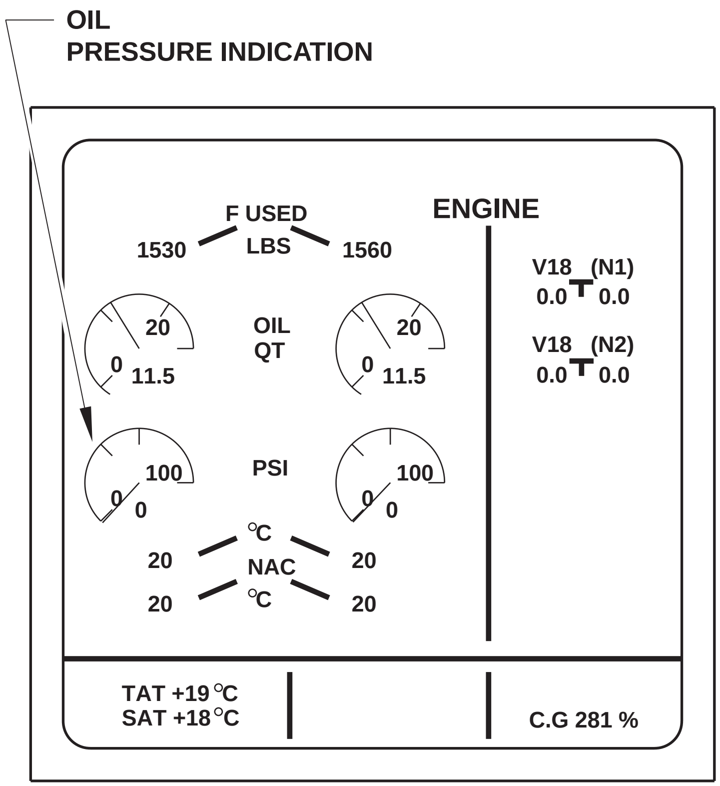
The pressure range is from 0 to 100 psid.
The oil pressure indications are normally displayed in green colour and become red if the pressure drops below 13 psid (low pressure limit).

If the oil pressure exceeds 90 psid, the indication flashes green.

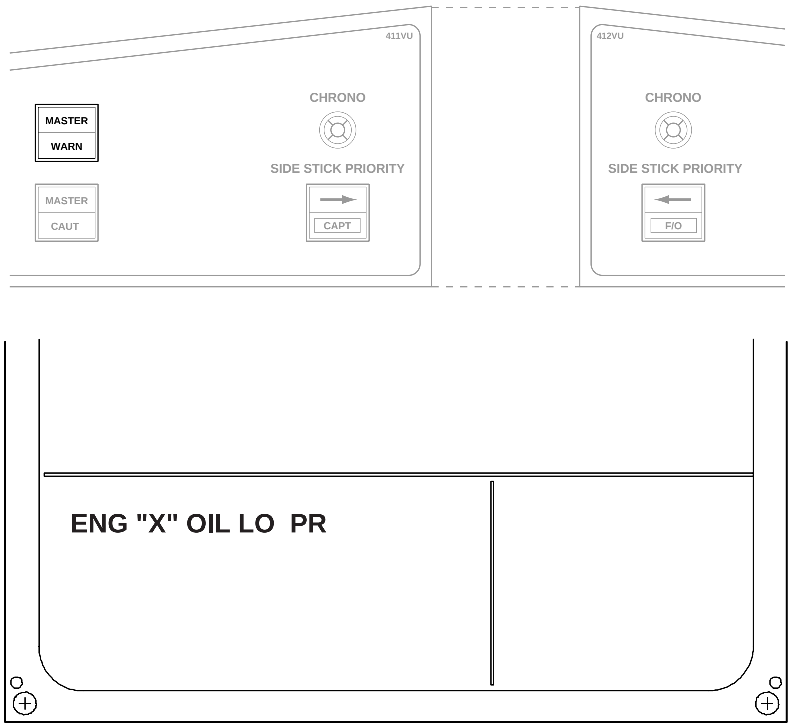
Oil low pressure indication.

If the differential pressure drops below 13 psid, the oil low pressure switch closes, and :

- Oil pressure indication is displayed in red.
- OIL LO PRessure message is displayed on the EWD.
- MASTER WARNING light flashes with audio warning activated.



SYSTEM DISPLAY (LOWER)



EWD (UPPER)

CTC-045-175-00

OIL LOW PRESSURE

Thrust reverser.

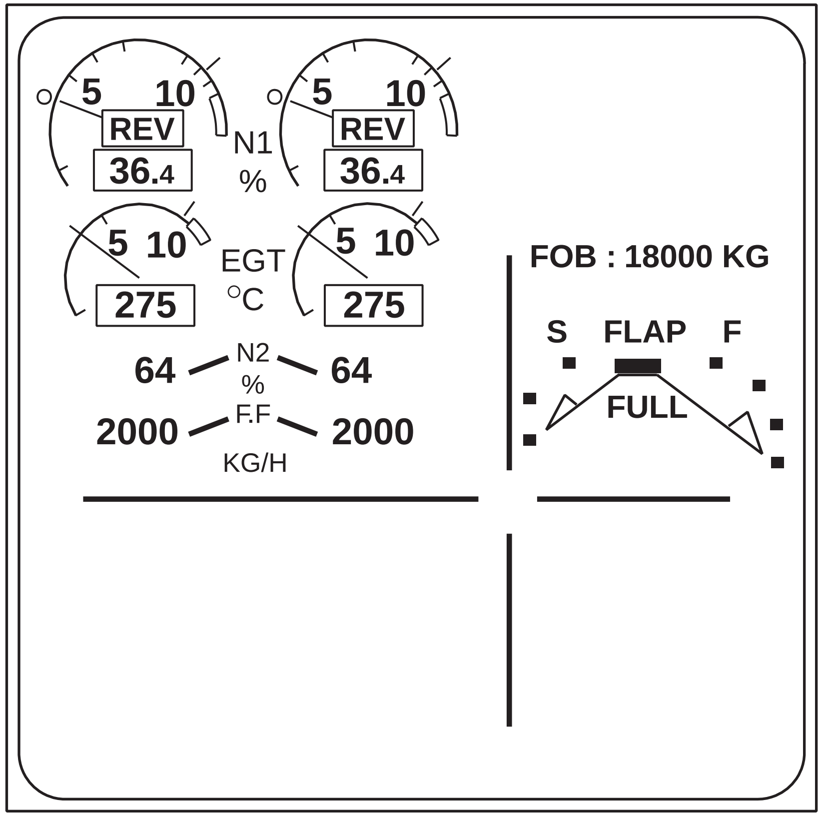
When the thrust reverser is selected, indication is available for the crew on the upper ECAM system.

