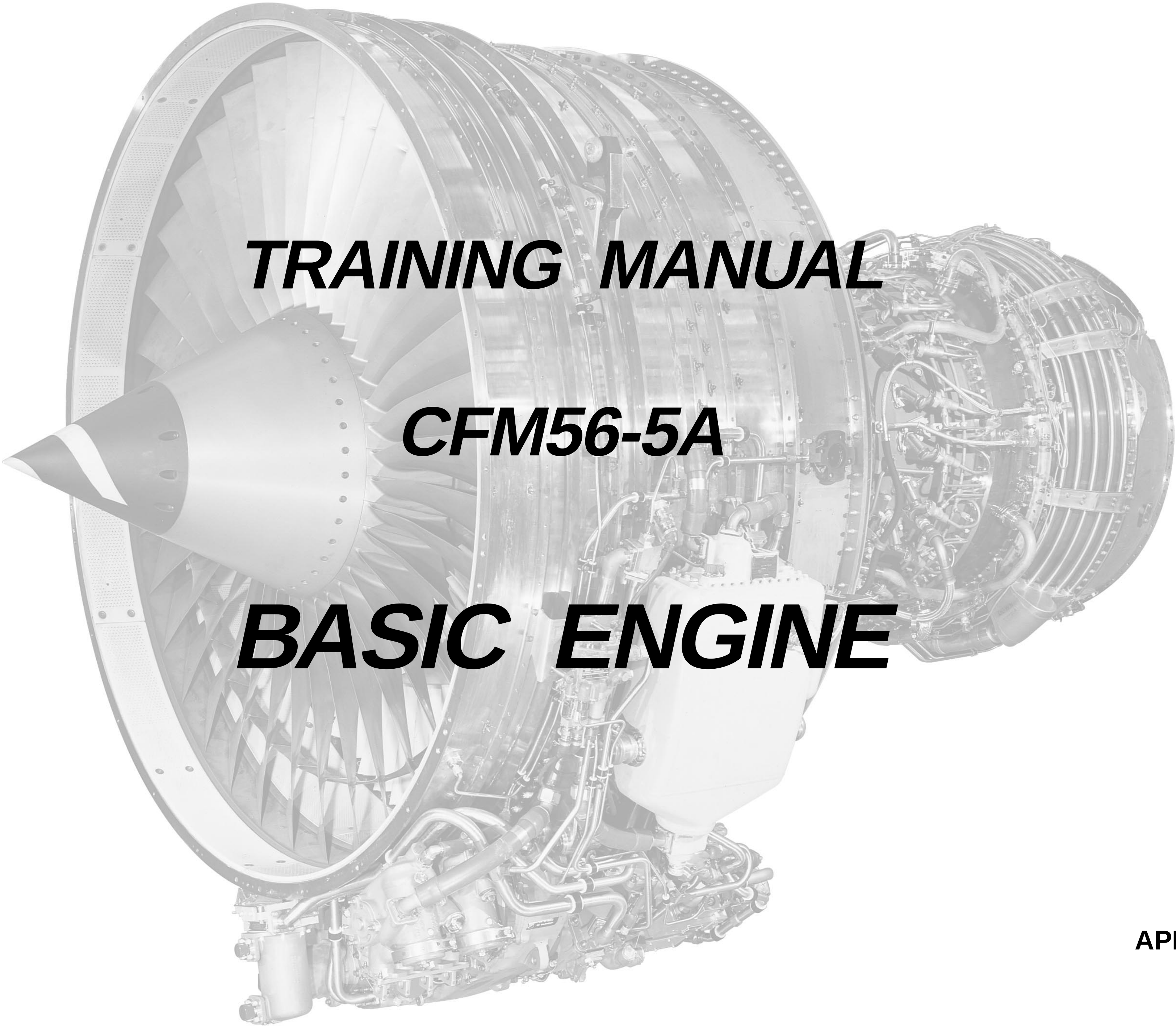
THE POWER
OF FLIGHT



TRAINING MANUAL

CFM56-5A

BASIC ENGINE

APRIL 2000

CTC-044 Level 4

BASIC ENGINE

THE POWER
OF FLIGHT

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Snecma (RXEF)
Direction de l'Après-Vente Civile
MELUN-MONTEREAU
Aérodrome de Villaroche B.P. 1936
77019 - MELUN-MONTEREAU Cedex
FRANCE

CFMI Customer Training Services
GE Aircraft Engines
Customer Technical Education Center
123 Merchant Street
Mail Drop Y2
Cincinnati, Ohio 45246
USA

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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 cm²
1 m² = 10.76 sq. ft.
1 cm² = 0.155 sq.in.

1 USG = 3.785 l (dm³)

1 in.³ = 16.39 cm³
1 m³ = 35.31 cu. ft.
1 dm³ = 0.264 US gallon
1 cm³ = 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

INTRODUCTION TO THE CFM56 FAMILY

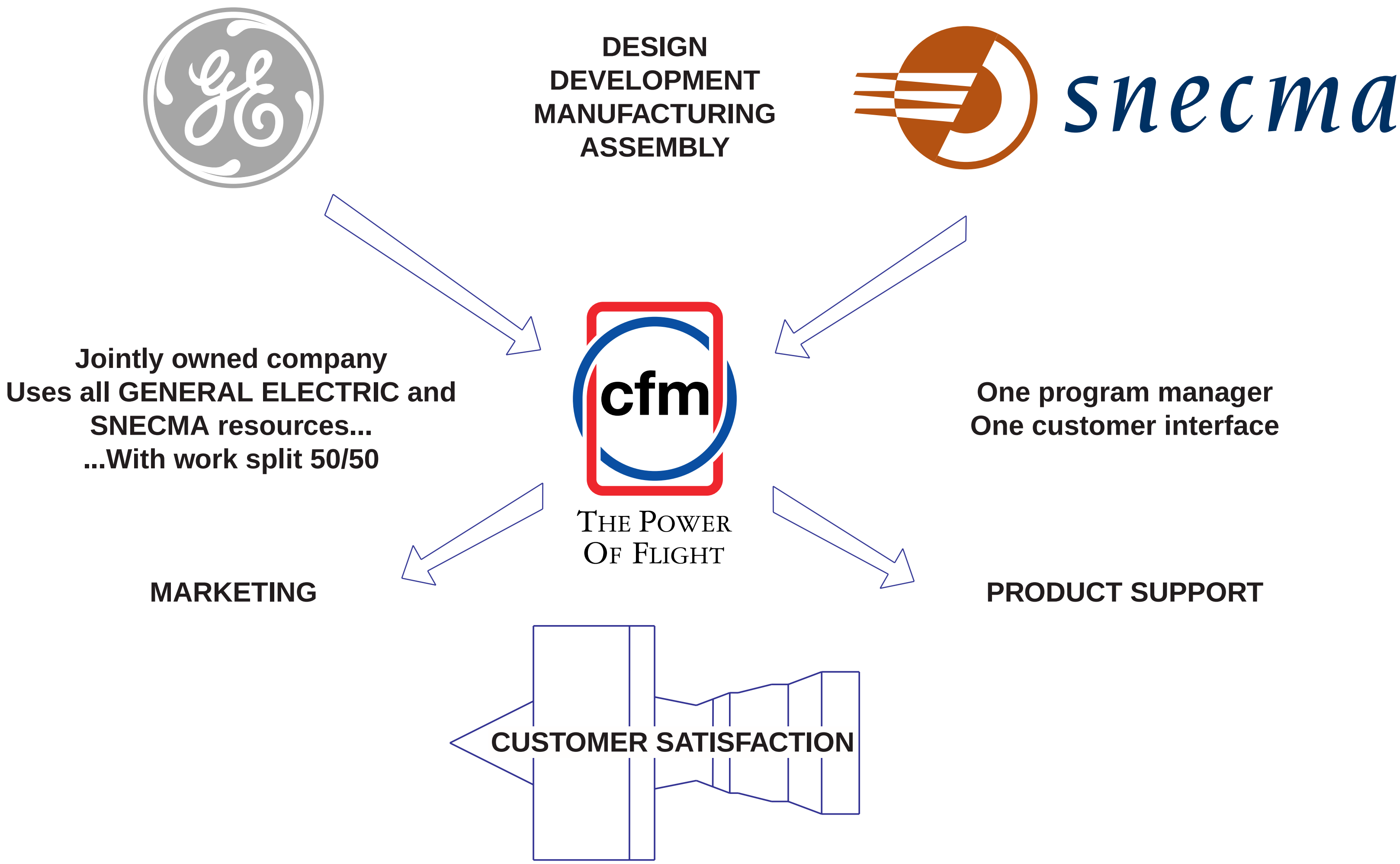
INTRODUCTION TO THE CFM56 FAMILY

The CFM56 engine, a high by-pass, dual rotor, axial flow advanced technology turbofan, was designed in the mid 70's.

It is a product of CFMI. CFM International is a company jointly owned by GENERAL ELECTRIC (GE) of the USA, and SOCIETE NATIONALE D'ETUDE ET DE CONSTRUCTION DE MOTEURS D'AVIATION (SNECMA) of France.

CFMI, with the full backing of parent companies holding equal shares, has a dual function:

- Overall program management, on behalf of both GE and SNECMA
- Single interface with customers for marketing and product support



CFM INTERNATIONAL ORGANIZATION

Engine Applications

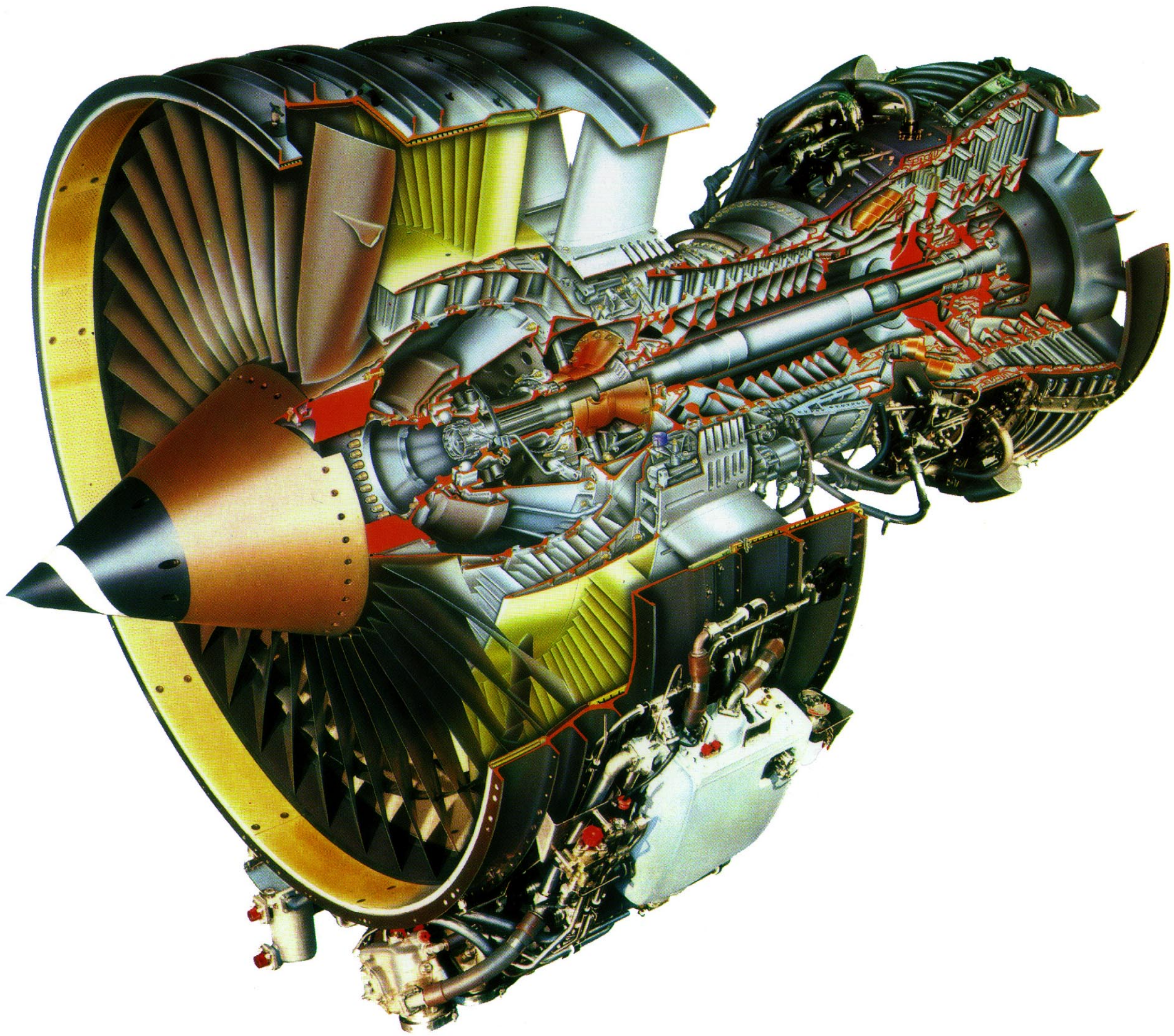
The following chart shows the various engine models for the Airbus A319-A320 aircraft.

The engine used on these aircraft is the CFM56-5A, which has several different thrust ratings, ranging from 22000 to 26500 lbs of thrust.

CFM56-5A FOR AIRBUS APPLICATIONS

CFM56-5A MAIN CHARACTERISTICS

Type of engine	Turbo fan
Arrangement	Two spool axial flow
Rotation	Clockwise (ALF)
Compressors	
- Low Pressure:	
Fan	Stage 1
Booster	Stages 2 to 4
- High Pressure:	
HP Compressor	Stages 1 to 9
Combustion chamber	Annular SAC
Turbines	
- HP Turbine	Single stage
- LP Turbine	Four stages
Weight	4995 lbs
Overall dimensions	
- Length	115 ins
- Height	82.7 ins
- Width	75.1 ins
- Fan diameter	71.5 ins



CFM56-5A

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ENGINE GENERAL

ENGINE GENERAL CONCEPT

The CFM56-5A engine uses a maintenance concept called ‘On Condition Maintenance’. This means that the engine has no periodic overhaul schedules and can remain installed under the wing until something important occurs, or when lifetime limits of parts are reached.

For this reason, to monitor and maintain the health of the engine, different tools are available, which are:

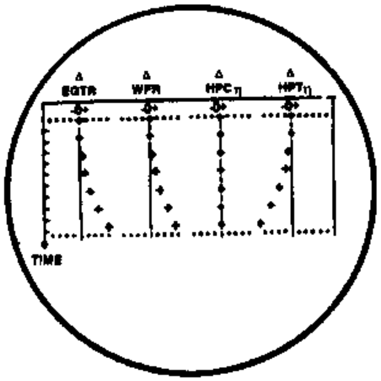
- **Engine performance trend monitoring**, to evaluate engine deterioration over a period of use: engine parameters, such as gas temperature, are recorded and compared to those initially observed at engine installation on the aircraft.

- **Borescope inspection**, to check the condition of engine internal parts: when parts are not accessible, they can be visually inspected with borescope probes inserted in ports located on the engine outer casing.

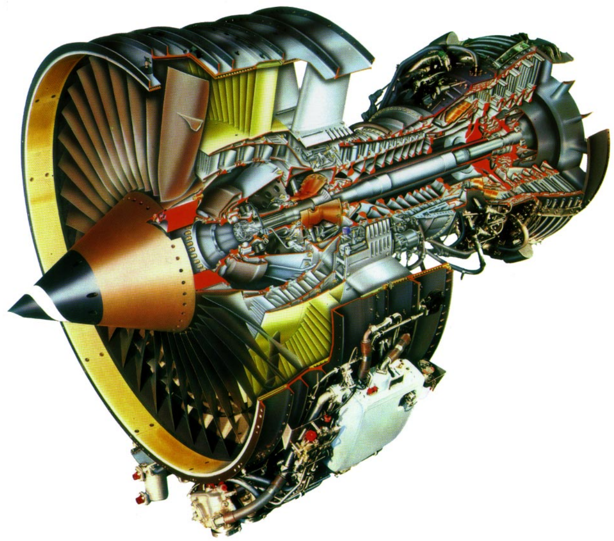
- **Lubrication particles analysis**: while circulating in the oil system, lubrication oil is filtered, and large, visible-to-the-eye particles (larger than 10 microns) coming from worn engine parts are collected in filters and magnetic chip detectors, for visual inspection and analysis.

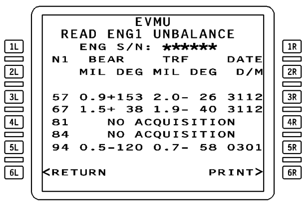
- **Spectrometric oil analysis program (S.O.A.P.)**: oil is sampled from the oil tank, and an analysis is made of all microscopic (smaller than 10 microns) metal particles it contains. The nature and concentration of metal found indicates the beginning of parts damage.

- **Engine vibration monitoring system**: sensors located in various positions in the engine, send vibration values to the on-board monitoring system. When vibration values are excessive, the data recorded can be used to take remedial balancing action.



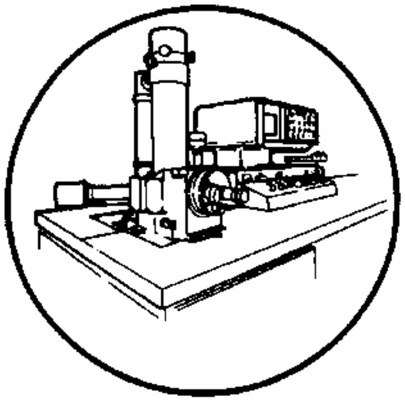
TREND MONITORING



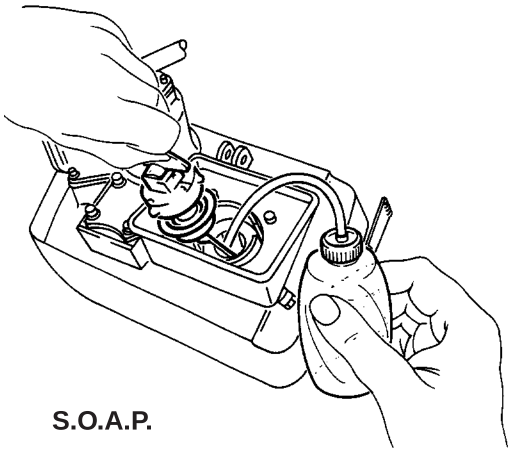


VIBRATION MONITORING

BORESCOPE INSPECTION



LUBE PARTICLE ANALYSIS



S.O.A.P.

CONDITION MONITORING

CTC-044-004-00

ENGINE GENERAL CONCEPT

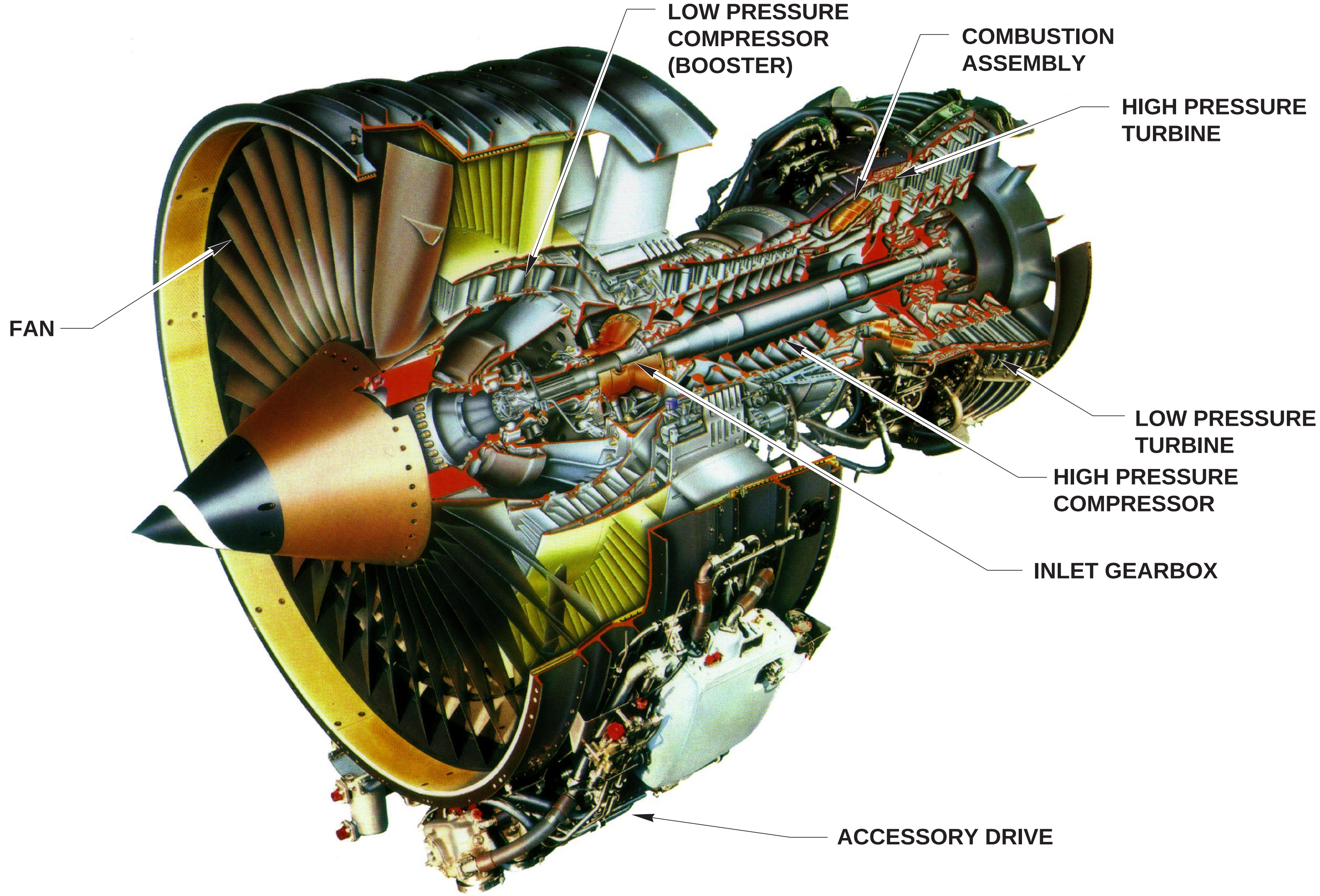
The CFM56-5A engine is a high by-pass, dual rotor, axial flow, advanced technology turbofan. It is supported by the wing pylon and streamlined by cowlings.

Air is sucked into the intake by the fan blades and split into two flow paths, the Primary and the Secondary.

The primary airflow passes through the inner portion of the fan blades and is directed into a booster (LPC).

The flow path then enters a High Pressure Compressor (HPC) and goes to a combustor. Mixed with fuel and ignited, the gas flow provides energy to a High Pressure Turbine (HPT) and a Low Pressure Turbine (LPT).

The secondary airflow passes through the outer portion of the fan blades, the Outlet Guide Vanes (OGV's) and exits through the nacelle discharge duct, producing approximately 80 % of the total thrust. It also plays a role in the thrust reverser system.



ENGINE DESIGN AND OPERATION

CTC-044-005-00

The CFM56-5A engine consists of two independent rotating systems:

- The low pressure system rotational speed is designated N1.
- The high pressure system rotational speed is designated N2.

The engine rotors are supported by 5 bearings, identified in manuals as numbers 1 thru 5, where No. 1 is the most forward and No. 5 the most aft. These bearings are housed in 2 dry sump cavities provided by the fan and turbine frames.

Engine structural rigidity is obtained with short lengths between two main structures (frames).

The accessory drive system uses energy from the high pressure compressor rotor to drive the engine and aircraft accessories. It also plays a major role in starting.

<u>Main Engine Bearings</u>

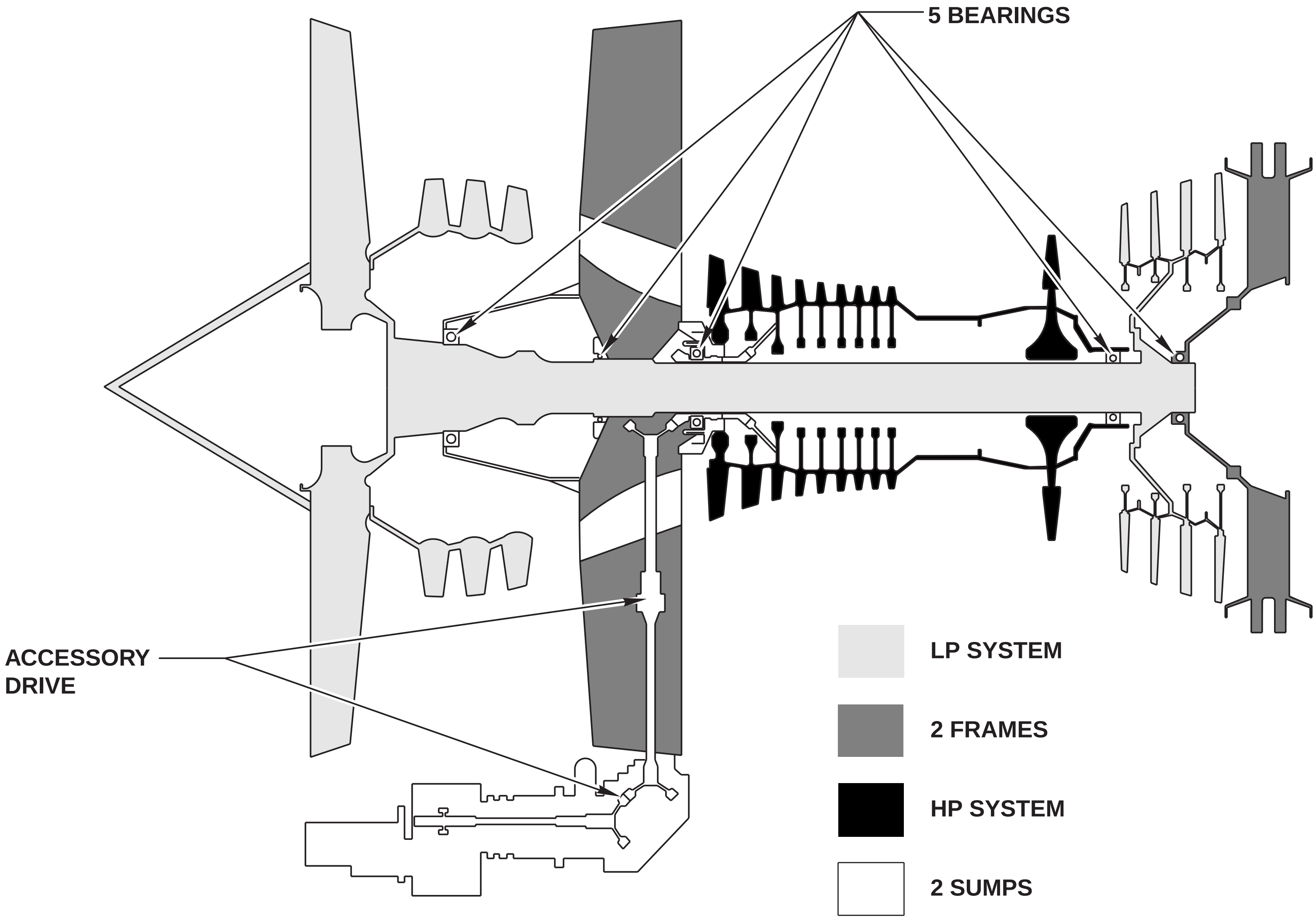
The engine contains five main bearings, which support the rotors.

There are two types of bearings:

- Ball bearings, which absorb axial and radial loads
- Roller bearings, which absorb only radial loads

Bearings need permanent oil lubrication, so they are located in the two dry sump cavities, which are pressure sealed.

- The forward sump cavity houses No. 1, No. 2 and No. 3 bearings:
    - No. 1 and No. 2 bearings hold the fan shaft
    - No. 3 bearing holds the front of the HP shaft
- The rear sump cavity houses No. 4 and No. 5 bearings:
    - No. 4 bearing holds the rear of the HP shaft
    - No. 5 bearing holds the rear of the LPT shaft



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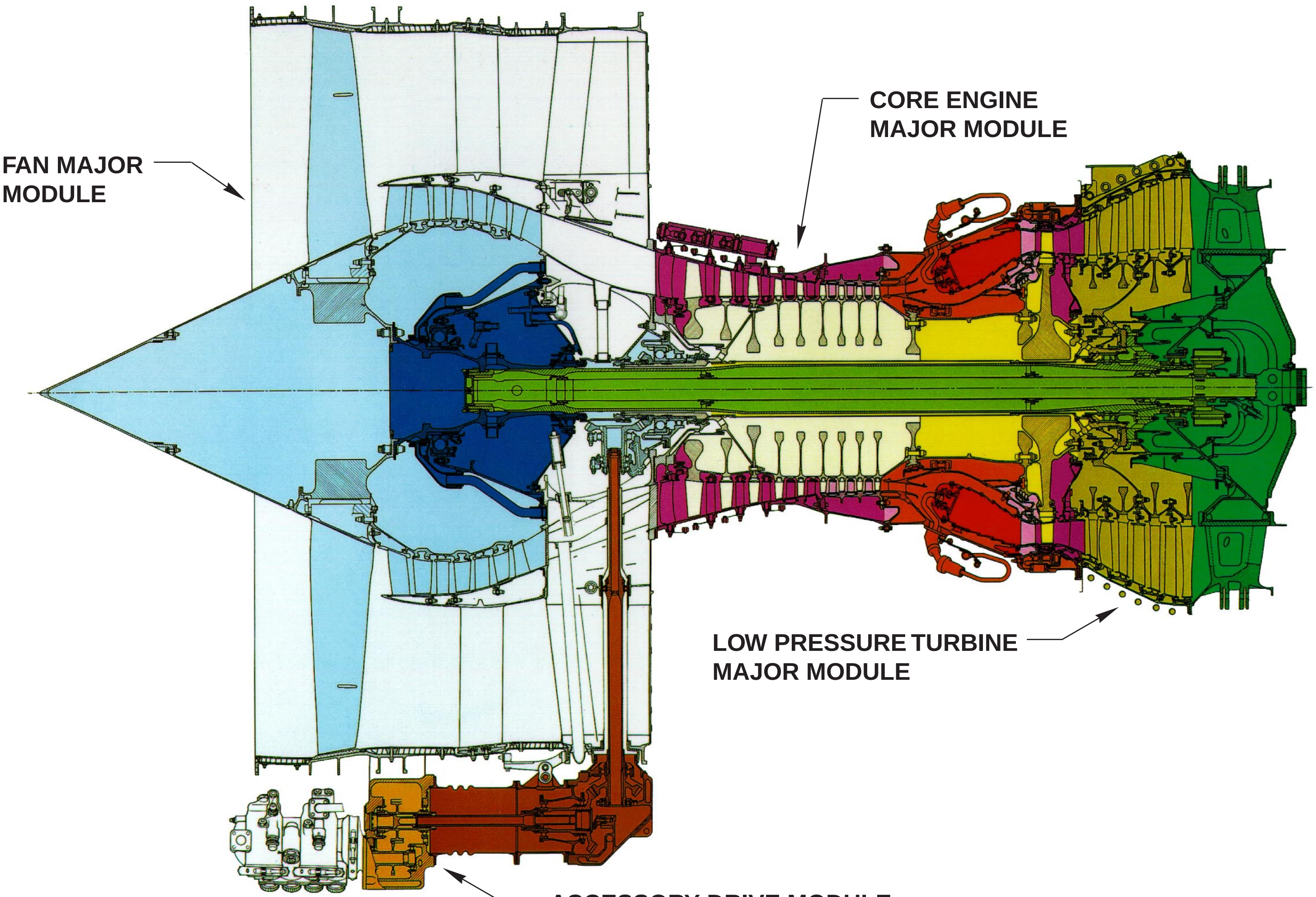
ENGINE GENERAL CONCEPT

ENGINE GENERAL CONCEPT

The CFM56-5A is a modular concept design engine. It has 17 different modules that are enclosed within three major modules and an accessory drive module.