In deploy mode :

- A box with REV appears when reverse is selected. This box is displayed in the N1 dial indication.
- The REV indication is displayed in amber colour when the throttle is in the reverse range and the blocker doors are not 95% deployed.
- The REV indication is displayed in green colour when the doors are fully deployed.

In stow mode :

- The REV indication is still displayed during the stow operation.
- The REV indication is displayed in amber colour when the doors are restowed.



1/ REV INDICATION DURING DEPLOY PHASE :
REV DISPLAYED IN AMBER WHEN THE THROTTLE IS IN THE REVERSE RANGE AND THE BLOCKER DOORS ARE NOT 95% DEPLOYED.
REV DISPLAYED IN GREEN WHEN THE DOORS ARE FULLY DEPLOYED

2/ REV INDICATION DURING STOW OPERATION :
REV DISPLAYED IN AMBER WHEN THE DOORS ARE RESTOWED

T/R INDICATING

CTC-045-176-00

INDICATING SYSTEM

Vibration

Vibration indication is given by the selected sensor, through the MCDU.

The vibration and speed signals provided from EVMU/ SDAC/DMC computers are displayed in green on the lower ECAM system on the :

- Engine page.
- Cruise page.

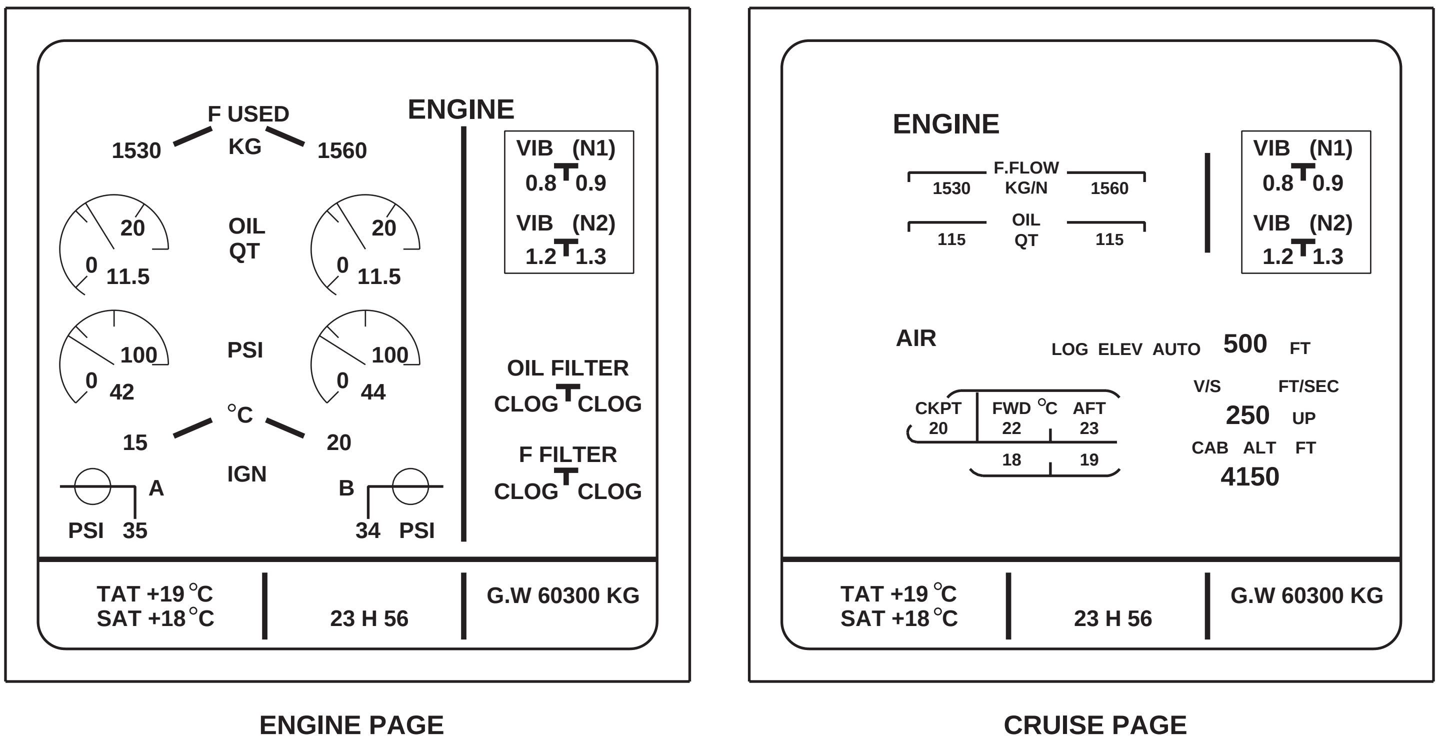
If an indication is not available, the corresponding indication is replaced by 2 amber crosses.

When the advisory level is reached, the indication flashes bright and normal to catch the crews attention. The advisory levels are :

- Vib N1 above 6 units.
- Vib N2 above 4.2 units.

The tracking of vibration is theoretically done in Mils for LP rotor and IPS for HP rotor.