The 4 modules are:

- The Fan Major Module
- The Core Engine Major Module
- The Low Pressure Turbine Major Module
- The Accessory Drive Module



MODULAR DESIGN

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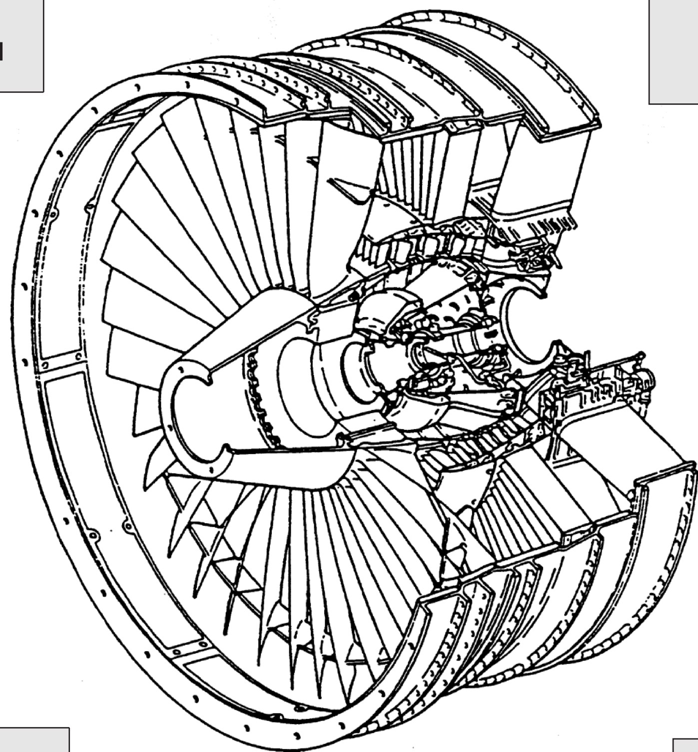
FAN MAJOR MODULE

FAN MAJOR MODULE

The fan major module is at the front of the engine, downstream from the air inlet cowl.

Its main purposes are :

- to provide approximately 80% of the engine thrust
- to provide the engine/pylon front attachment
- to enclose the fan stage and Low Pressure Compressor stages
- to provide structural rigidity in the front section
- to provide containment for front section major deterioration and/or damage
- to provide noise reduction for the fan section
- to provide attachment for gearboxes and nacelle equipment
- to provide attachment for the core engine



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FAN MAJOR MODULE PURPOSES

FAN MAJOR MODULE

The fan major module consists of 4 modules :

- Fan and booster module.
- No 1 and 2 bearing support module.
- Fan frame module.
- Inlet gearbox and No 3 bearing.

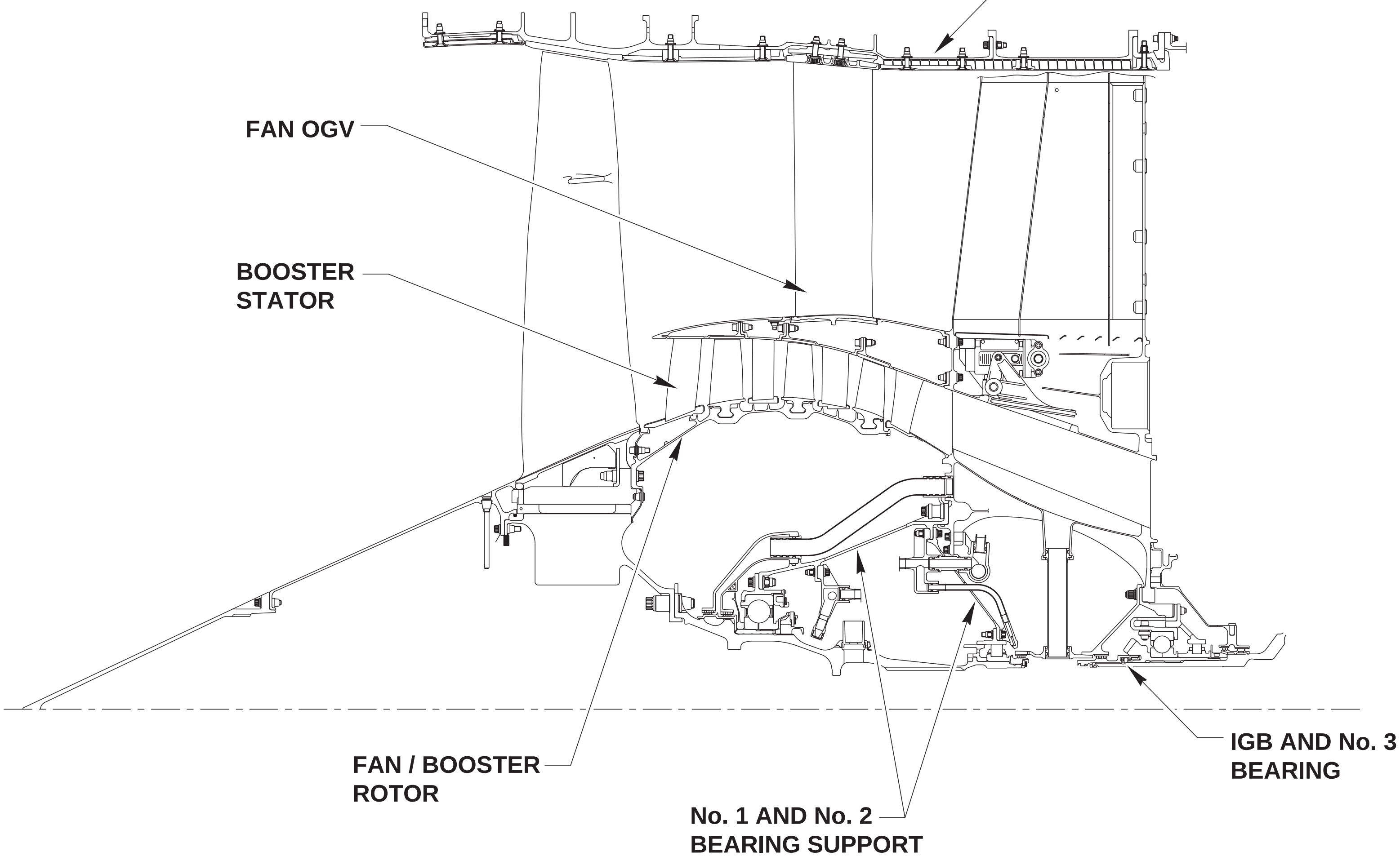
The fan is a single-stage rotor which is cantilever mounted at the forward end of a shaft held by 2 bearings.

The booster contains 3 stages and is cantilever mounted to the aft side of the fan rotor.

The No.1 and 2 bearing module supports the fan and booster rotor.

The inlet gearbox and No.3 bearing module supports the high pressure compressor forward section and gives power transmission from the core engine to the accessory drive section.

The fan frame module is the main forward structural component to supply mounting of the front of the engine on the aircraft.



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FAN MAJOR MODULE

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FAN AND BOOSTER

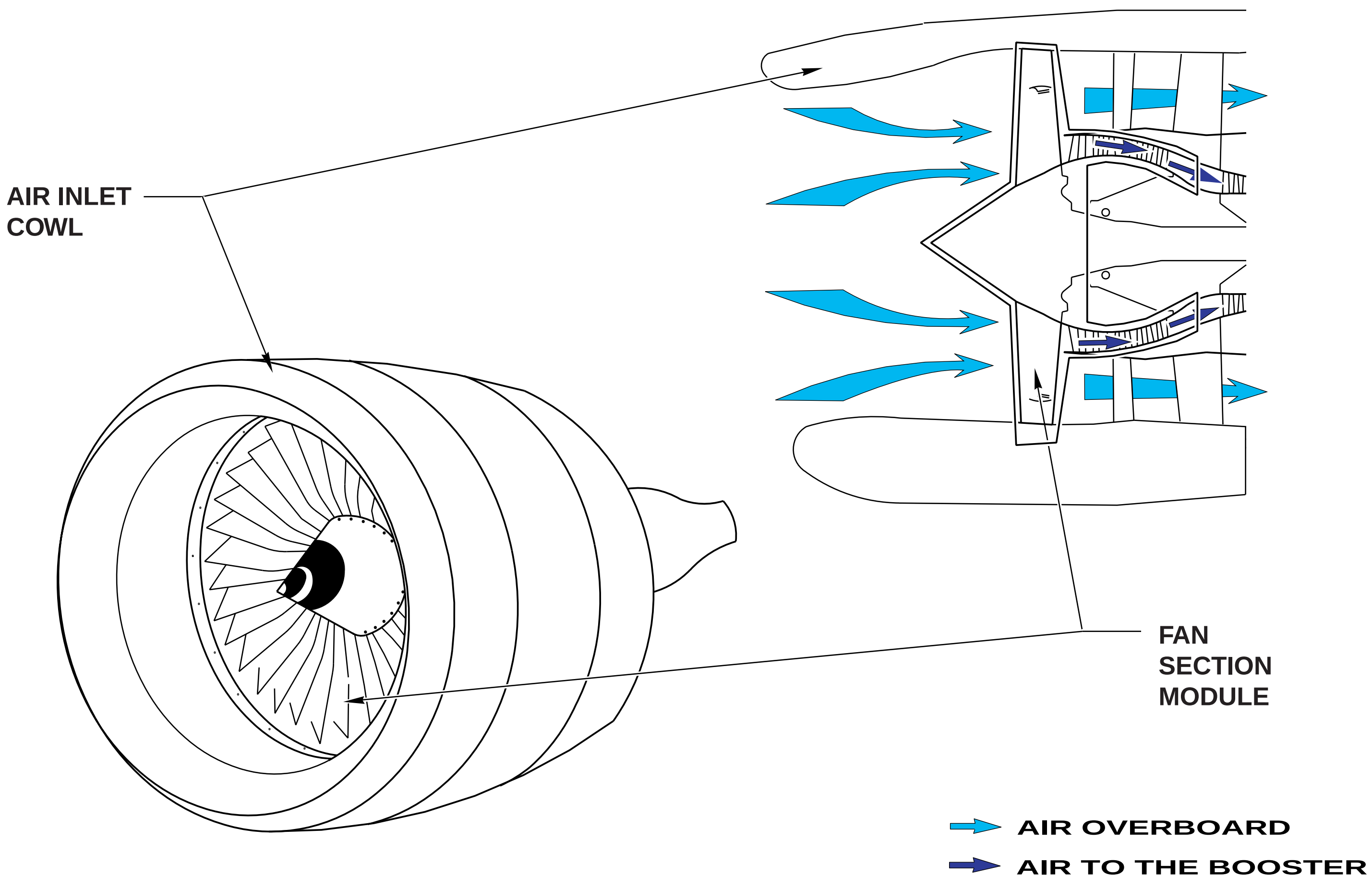
FAN AND BOOSTER

The purposes of the fan and booster are :

- to accelerate air overboard to generate thrust
- to increase the pressure of the air directed to the High Pressure Compressor (HPC)

After entering the air inlet cowl, the total engine airflow passes through the fan rotor, which increases the air’s kinetic energy.

Most of the airflow is ducted overboard producing approximately 80% of the total thrust. The remainder is directed through the booster, where it is pressurized before entering the HPC.



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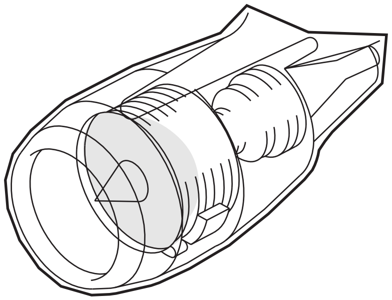
FAN AND BOOSTER MODULE

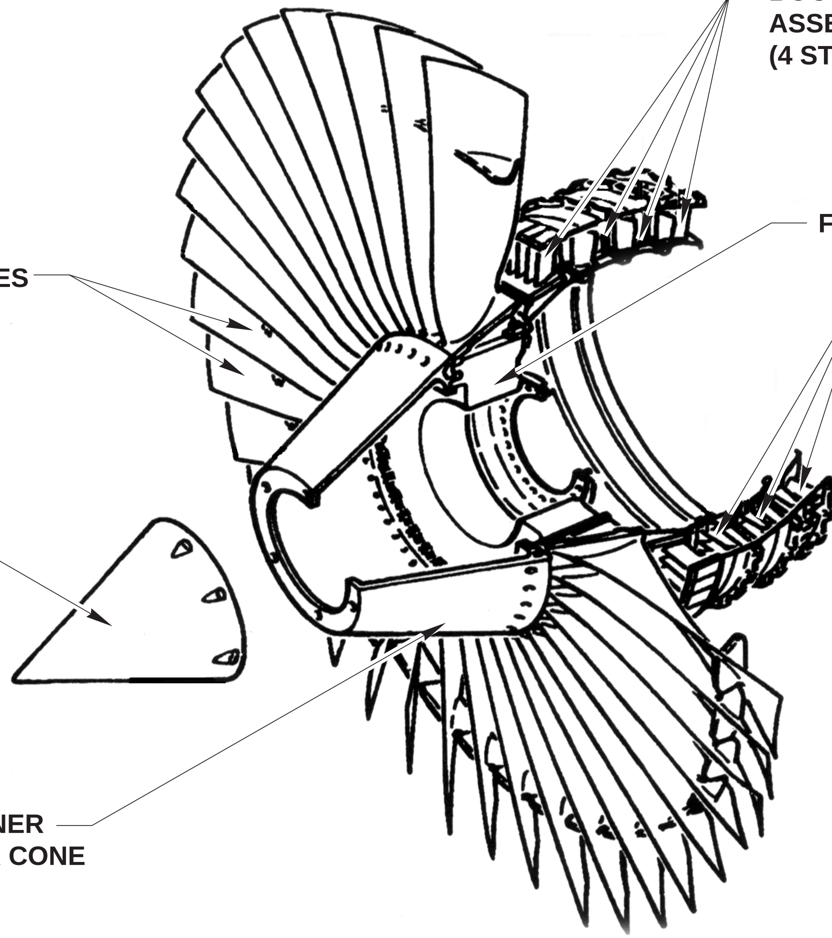
FAN AND BOOSTER (CONTINUED)

The fan and booster is located at the front of the engine, downstream from the air inlet cowl, and consists of the following major parts :

- spinner front cone.
- spinner rear cone.
- fan disk.
- fan blades.
- booster rotor.
- booster vanes assemblies.

Its rotating assembly is mounted on the fan shaft and its fixed assembly is secured to the fan frame.





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FAN AND BOOSTER ASSEMBLY

FAN AND BOOSTER (CONTINUED)

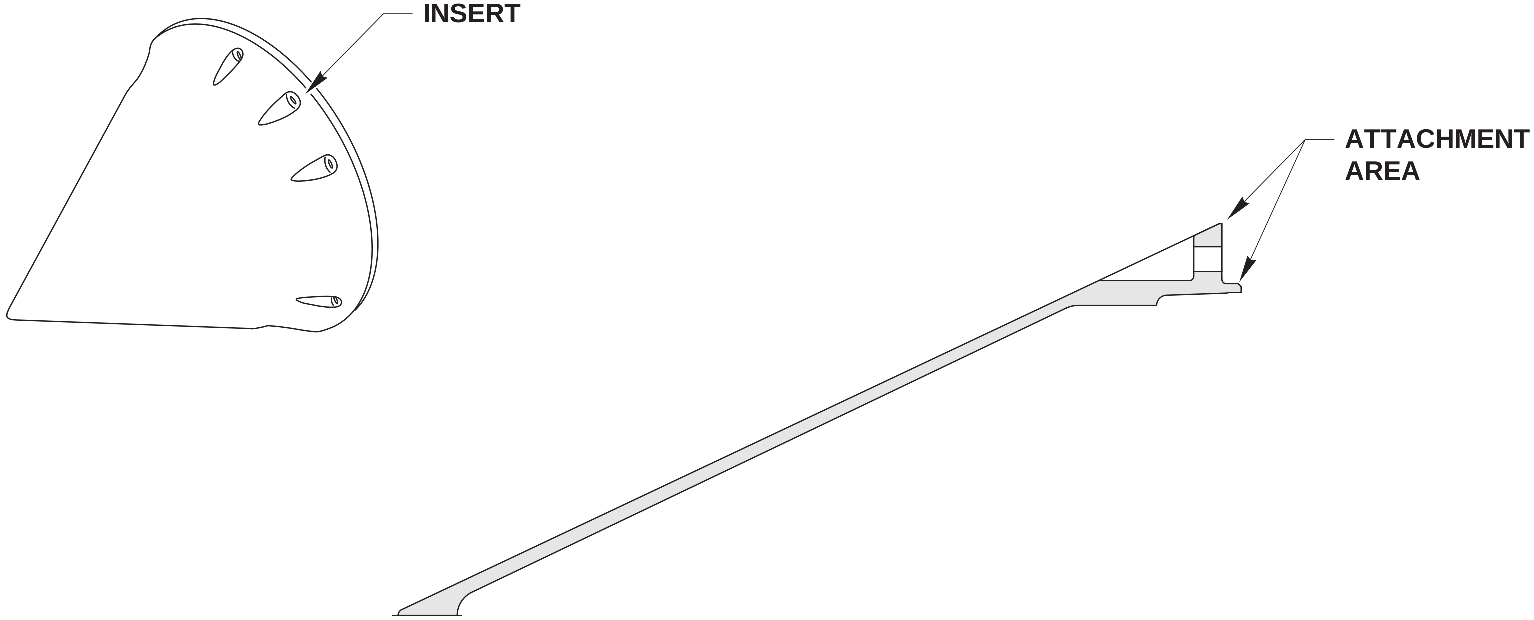
Spinner front cone

The spinner front cone is made of composite material and it is conical in shape to prevent buildup of large ice particles without the need for an engine nose anti-icing system.

It is at the front of the engine and is a hollow cone-shaped structure, which is attached on its rear flange to the spinner rear cone. The attachment is an interference fitting.

The rear flange has 6 mounting screw locations and 3 threaded inserts, located every 120°, for installation of jackscrews used in removal procedures.

An offset hole, identified by an indent mark, ensures correct installation and centering onto the rear cone front flange.



CTC-044-012-00

SPINNER FRONT CONE

FAN AND BOOSTER (CONTINUED)

Spinner rear cone

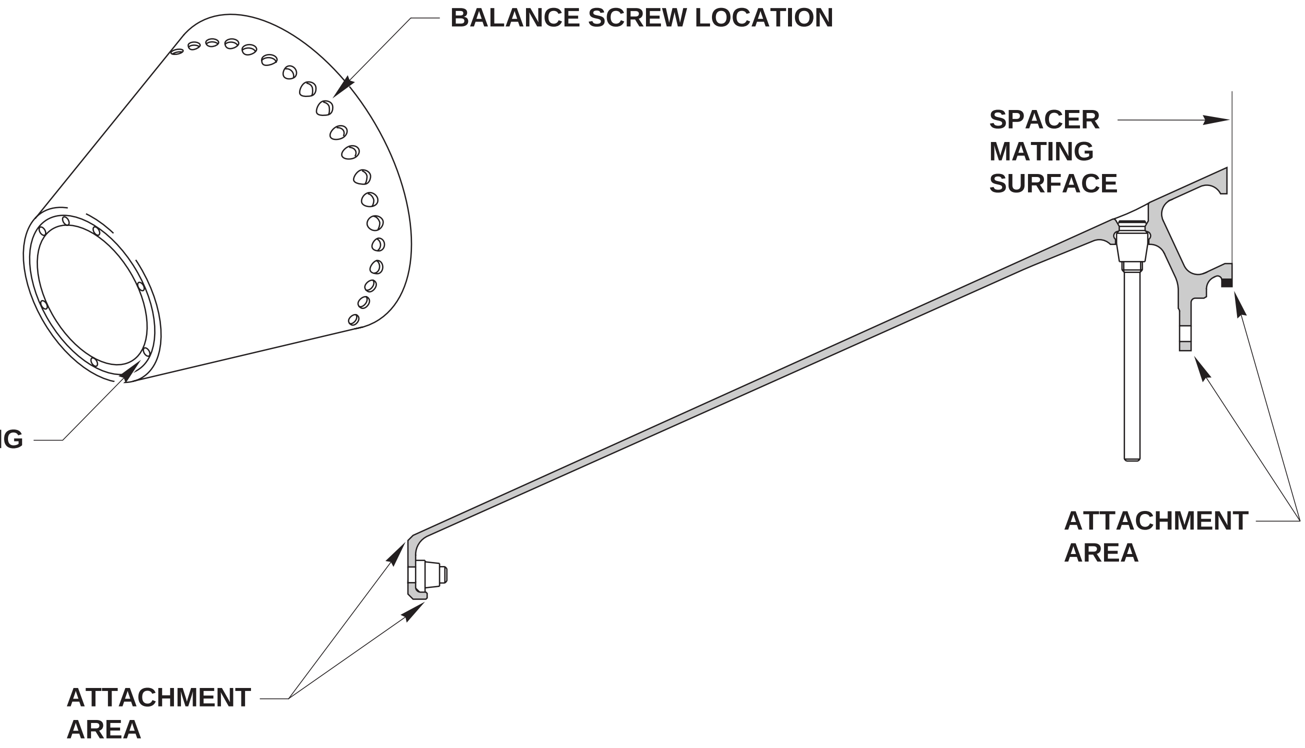
The rear cone prevents axial disengagement of spacers used in the fan blade retention system and 36 threaded inserts on the outer rim of the rear flange accommodate balancing screws used in fan trim and static balance procedures.

It is a hollow elliptical structure made of aluminium alloy and is mounted on interference fit flanges between the spinner front cone and the fan disk.

The front flange has 6 line replaceable, crimped, self-locking nuts.

The inner rear flange has 12 mounting screw holes for installation onto the fan disk and there are a further 6 threaded holes for the installation of jackscrews used in rear cone removal procedures.

Both front and rear flanges have an offset hole to ensure correct installation and they are identified by indent marks. On the front flange of the rear cone, the indent mark is next to the offset hole. The other indent mark is on the outer rim of the rear cone, facing fan blade No.1.



CTC-044-013-00

SPINNER REAR CONE

FAN AND BOOSTER (CONTINUED)

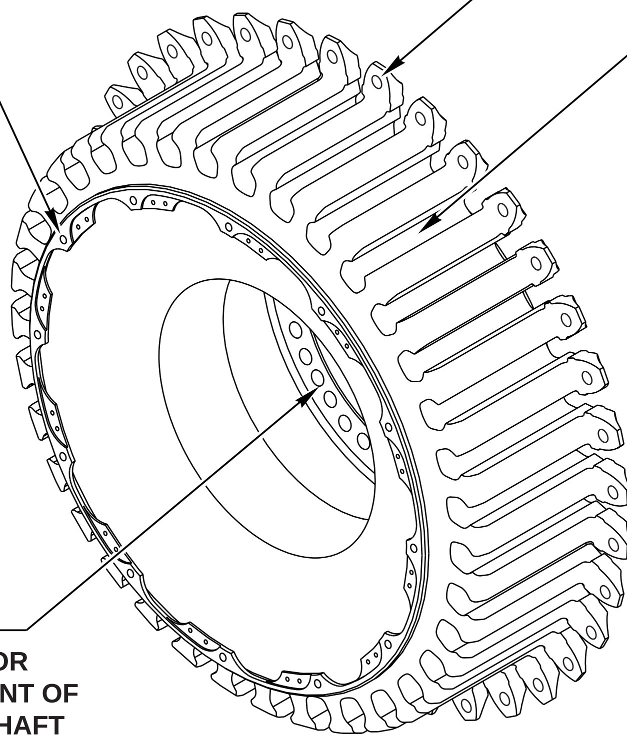
Fan disk

The fan disk is a titanium alloy forging. The spinner rear cone is attached to its outer front flange and its outer rear flange supports the booster rotor.

The fan disk outer rim has 36 dovetail recesses for installation of the fan blades.

Its inner rear flange provides attachment for the fan shaft (No.1 & 2 bearing support module). This flange also features holes to allow the riveting of balance weights used at shop maintenance level for fan and booster rotor balancing.

A circumferential groove on the outer front flange provides for an o-ring seal, which ensures air sealing between the disk and the rear spinner during engine operation.



FAN DISK

CTC-044-014-00

FAN AND BOOSTER (CONTINUED)

Fan blades

The fan blades form the first stage of the Low Pressure Compressor and accelerate the air entering the engine through the air inlet cowls.

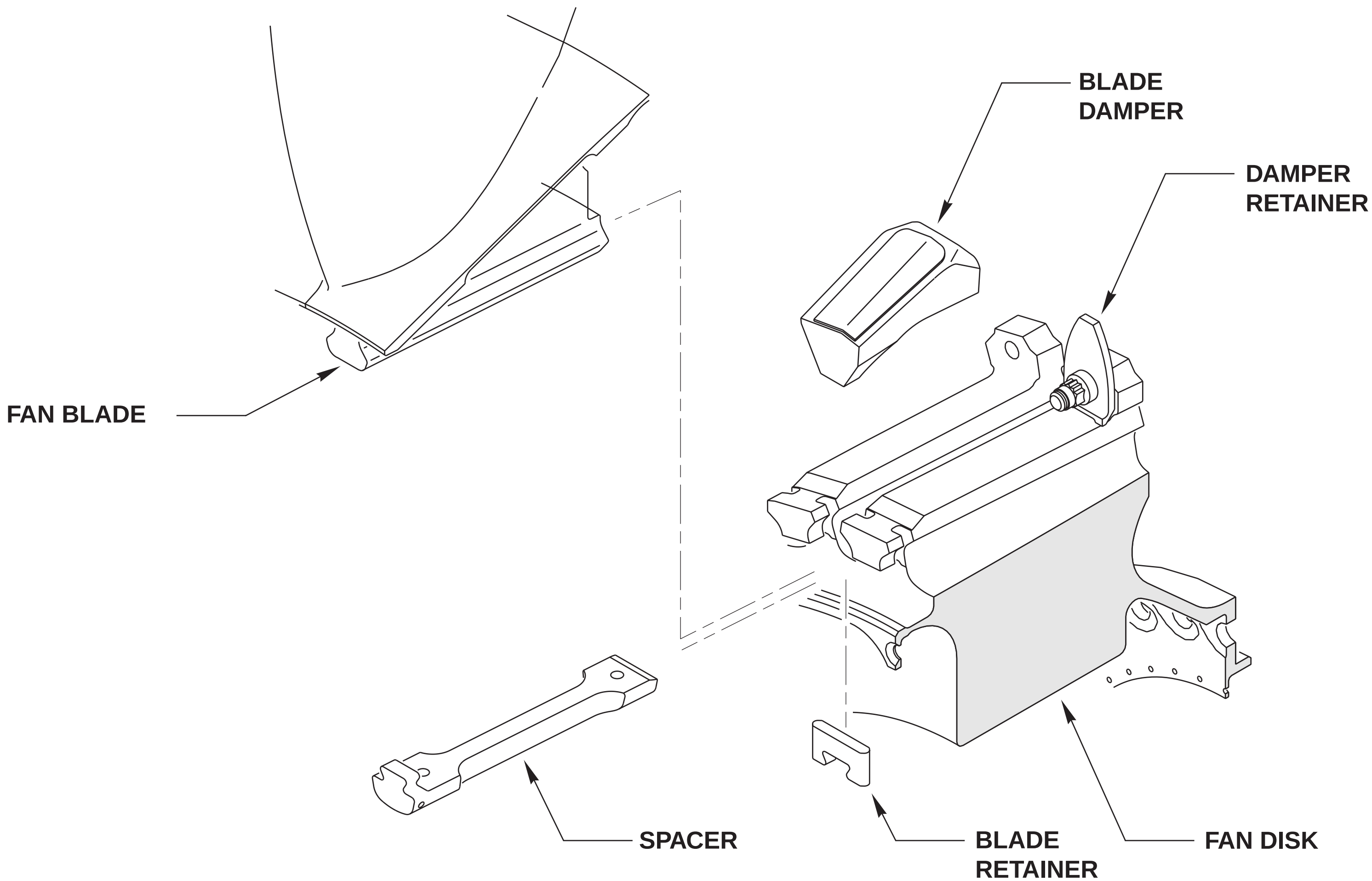
There are 36 titanium alloy, mid-span shrouded fan blades.

Each blade has a dovetail base that slides into a recess on the fan disk outer rim.

The fan blades are approximately 23ins (0.58m) long.

The blades are individually retained by a spacer that limits radial movement, a blade retainer that limits forward axial movement and by the booster spool front flange that limits axial movement rearward.

In order to limit vibration, dampers are installed in the cavity between adjacent blades, below the inner platform. The damper is axially retained by a plate of metal bolted on the rear flange of the fan disk.



FAN BLADE RETENTION

CTC-044-015-00

FAN AND BOOSTER (CONTINUED)

Fan blades (continued)

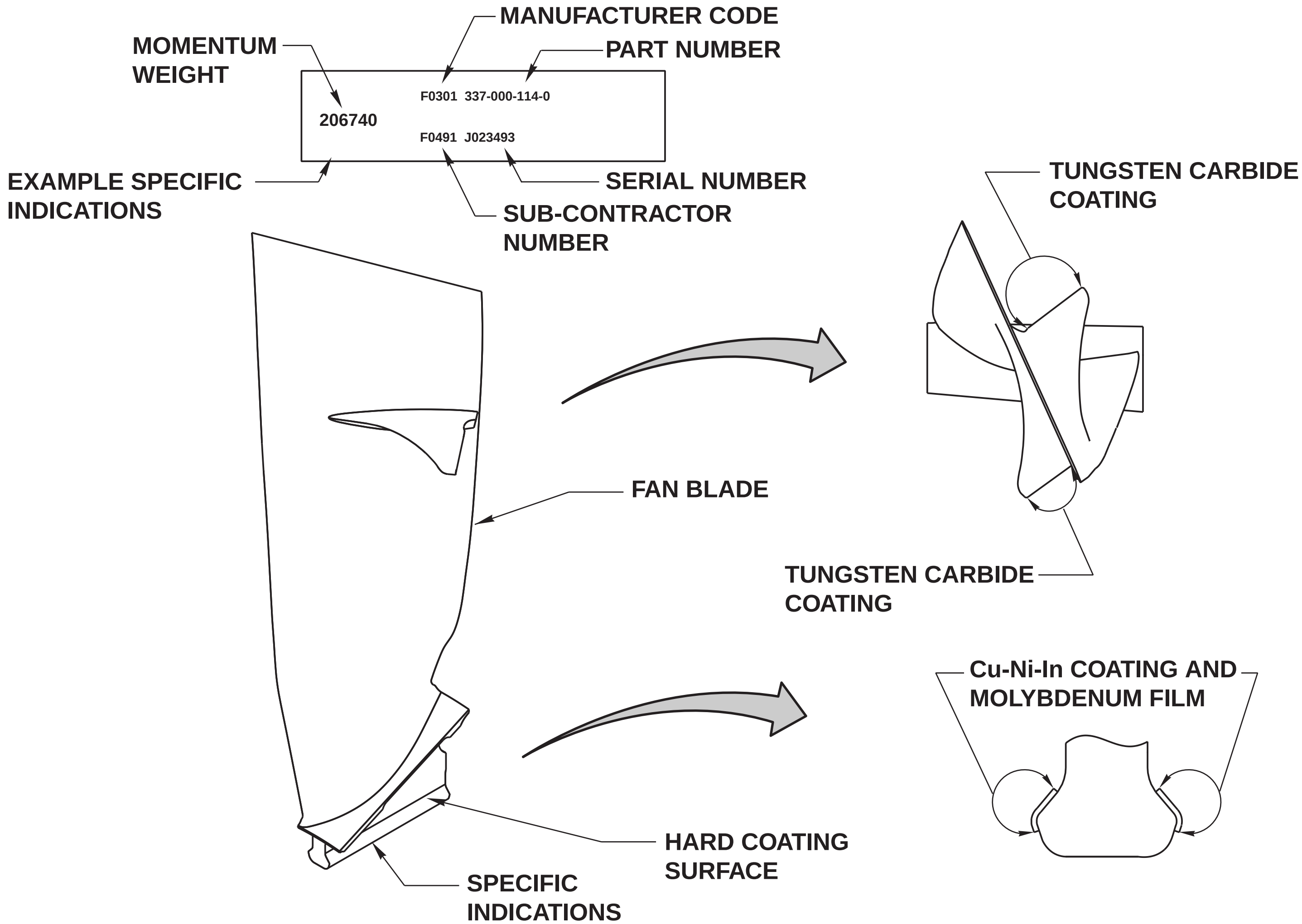
Each blade has specific indications engraved on the bottom of the root.

- Part number
- Serial number
- Momentum weight
- Manufacturer code

The fan blade root faces have an anti-friction plasma coating (Cu-Ni-In) and a top coat of cured molybdenum-base film varnish, which acts as a lubricant.

Lubrication of blade roots is further improved by the application of solid molybdenum-base lubricant before installation on the fan disk.

The mid-span shroud contact surfaces have a tungsten-carbide coating. They are also lubricated with solid molybdenum-base lubricant at blade installation.



FAN BLADE ROOT

CTC-044-016-00

FAN AND BOOSTER (CONTINUED)

Booster rotor

The booster rotor accelerates the air as it passes from stage to stage.

The 4-stage booster rotor consists of the fan blades and a booster spool, forged and machined from titanium alloy, that is cantilever mounted on the rear of the fan disk.

The inner front flange acts as a stop for the fan blades and spacers and the outer front flange is designed with a forward rotating air seal.