In order to avoid two different types of unit indication being provided to the crew, the two values for LP and HP vibration are transformed and displayed in cockpit units.



VIBRATION INDICATING

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CENTRALIZED FAULT AND DISPLAY SYSTEM

Centralized Fault and Display System (CFDS).

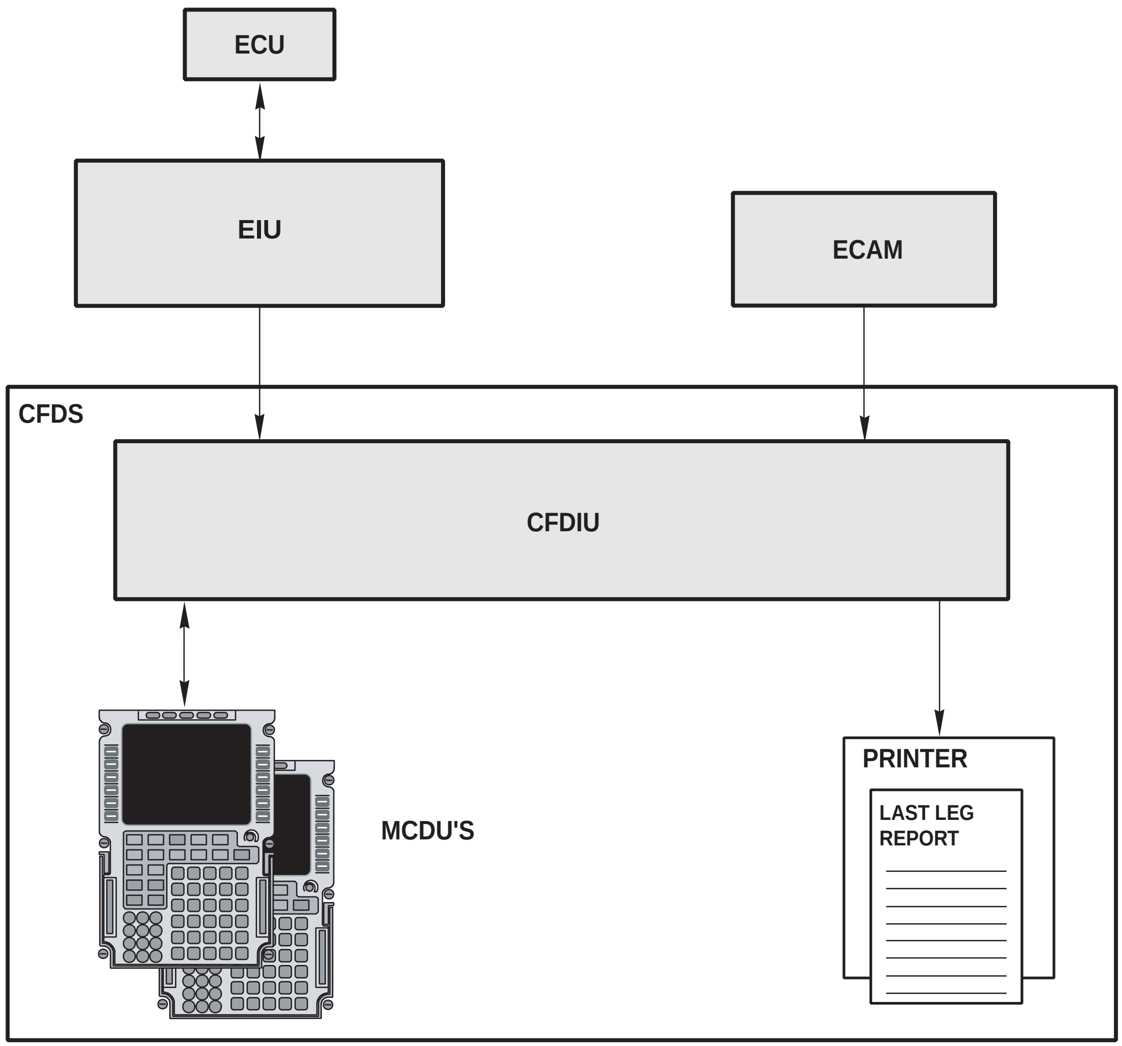
The CFDS collects all the information concerning the aircraft and engine failures.

The system is made up of the following components :

- The Centralized Fault Display Interface Unit (CFDIU), which is the aircraft maintenance computer.
- The Multi-Purpose Control and Display Unit (MCDU), which is an interface computer between the crew and maintenance personnel and the aircraft systems.
- The printer, which is located behind the throttle assembly.

Two MCDU's are installed on the cockpit console on each side of the throttles.

The CFDIU communicates with the EIU through an ARINC 429 connection.