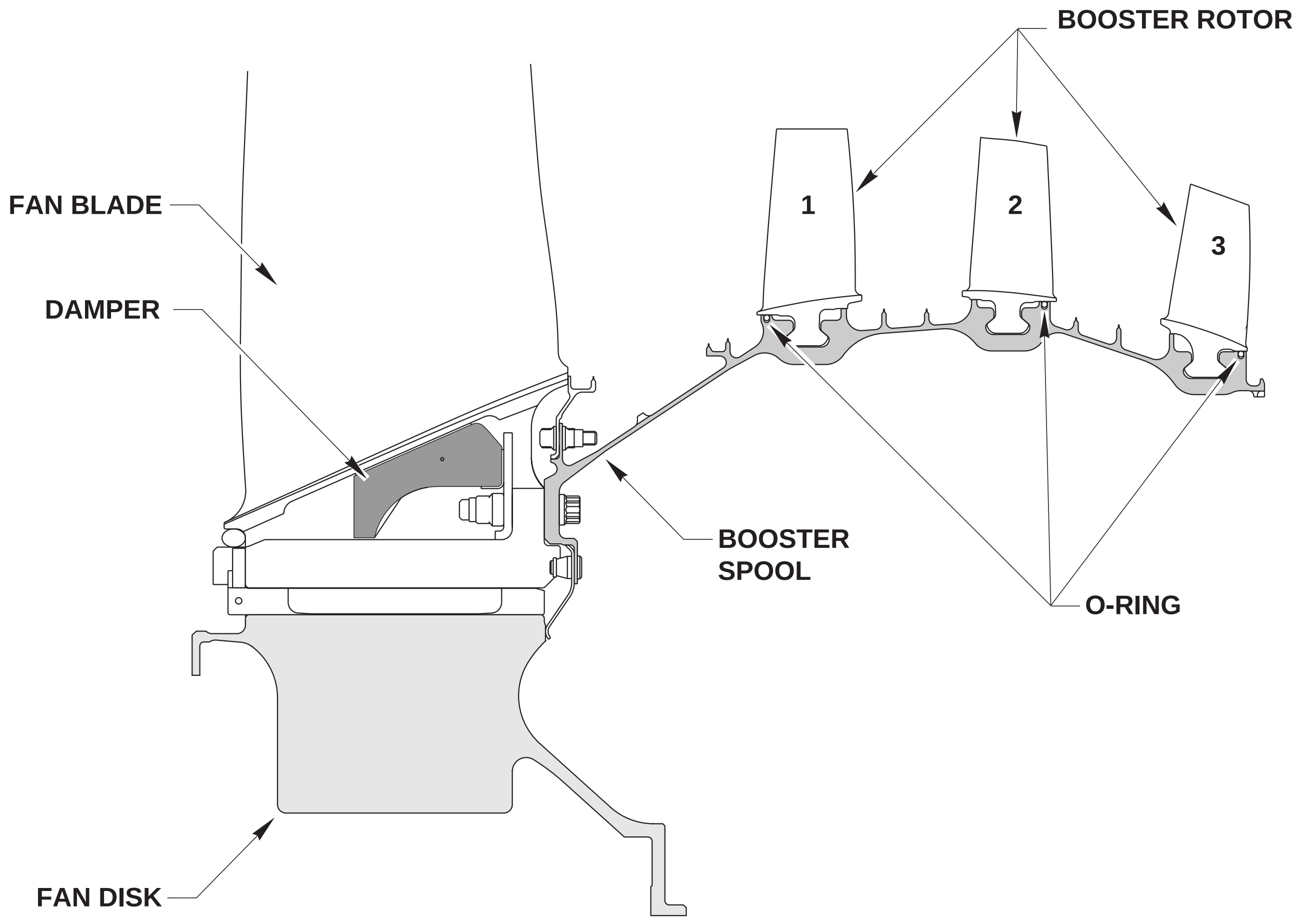
The 3-stage spool has circumferential slots that retain the stages 2, 3 and 4 blades.

Each stage is provided with two retaining lugs which ensure blade locking in the slot. The retaining lugs location is shifted 120 degrees from one stage to the other in order to ensure first static balancing of the booster.

Circumferential slots are located at the front of the stage 2 blade location, the rear of the stage 3 blade location and the rear of the stage 4 blade location. They also provide a location for O-ring seals, which ensure air sealing during engine operation.

Each stage has 76 titanium alloy blades. Two types of blades are provided, which have different platform widths (narrow and wide). This allows circumferential gap adjustment during blade assembly.

Balancing weights can be installed in the slot of stage No.4 to provide balancing of the fan and booster rotor at shop maintenance level.



CTC-044-017-00

BOOSTER ROTOR

FAN AND BOOSTER (CONTINUED)

Booster stator vane assembly

The stator vane assembly changes the air velocity into pressure.

The stacked vane assemblies are cantilever mounted on the fan frame mid-box inner front flange.

Each vane assembly consists of the stator vanes and inner and outer shrouds.

The outer shroud, depending on its assembly location, is fitted with 1 or 2 mounting flanges at its ends.

A splitter fairing, installed on the outer shroud of stage 1, separates the Primary and Secondary airflows.

The inner face of the shrouds, which faces the rotor blades, is lined with an abradable material. The outer shroud rear flange of stage 4 is bolted on the fan frame.

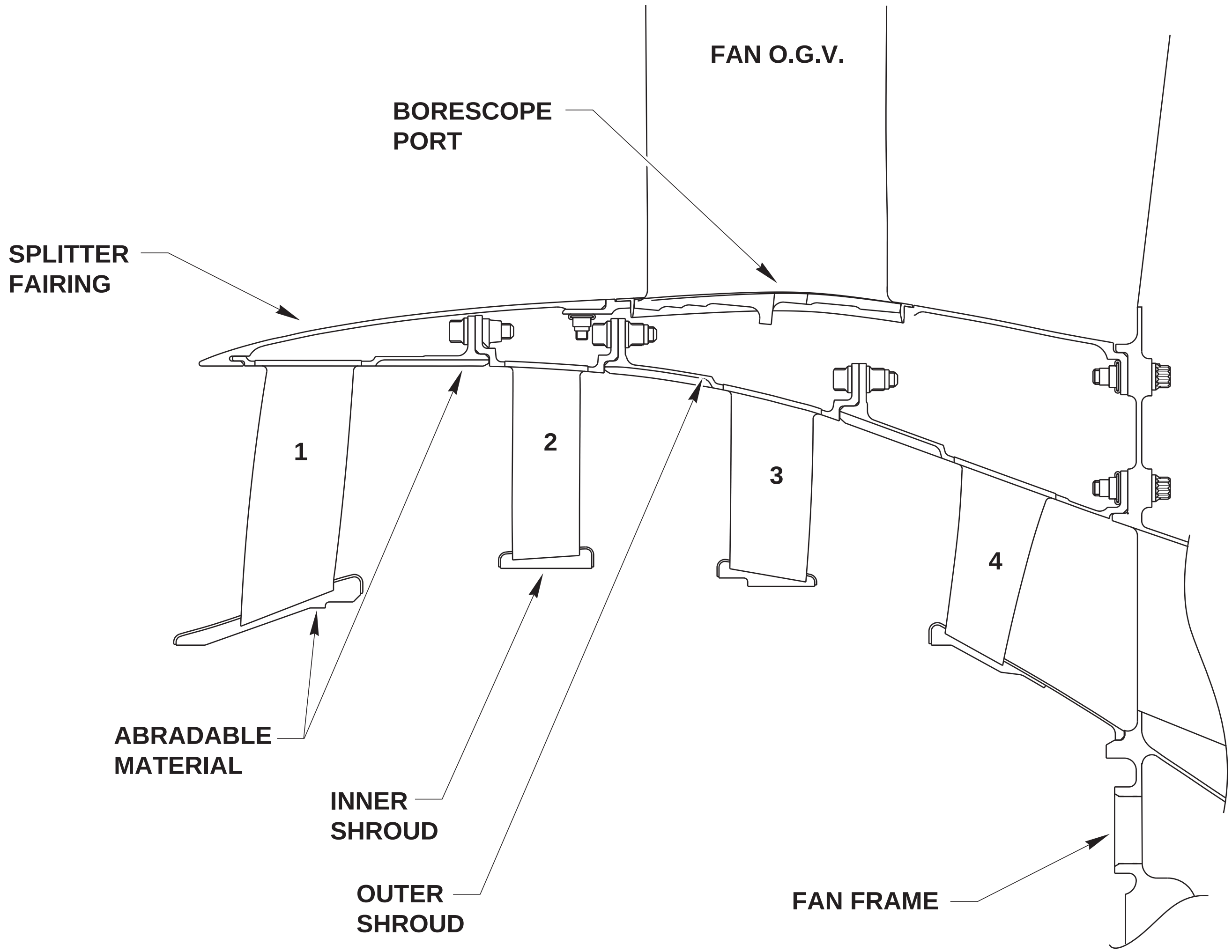
The outer shroud of stage 3 has an orifice at the 3:30 clock position, allowing for borescope inspection.

The stator vanes are welded on the outer shrouds.

The number of vanes for each stage are :
- stage 1 : 114
- stage 2 : 128
- stage 3 : 132
- stage 4 : 102.

The inner shrouds are bonded with their corresponding stage of vane by application of abradable material on the shroud inner side.

The abradable material of each stage faces the rotating air seals machined on the booster spool.



CTC-044-018-00

BOOSTER VANES ASSEMBLIES

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No.1 AND No.2 BEARING SUPPORT MODULE

NO.1 AND 2 BEARING SUPPORT MODULE

The No.1 and 2 bearing support module belongs to the fan major module and its purpose is :

- to support the fan and booster rotor
- to enclose the front section of the forward oil sump
- to support one of the vibration sensors
- to vent the forward sump
- to provide the fan speed indication
- to direct bearings lubrication

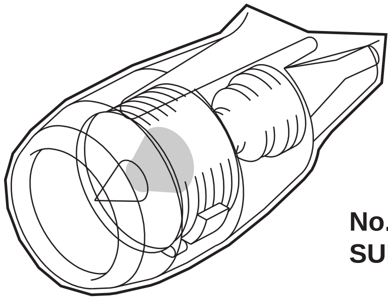
The LP compressor and LP turbine coupling is provided by a shaft attached to the fan disk at the front and coupled to the LPT shaft at the back (splines and nut arrangement).

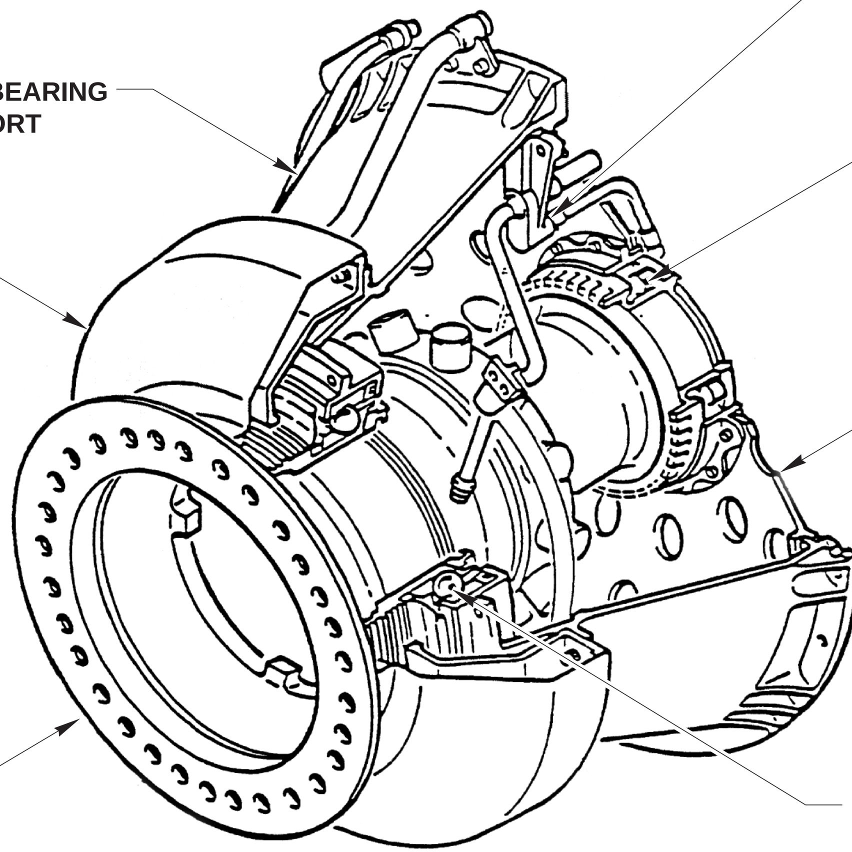
Fan and booster rotor support is ensured by two bearings, which support the rotor assembly through the fan shaft. This bearing assembly is secured to the engine fan frame.

The bearing support assembly forms the front end of the forward sump and is designed to be plugged into the fan frame assembly.

The No.1 and 2 bearing support module includes the following major parts :

- No.1 bearing support.
- Stationary air/oil seal.
- Fan shaft.
- No.1 ball bearing.
- No.2 bearing support.
- No.2 roller bearing.
- Oil manifold assembly.
- External piping.





CTC-044-019-00

No. 1 & No. 2 BEARING SUPPORT ASSEMBLY

NO.1 AND 2 BEARING SUPPORT MODULE (CONTINUED)

No.1 bearing support

The No.1 bearing support is a titanium alloy weldment which transmits loads from the No.1 bearing to the fan frame.

Its rear outer flange is bolted to the fan frame center hub.

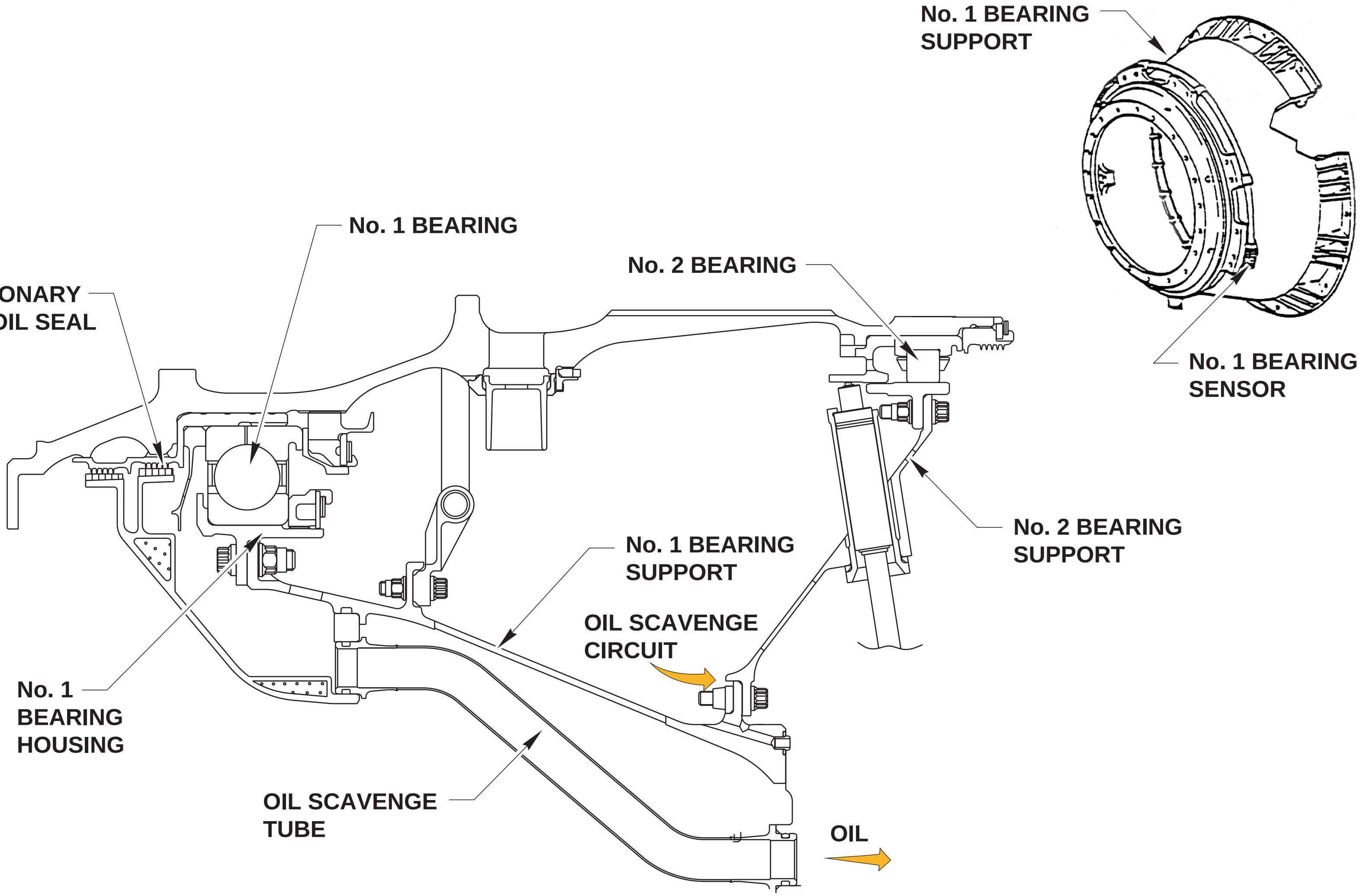
At the 6 o'clock position, the flange is provided with a coupling sleeve which connects the bottom of the No.1 bearing support cavity with the forward sump oil scavenge collector inside the fan frame hub.