CFDS SYSTEM

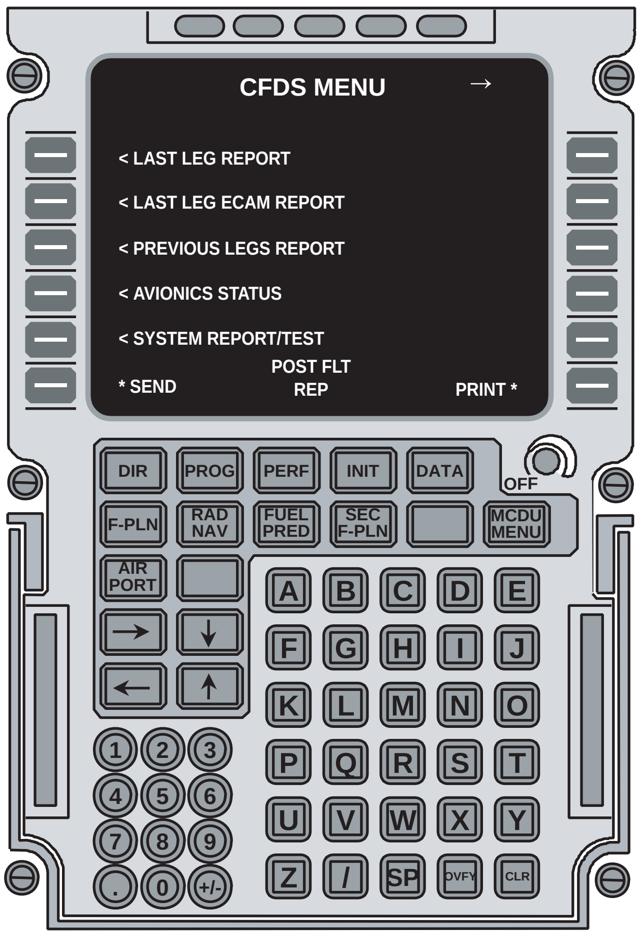
CTC-045-178-00

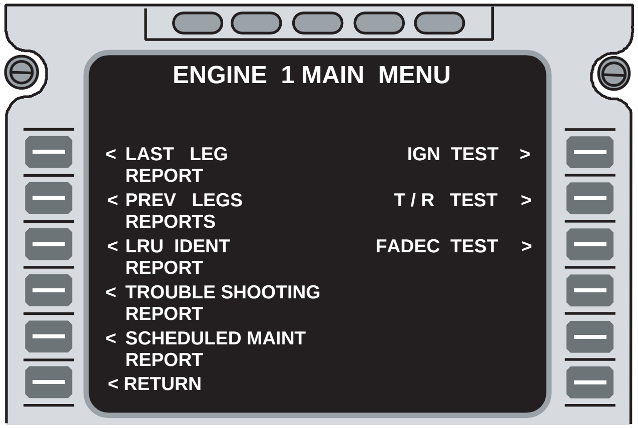
CENTRALIZED FAULT AND DISPLAY SYSTEM

The reporting functions provided by the CFDS are :

- The last leg report.
- The last leg ECAM report.
- The previous leg report.
- The post flight report.

Through the systems report/test, there is access to engine reports, specific data and tests such as FADEC test, ignition test, etc.





CTC-045-179-00

CFDS REPORTING SYSTEM

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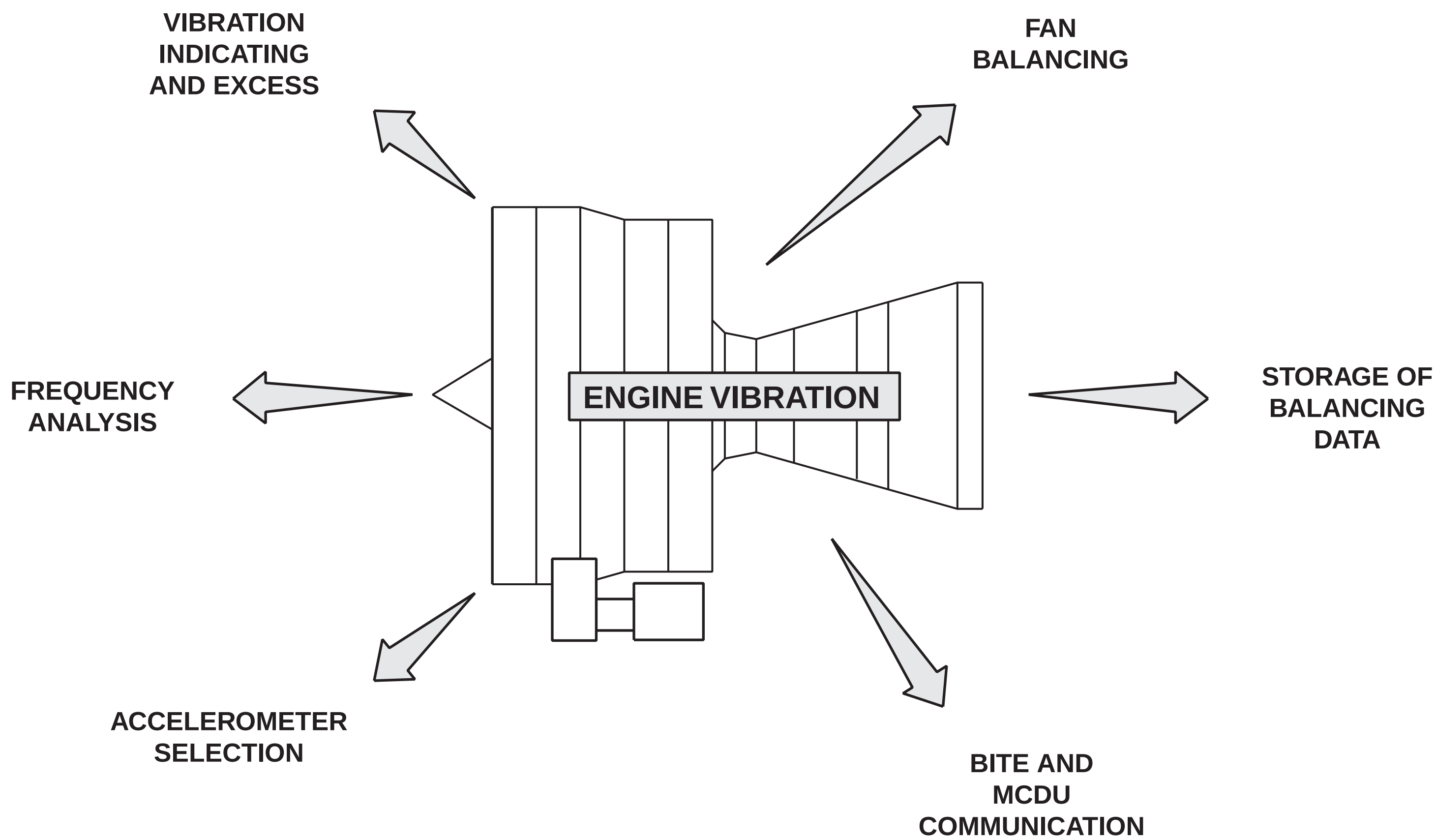
VIBRATION SENSING

Sensing system introduction.

The engine vibration sensing system enables the crew to monitor engine vibration on the ECAM system, and also provides maintenance staff with the following :

- Vibration indication.
- Excess vibration (above advisory levels).
- Storage of balancing data.
- Bite and MCDU communication with other A/C systems
- Accelerometer selection.
- Frequency analysis for component vibration search.



CTC-045-180-00

INTRODUCTION TO VIBRATION SENSING

Engine/aircraft vibration systems.

The engine/aircraft vibration sensing system is made up of the following devices :

- The engine sensors.
- The Engine Vibration Monitoring Unit (EVMU), which interfaces with engine and aircraft systems.

Vibration information is provided to the following :

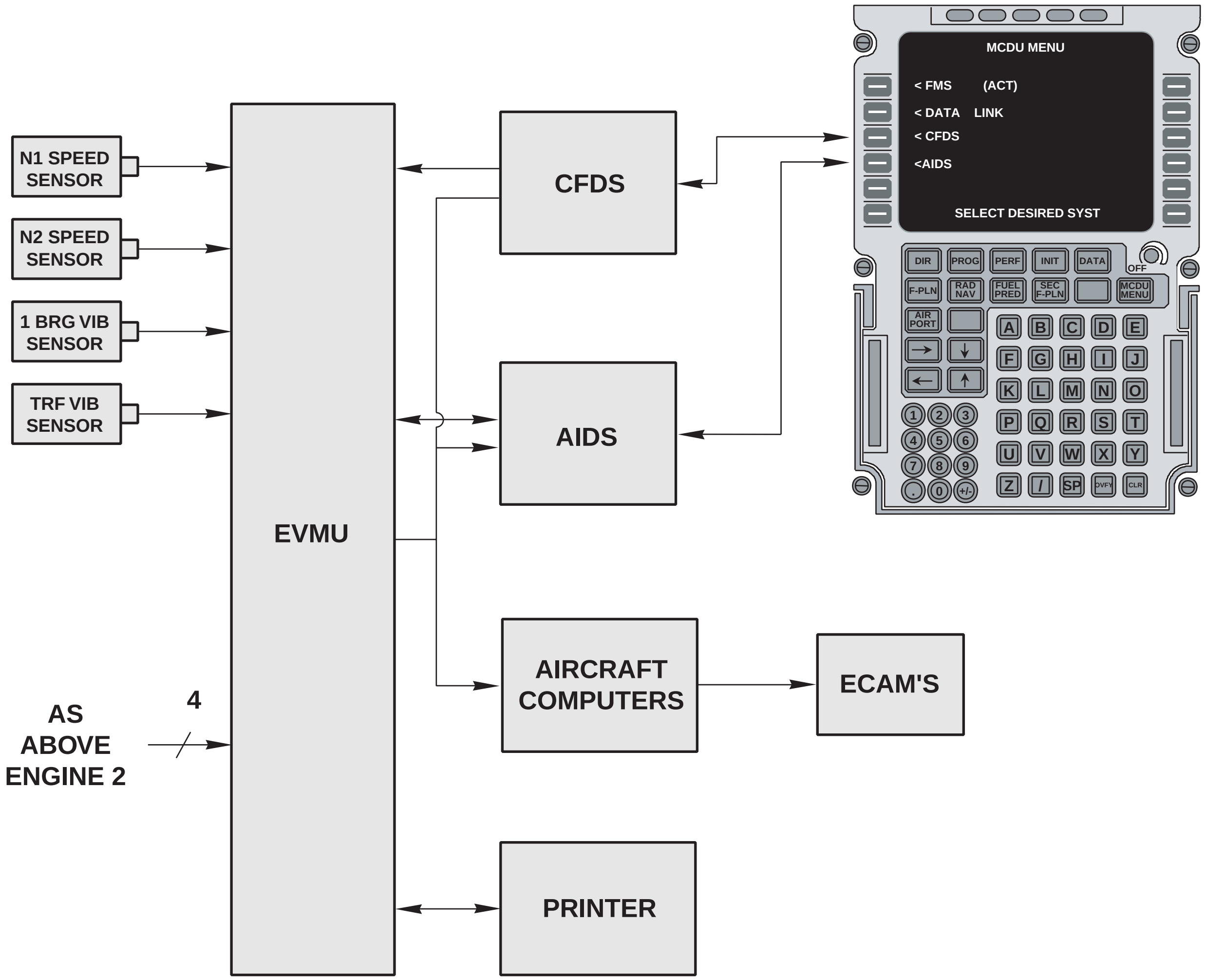
- The ECAM system, for real time monitoring.
- The CFDS (Centralized Fault Display System).
- The AIDS (Aircraft Integrated Data System).

The CFDS system is used to :

- recall and print previous leg events.
- initiate tests.
- reconfigure engine sensors.

The AIDS system is used to perform :

- troubleshooting.
- condition monitoring.