The inner rear flange accommodates the No.2 bearing support.

The front flange of the support provides attachment for the No.1 bearing housing.

The outer suface of the support features a land and a flange to accommodate the forward sump stationary air/oil seal.

The forward casing has holes for oil and air venting into the No.1 bearing air/oil seal and subsequent tube transfer to the front sump.



No. 1 BEARING SUPPORT

CTC-044-020-00

NO.1 AND 2 BEARING SUPPORT MODULE (CONTINUED)

No.1 bearing

The No.1 ball bearing is a thrust bearing which takes up the axial and radial loads generated by the low pressure rotor system.

The No.1 bearing housing is bolted to the front flange of the No.1 bearing support and the housing bore accommodates the bearing outer race and its retainer nut.

A sleeve is installed on the fan shaft to accommodate the bearing inner race.

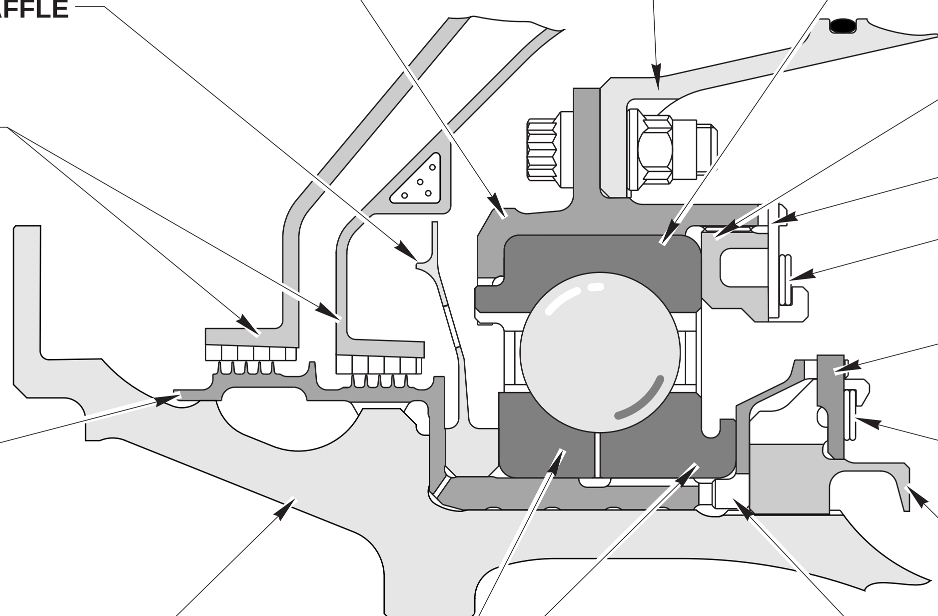
The forward outer diameter features 2 series of sealing ribs to form the rotating air/oil seal.

The sleeve forward bore has locating slots to lock onto the shaft and the rear of the center bore has circular and axial grooves connected to radial holes to supply lube oil to the bearing inner race.

The outer race is secured inside the housing with a nut, a keywasher and a retaining ring (axial lock).

The inner race consist of 2 halves mounted on the bearing sleeve and secured with a lock ring, a retainer nut, a keywasher and a retaining ring.

An oil baffle, installed on the sleeve forward of the No.1 bearing, uses centrifugal force to prevent oil from flooding the forward sump front oil seal. The baffle also acts as a shim during bearing installation.



CTC-044-021-00

No. 1 BEARING ASSEMBLY

NO.1 AND 2 BEARING SUPPORT MODULE (CONTINUED)

No.2 bearing support

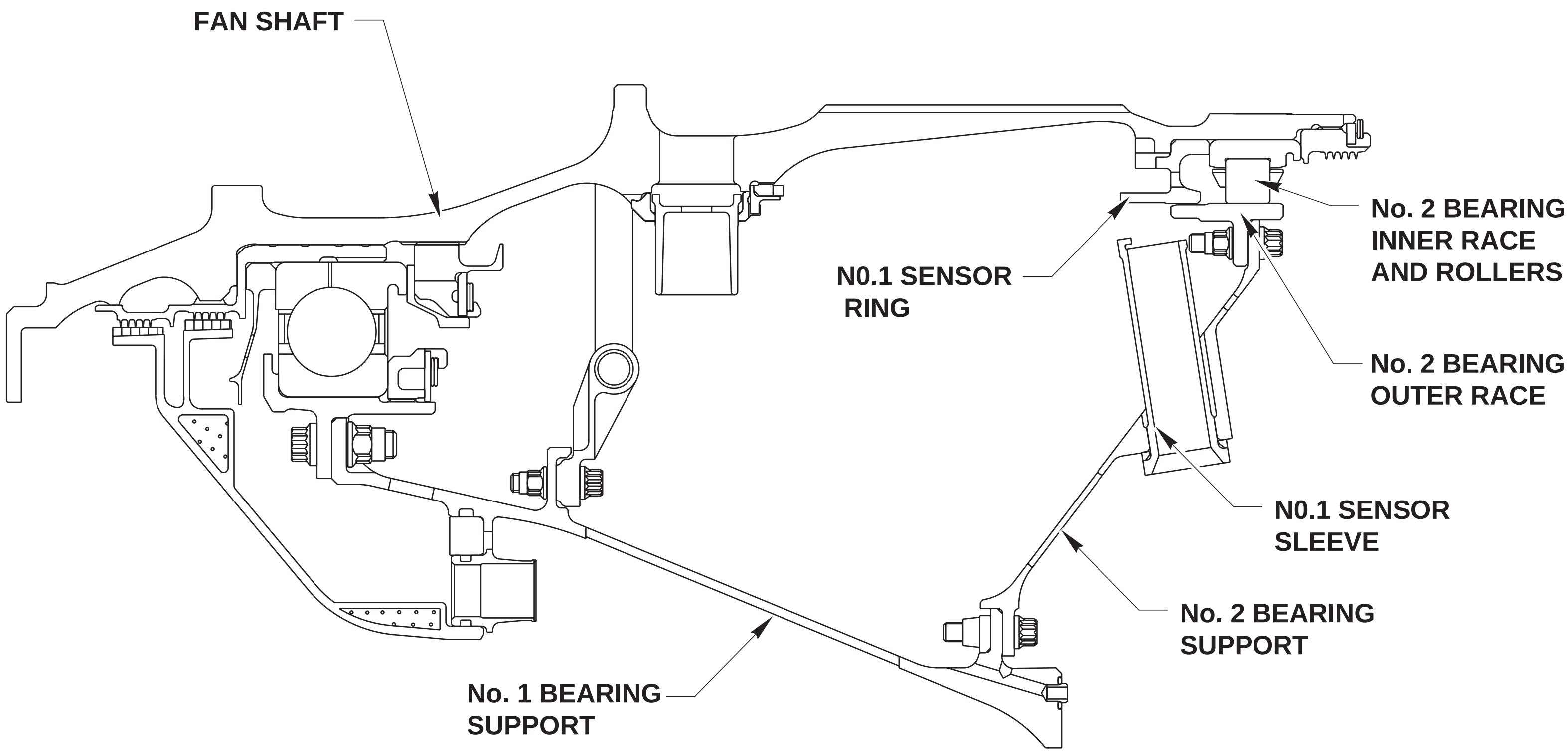
The No.2 bearing support is a steel alloy assembly, which transmits radial loads from the No.2 bearing to the No.1 bearing support.

Its front flange is bolted to the No.1 bearing support and its rear flange accommodates the No.2 bearing outer race.

There are holes in the support to balance internal pressures in the forward sump.

The support also accommodates an integral guide sleeve, at the 5 o'clock position, for installation of the N1 speed sensor probe.

There are holes, at the 9 o'clock position, to supply oil to the oil manifold assembly and for installation of the No.2 bearing oil nozzle.



CTC-044-022-00

No. 2 BEARING SUPPORT

NO.1 AND 2 BEARING SUPPORT MODULE (CONTINUED)

No.2 bearing

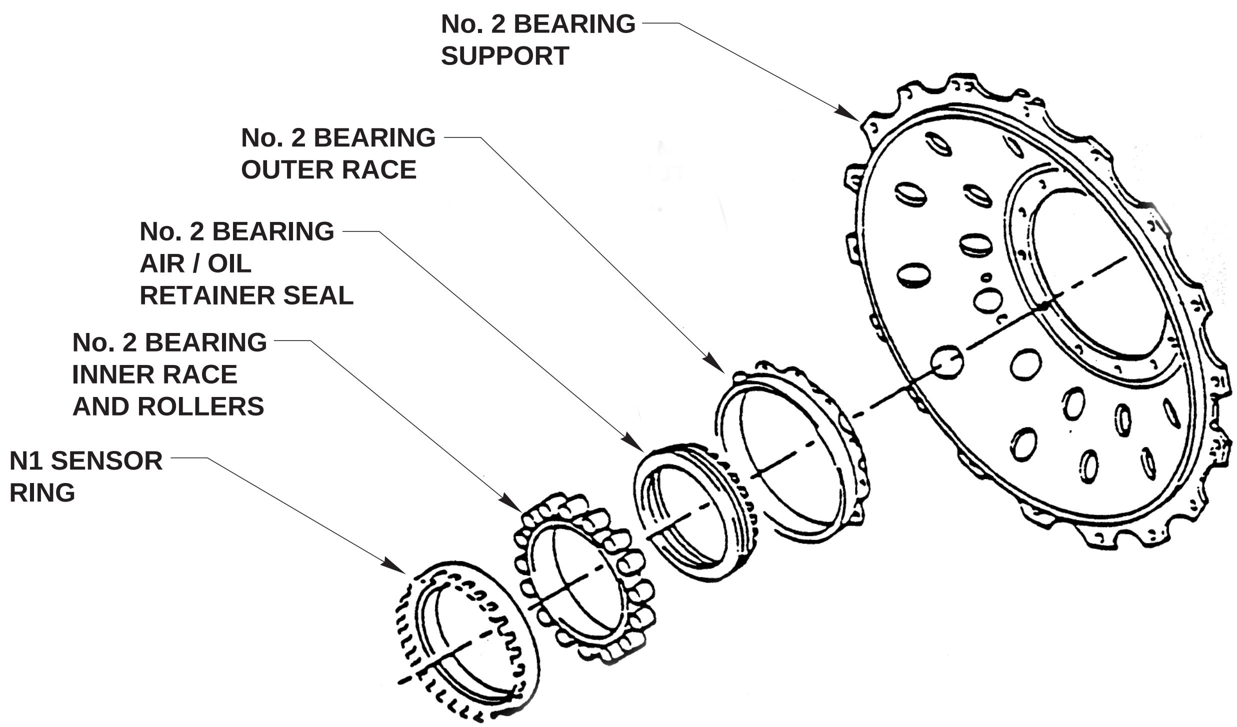
The No.2 roller bearing takes up some of the radial loads from the fan and booster rotor.

Its outer race is bolted to the No.2 bearing support and its inner race is directly installed on the fan shaft and secured with a retainer seal.

The No.2 bearing air/oil retainer seal completes axial locking of the bearing. The retainer seal is threaded onto the fan shaft and is locked with a keywasher and a retaining ring. Its outer diameter has sealing ribs which form the rotating element of a sump pressurization seal.

The N1 speed sensor ring is located between the No.2 bearing inner race and the fan shaft. It has two lugs on its forward face which engage into matching slots on the fan shaft, giving a single angular position.

The outer diameter of the ring has 30 teeth counted by a magnetic sensor to provide a signal proportional to the rotational speed. The hub of the ring has a land designed to momentarily take up radial loads in case of No.2 bearing failure.



CTC-044-023-00

No. 2 BEARING

NO.1 AND 2 BEARING SUPPORT MODULE (CONTINUED)

The fan shaft

The fan shaft is a steel alloy forging and is supported by the No.1 & 2 bearings.

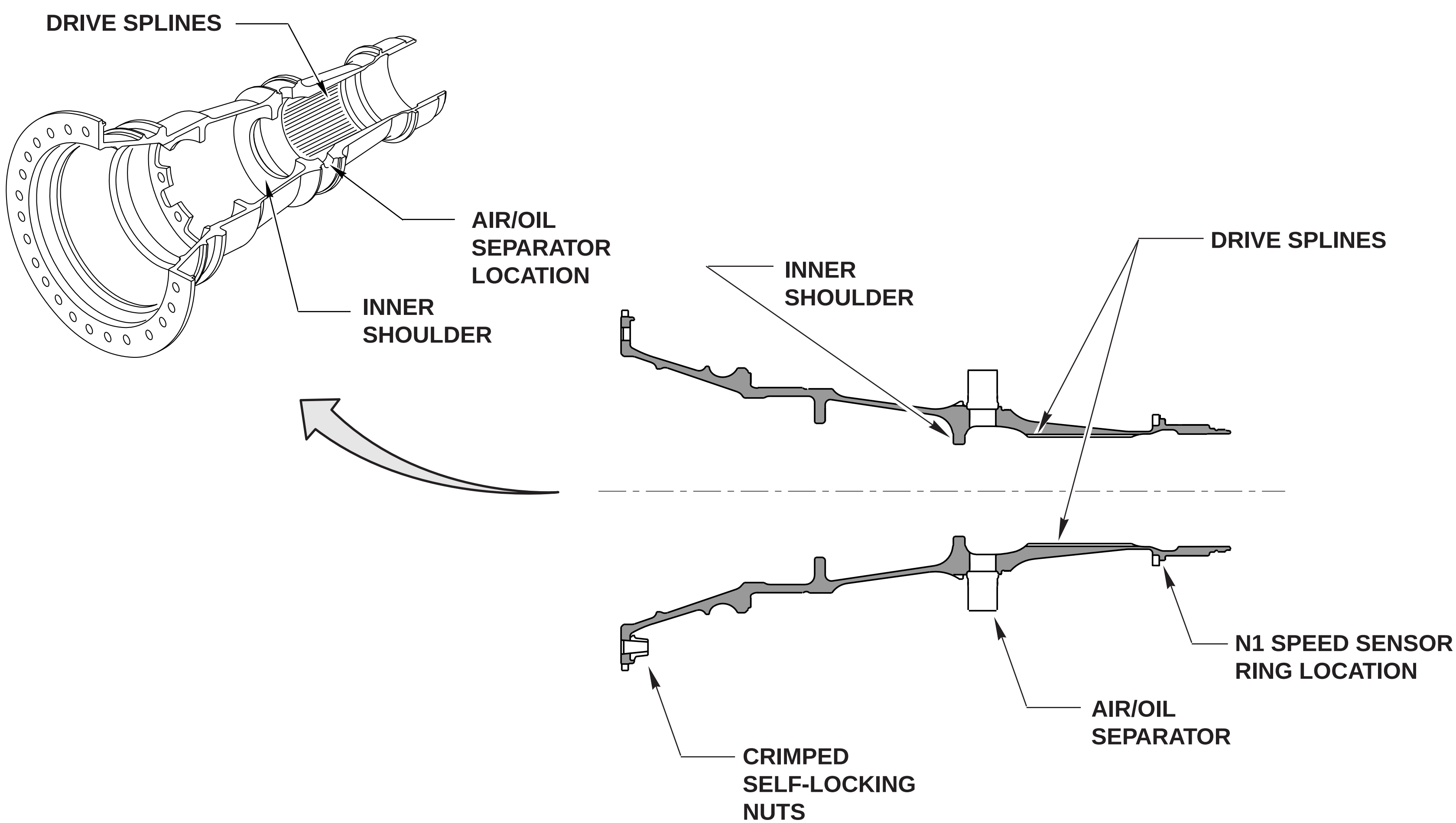
Its front flange provides for centering of the fan disk and is attached through crimped self-locking nuts.