CTC-045-181-00

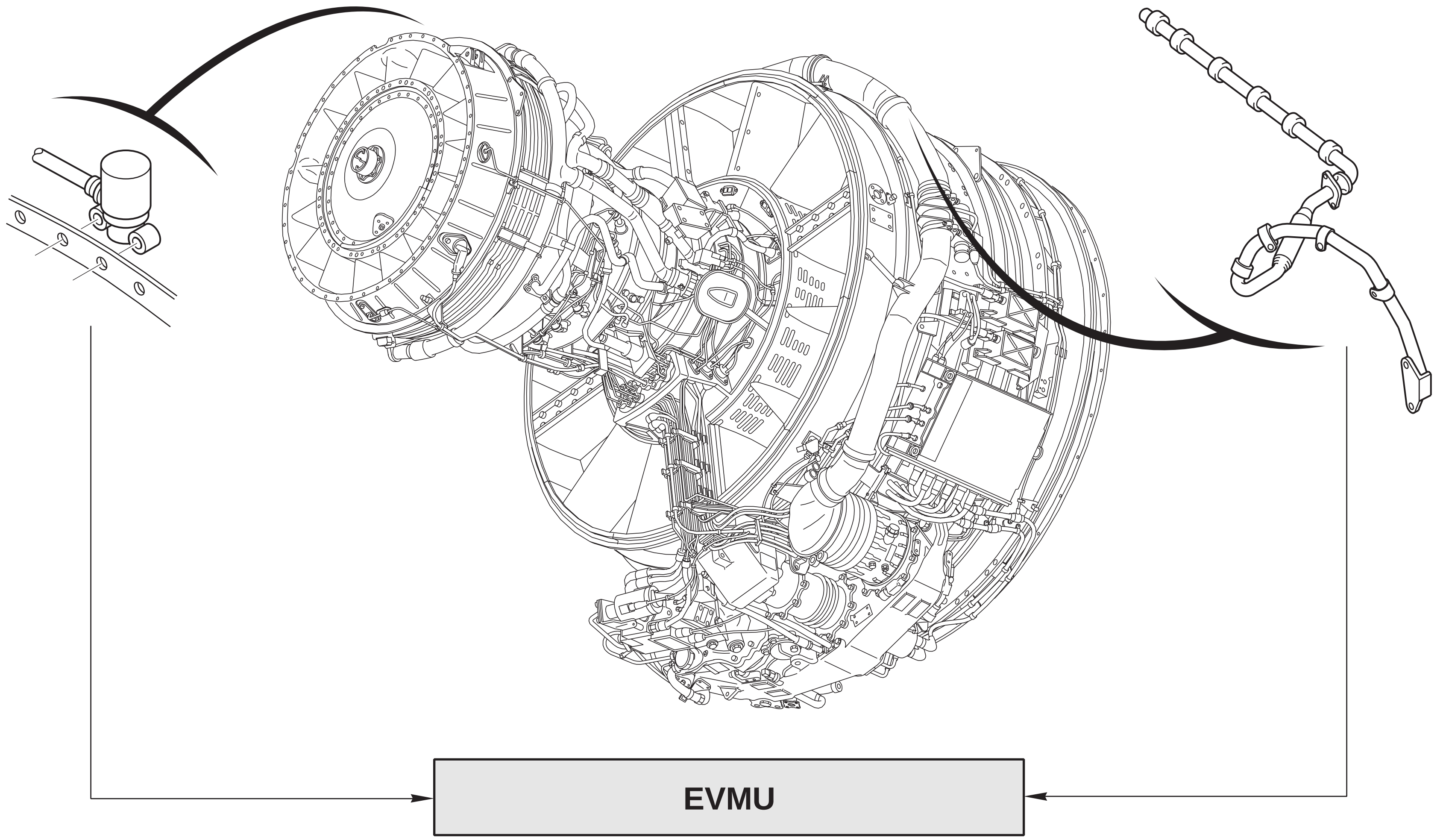
ENGINE/AIRCRAFT VIBRATION SYSTEMS

Engine Vibration sensing components.

The vibration sensing components installed on the engine consist of :

- The #1 bearing vibration sensor.
- The Turbine Rear Frame (TRF) vibration sensor.

The vibration information produced by these two accelerometers is only provided to the EVMU.