It has internal drive splines and an inner shoulder for axial retention and mechanical coupling of the LPT shaft.

A flange at mid-length inside the center bore acts both as an axial stop for the LPT shaft and as a shouldering surface for the LPT coupling nut.

An air/oil separator is located on the fan shaft between the No.1 & 2 bearings.

The fan shaft also provides a single annular position for installation of the N1 speed sensor ring.



FAN SHAFT

CTC-044-024-00

NO.1 AND 2 BEARING SUPPORT MODULE (CONTINUED)

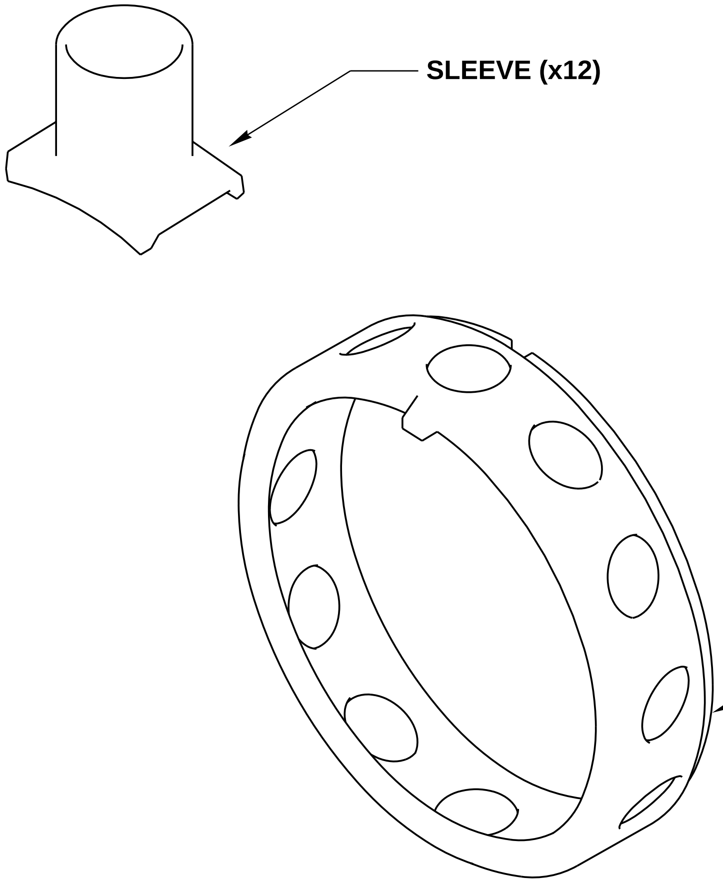
Air/oil separator

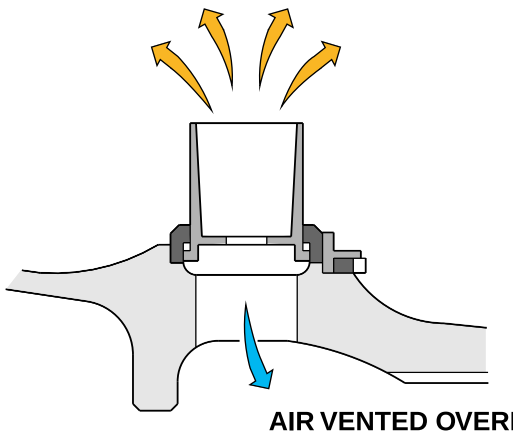
The air/oil separator uses centrifugal force to separate oil particles from the air, which is then vented overboard.

It consists of a support ring, holding 12 sleeves, and is held in position by a nut and keywasher.

Each sleeve has an integral restrictor slowing down the air/oil mixture flowing out of the sump.

Oil vapors condense on the inner diameter of the sleeve and are subjected to centrifugal force.





AIR/OIL SEPARATOR

CTC-044-025-00

NO.1 AND 2 BEARING SUPPORT MODULE (CONTINUED)

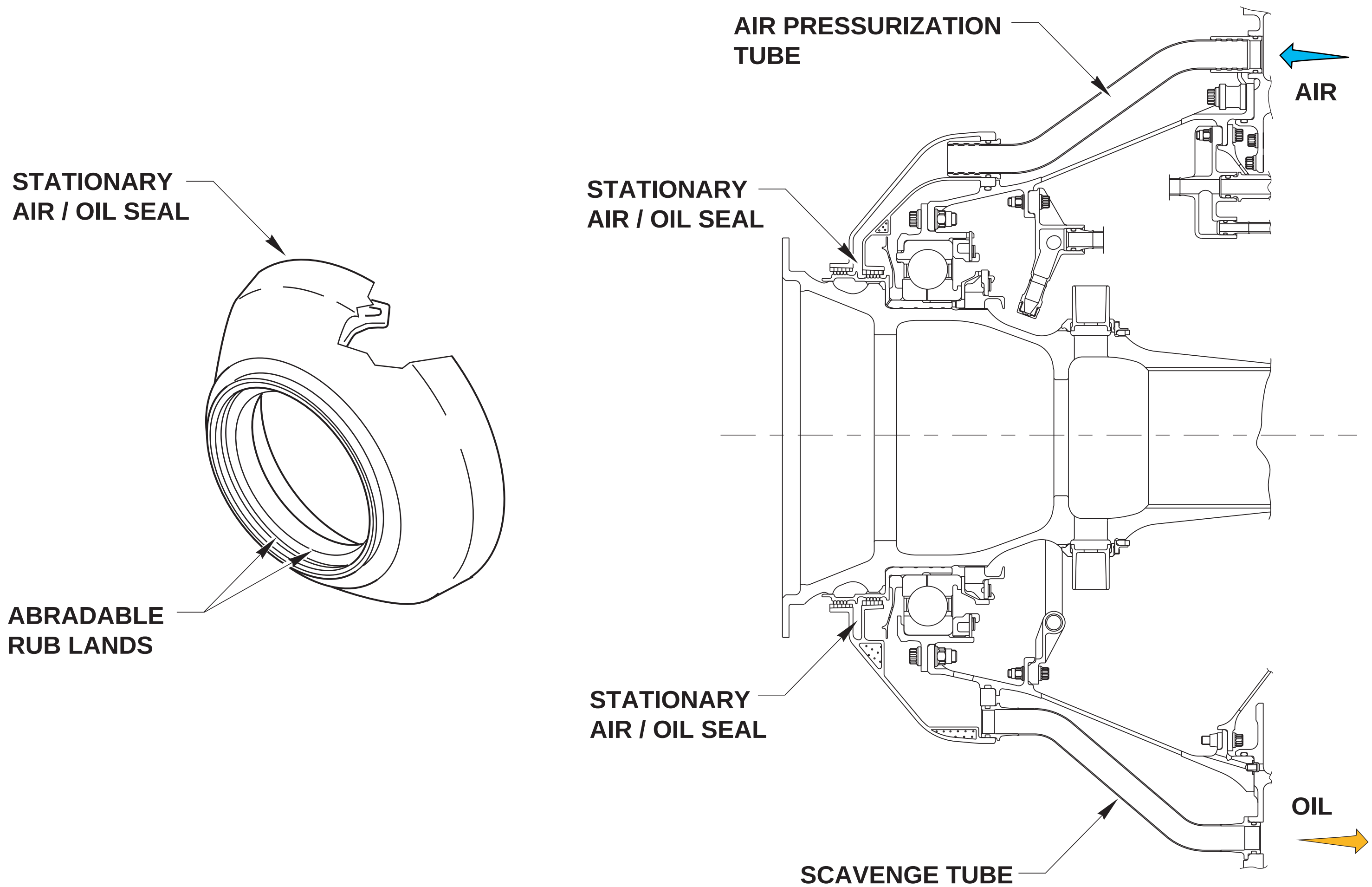
Forward stationary air/oil seal

The forward stationary air/oil seal limits the engine forward sump at its front end and ducts air for seal pressurization.

It is a composite material structure bolted to the No.1 bearing support front flange.

Its forward end has two separate lands coated with abradable material that surrounds sealing ribs on the bearing sleeve. These ribs form the rotating element of the forward sump front air/oil seal.

Space located between the seal inner and outer skin is divided into independent compartments for pressurization, drainage and oil scavenge.



CTC-044-026-00

FORWARD STATIONARY AIR/OIL SEAL

NO.1 AND 2 BEARING SUPPORT MODULE (CONTINUED)

Oil manifold assembly

The oil manifold assembly supplies oil from the fan frame hub to the No.1 & 2 bearings.

The assembly is installed on the No.1 & 2 bearing support and consists of :

- No.1 & 2 bearing oil tube assembly and coupling tube.
- A removable coupling tube
- No.1 bearing manifold
- No.2 bearing oil tube

The No.1 & 2 bearing oil tube assembly has two end fittings. The aft end fitting is bolted onto the rear inner flange of the No.1 bearing support. This aft end fitting accommodates a removable coupling tube and the No.2 bearing oil tube.

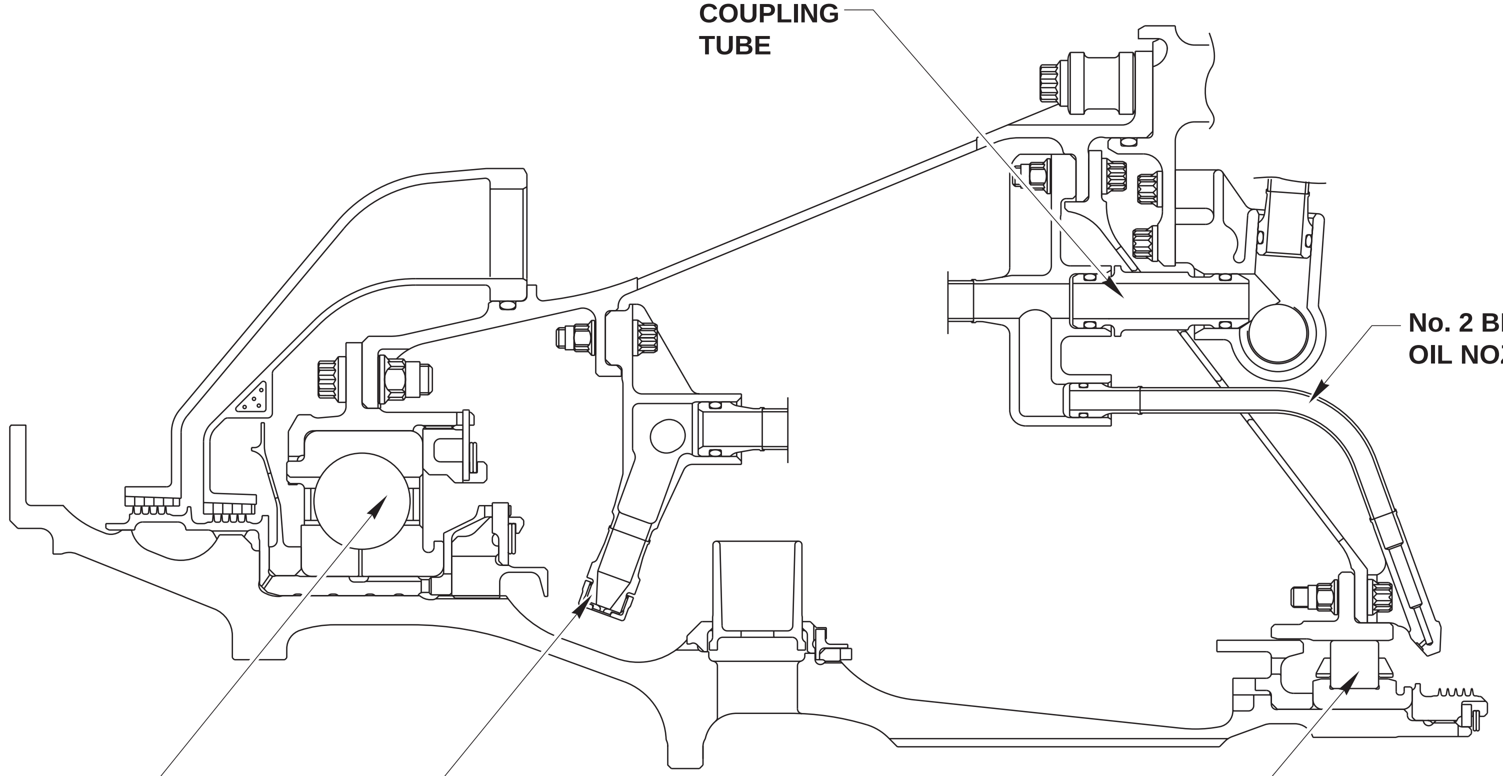
The other end of the removable coupling tube forms the connection with the fan frame hub oil supply circuit.

The No.1 bearing manifold is secured to the inner forward end of the No.1 bearing support. It has two oil nozzles and one end fitting which connects the manifold with the forward end of the No.1 & 2 bearing oil tube assembly.

The 2 oil nozzles, at approx the 9 and 3 o'clock position ALF, direct oil jets into a cavity formed by the fan shaft and the No.1 bearing inner race retainer nut.

The No.2 bearing oil tube fits into the aft end of the No.1 & 2 bearing oil tube assembly and is routed through the No.2 bearing support.

It has one nozzle and this is secured to the aft flange of the support. It directs a jet of oil directly onto the roller of the bearing.



CTC-044-027-00

No. 1 & No. 2 BEARING OIL MANIFOLD ASSEMBLY

NO.1 AND 2 BEARING SUPPORT MODULE (CONTINUED)

External piping

The external piping consist of 5 tubes mounted on the outside of the No.1 bearing support.

Their purposes are :
- Sump pressurization
- Oil drainage
- Oil scavenge

Sump pressurization

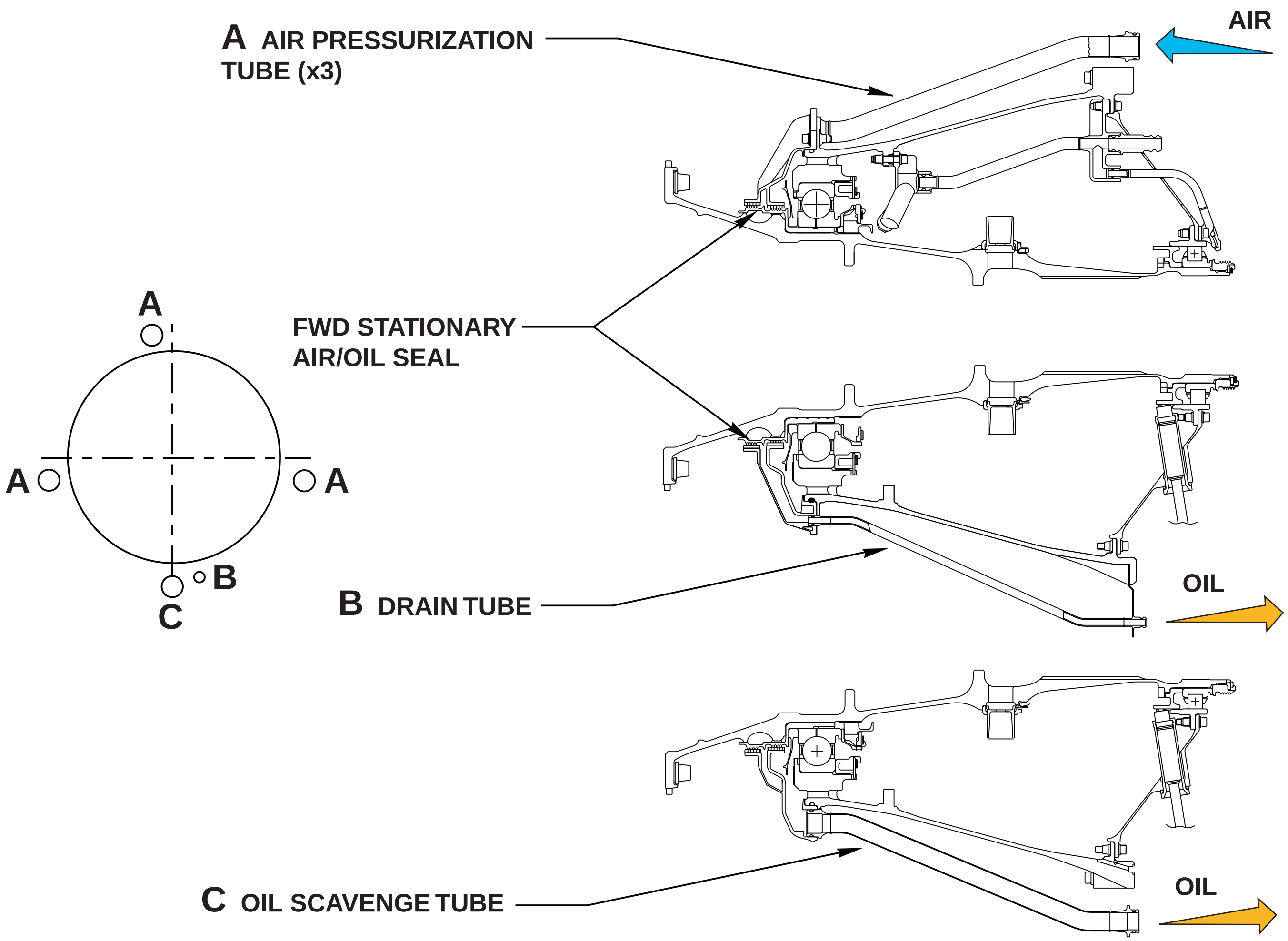
Three tubes direct booster discharge air to a cavity of the stationary air/oil seal.
They are located at approximately the 3:30, 8:30 and 11:30 clock positions.
There is a restrictor at the air inlet, to reduce the airflow.