ENGINE VIBRATION SYSTEM

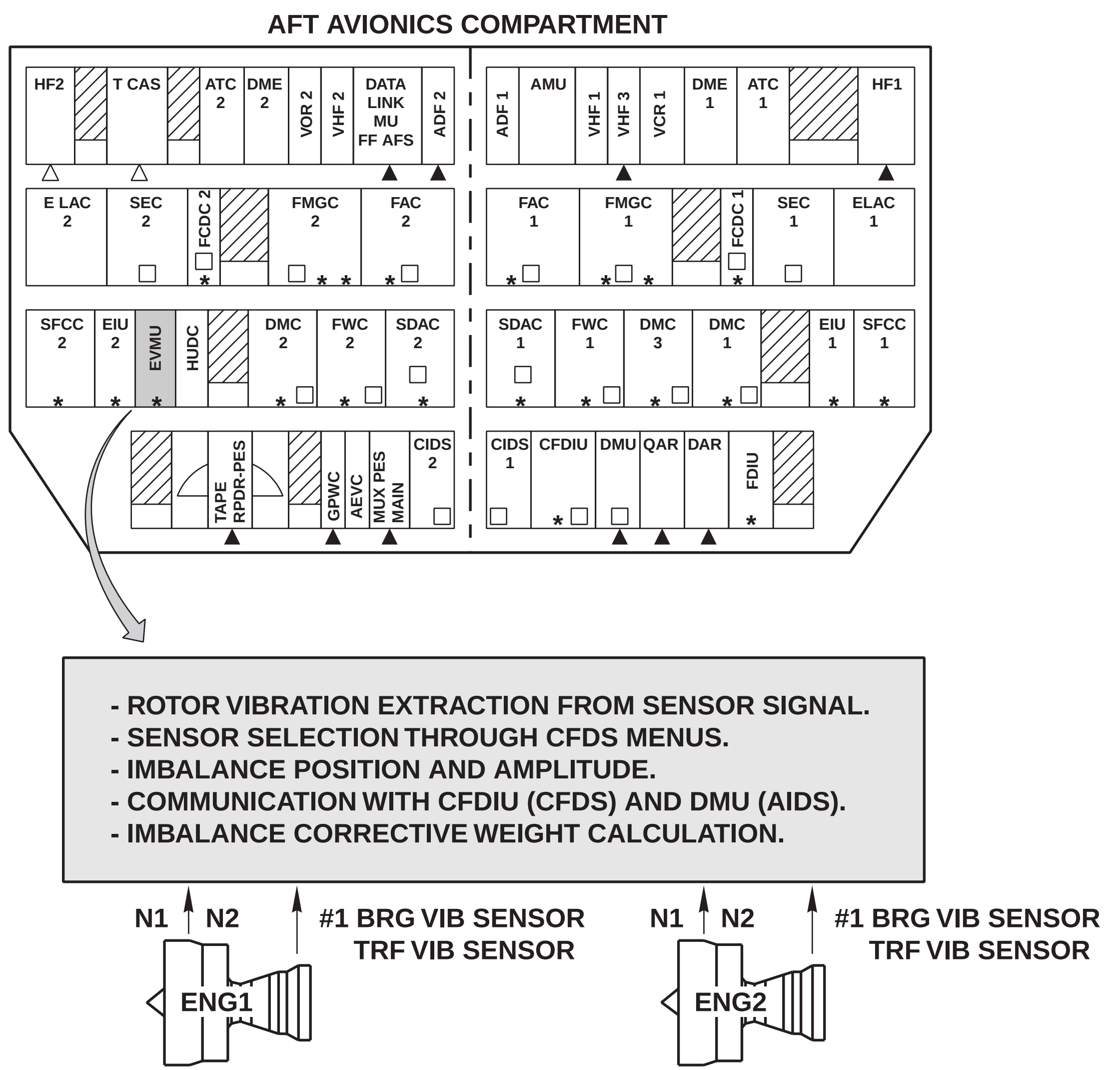
CTC-045-182-00

EVMU description.

The EVMU, which is located in the aircraft electronic bay, receives analog signals from the engine (speed and vibration), and communicates with the other computers (CFDS, AIDS) through ARINC 429 data busses.

The EVMU performs the following tasks :

- Rotor vibration extraction from the overall vibration signals received.
- Vibration sensor configuration, through CFDS menu. The #1 bearing vibration sensor is the default sensor.
- Computing of position and amplitude of the unbalanced signal.
- Communication with the CFDS (CFDIU) in normal and maintenance mode.
- Communication with the AIDS (DMU) for vibration monitoring.
- Fan trim balance calculations for the positions and weights of balancing screws to be installed on the engine rear spinner cone (latest EVMU's only).



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EVMU DESCRIPTION

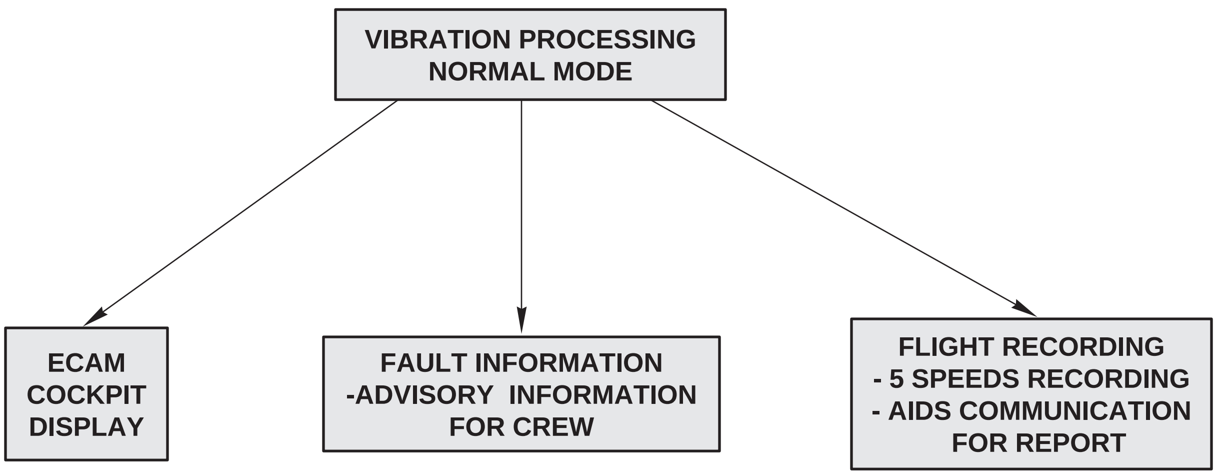
EVMU operation.

The normal mode of operation allows the system to :

- display the vibration information on the ECAM.
- provide fault information when advisory levels are reached, or exceeded.
- provide flight recordings.

Vibration recordings are made at five different engine speeds to provide information for fan trim balance procedures and frequency analysis.

They are also transmitted to the AIDS system to be included in the printing of all the reports, such as cruise, or take-off.



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EVMU OPERATION

EVMU operation (continued).

The maintenance mode (or, CFDS mode) of operation, through the MCDU menu, allows maintenance staff to obtain, or print the following :

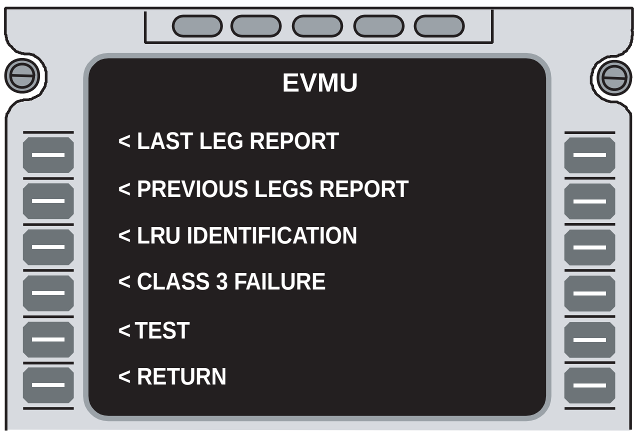
First page :

- Last leg report : lists the LRU's detected faulty during the last leg.
- Previous leg report : lists the LRU's detected faulty during the legs (Max 62) previous to the last leg.
- LRU identification : provides the unit part number and manufacturer name.
- Class 3 failures : lists the LRU's detected faulty during a ground test. Only the last 3 failures detected are displayed.
- Test : enables a complete check of the EVM system. If no failure has been detected, the message TEST OK is displayed. If any failure has been detected the failed LRU is displayed.

Second page :

- Accelerometer reconfiguration : allows selection of the accelerometer (fan no. 1 bearing or TRF) to be used for the next flights. The EVMU also indicates which accelerometer is in operation.
- Engine unbalance : allows selection of 5 different speeds per engine (from 50% to 100% N1 RPM) at which unbalance data is stored. It also enables previously acquired unbalance data to be read, and performs balancing calculations for both engines using both accelerometers.
- Frequency analysis : enables a frequency analysis of the acceleration signal to be performed. The results are sent to the printer.

1st PAGE



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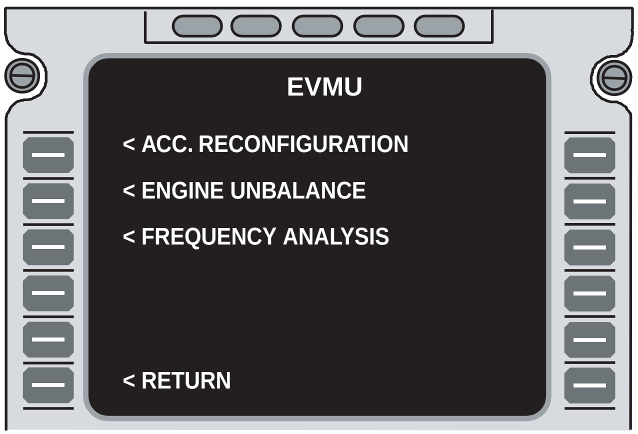

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EVMU OPERATION

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AIRCRAFT INTEGRATED DATA SYSTEM

AIDS reports.

The Aircraft Integrated Data system (AIDS) is used to monitor aircraft and engine parameters.

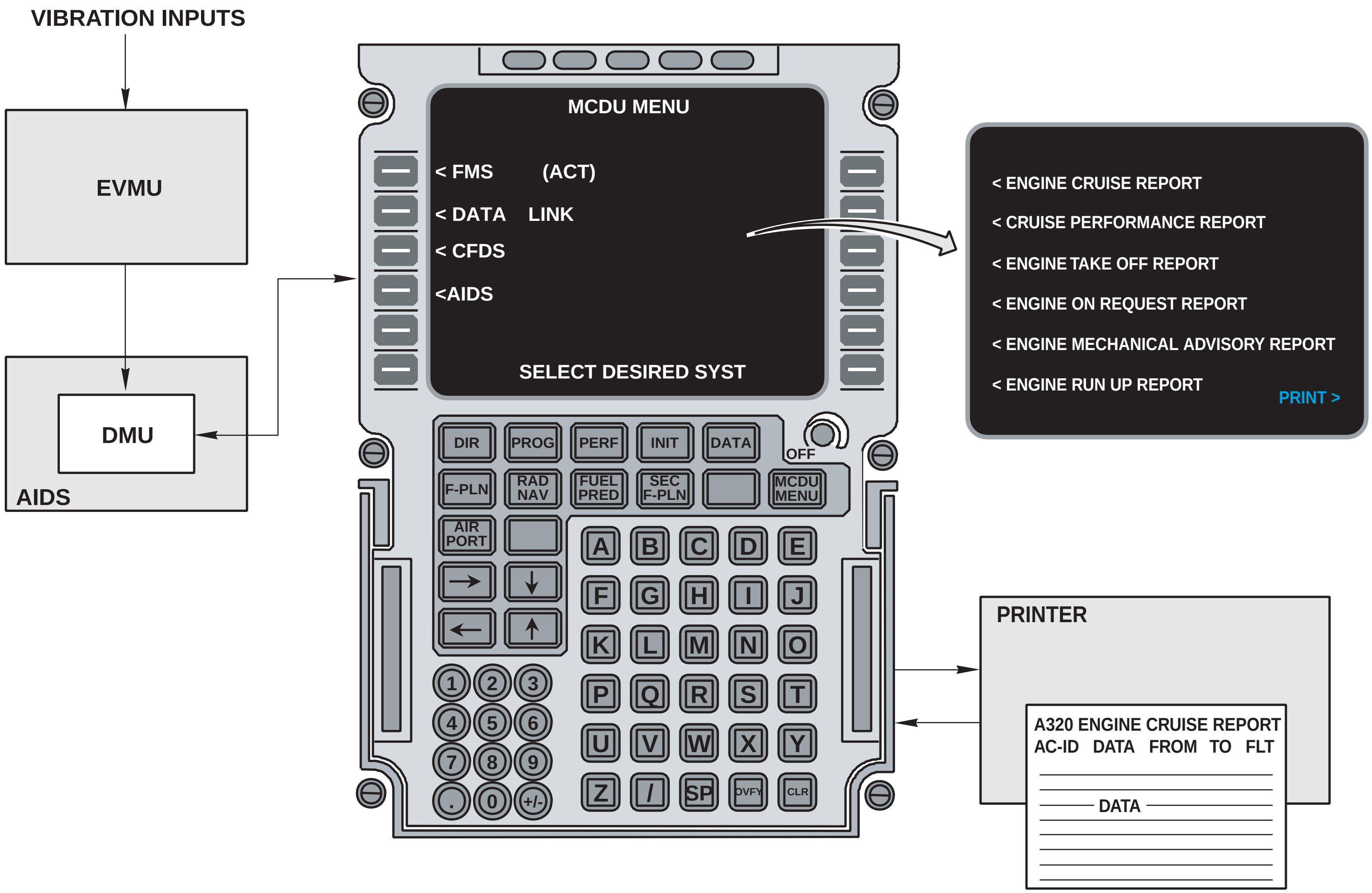
It allows maintenance staff to perform engine parameter trend monitoring and troubleshooting.

The AIDS system enables engine parameters to be displayed in real time and can also access specific reports.

The following reports are specific for engine data :

- Engine cruise report.
- Cruise performance report.
- Engine take-off report.
- Engine on-request report.
- Engine mechanical advisory report.
- Engine run-up report.

Some reports can be generated on request.



AIDS

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