Oil drainage

This tube connects to a compartment between the air/oil seals at the lowest point. Any oil from the sump that escapes through the seals is collected and drained overboard.
It is located at approximately the 5 o'clock position.

Oil scavenge

This tube connects to a compartment at the bottom of the stationary air/oil seal structure. This compartment is opened to the sump cavity at the rear of the No 1 bearing. It is installed at the 6 o'clock position.



EXTERNAL PIPING

CTC-044-028-00

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FAN FRAME MODULE

FAN FRAME MODULE

The fan frame module is the structure at the front of the engine.

Its main purposes are :

- to transmit power plant thrust to the aircraft.
- to support the LPC rotor, through the No.1 & 2 bearing support.
- to support the front of the HPC rotor through the No.3 bearing support.
- to provide ducting for both the primary and the secondary airflows.
- to provide attachment for the forward engine mounts, front handling trunnions and lifting points.
- to support the fan inlet cowl.

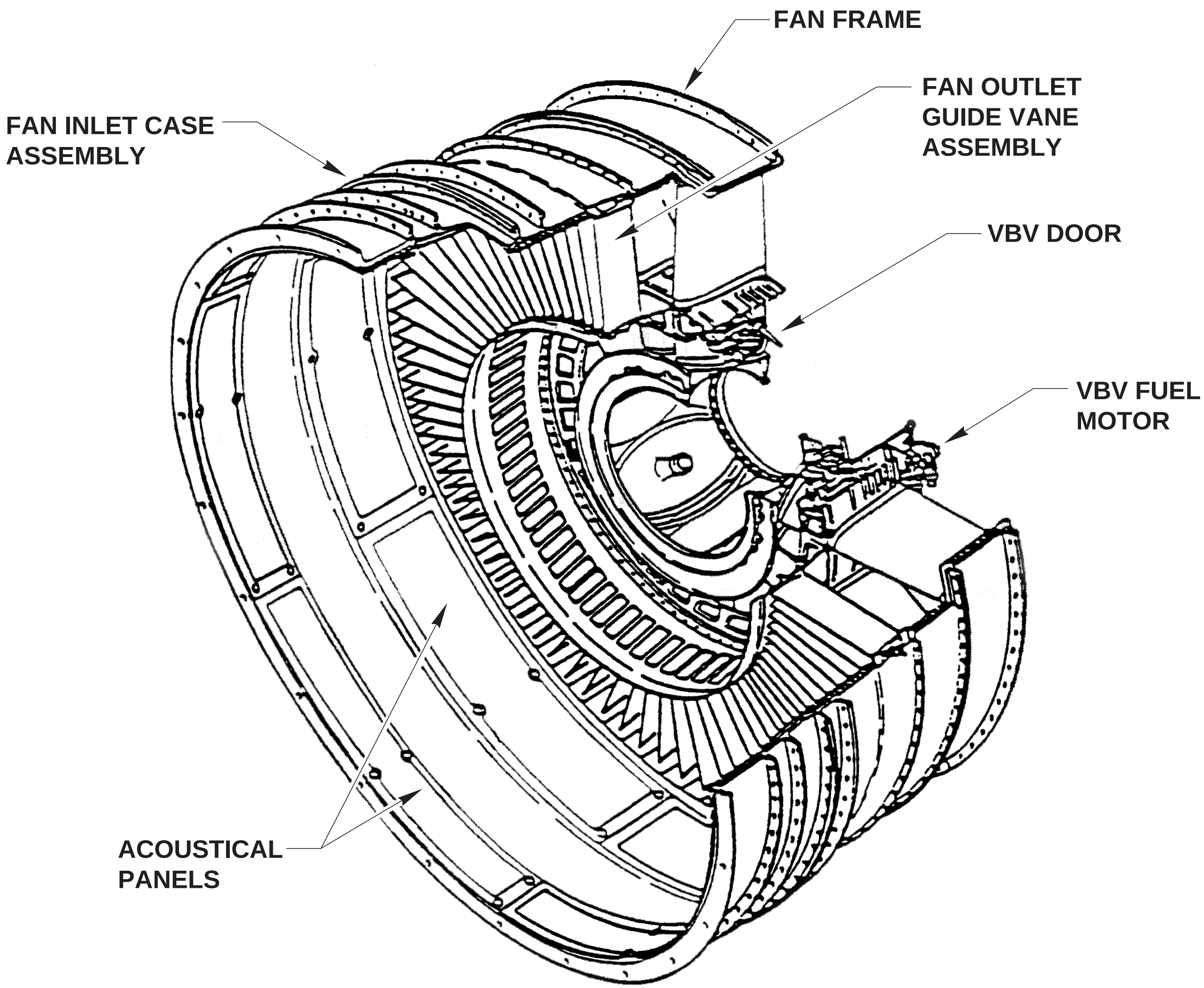
The fan inlet case front flange accommodates the nacelle air inlet cowl and its rear flange is attached to the fan frame outer front flange with bolts.

The outer surface has flanges and ribs to give more strength to the case during engine operation and to provide attachment for equipment brackets.

It also has 2 hoisting points, at the 2 and 10 o'clock positions, for ground handling purposes, 2 AGB mounts and various other mounting devices for engine equipment.

The fan frame center hub accommodates the Nos.1, 2 & 3 bearing assemblies.

The fan frame mid-box structure supports the booster stator assembly at the front and the HP compressor stator at the back. It also houses the VBV system and provides attachment of the engine to the airframe.



FAN FRAME ASSEMBLY

CTC-044-029-00

FAN FRAME MODULE (CONTINUED)

The fan inlet case

The fan inlet case is a weldment structure, designed to contain a failed fan blade, and it houses the fan rotor and its OGV assembly.

The inner surface of the fan inlet case is lined with 6 forward acoustical panels, an abradable shroud located radially in line with the fan rotor blades, 6 mid acoustical panels, the OGV assembly and 12 aft acoustical panels.

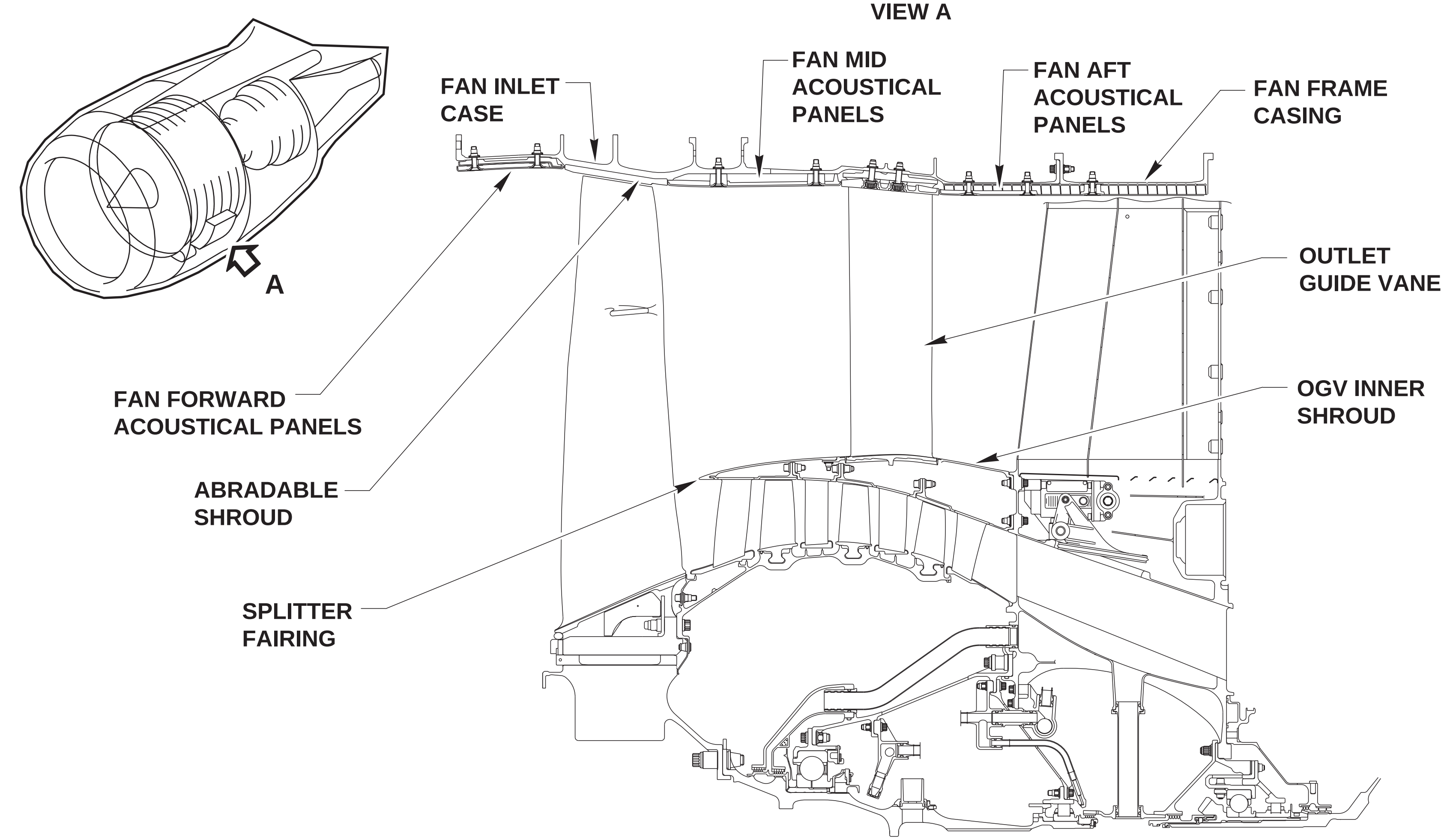
The Outlet Guide Vane (OGV) assembly

The OGV assembly is housed in the fan inlet case and its purpose is to direct and smooth the secondary airflow to increase thrust efficiency. It also plays a role in noise reduction.

The OGV assembly consists of an inner shroud and 70 individual vanes made of composite material.

The OGV inner shroud is bolted to the fan frame. Its outer suface contains 70 apertures to allow passage for the vane inner platforms. The vane outer platforms are bolted to the fan case.

There is a port for borescope inspection and an aluminium alloy splitter fairing, which is attached to the forward end of the inner shroud.



FAN FRAME AND OGV ASSEMBLY

CTC-044-030-00

FAN FRAME MODULE (CONTINUED)

The fan frame

The fan frame is the main forward structural component of the engine. It is a weldment structure made of steel alloy.

The fan frame is made up of concentric rings linked by 12 radial hollow struts that house various equipment and lines.

It consists of :
- the outer case
- the radial struts
- the mid-box structure
- the center hub

The secondary airflow is ducted between the outer case and the mid-box structure and the primary airflow from the booster is ducted to the HPC between the mid-box structure and the center hub.

The radial struts

The radial struts give structural strength to the fan frame.

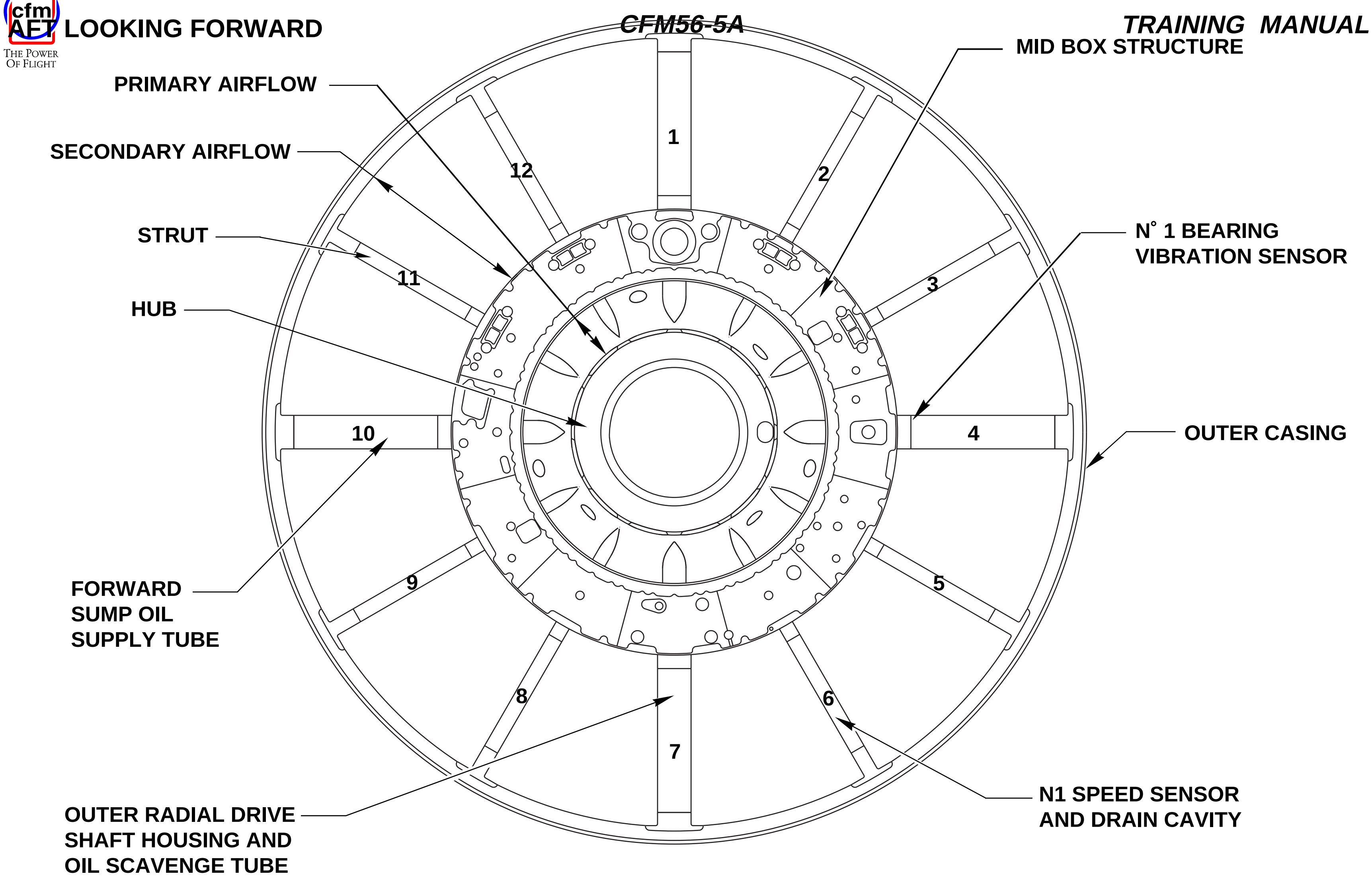
There are 12 hollow struts, numbered 1 to 12 in a clockwise direction (ALF), where No.1 is at the 12 o'clock position.

In the primary flowpath, the 12 struts have a narrow, aerodynamic cross section to reduce drag losses.

In the secondary flowpath, the vertical and horizontal struts (Nos.1, 4, 7 and 10), have a wider cross section.

All the others have the same narrow cross section as in the primary airflow.

The hollow radial struts provide passages for the following equipment :
- The No.1 bearing vibration sensor cable (strut No.4).
- The N1 speed sensor and the forward sump oil drain (strut No.6).
- The TGB radial drive shaft and forward sump scavenge tube (strut No.7).
- The forward sump oil supply tube (strut No.10).



FAN FRAME RADIAL STRUTS

CTC-044-031-00

FAN FRAME MODULE (CONTINUED)

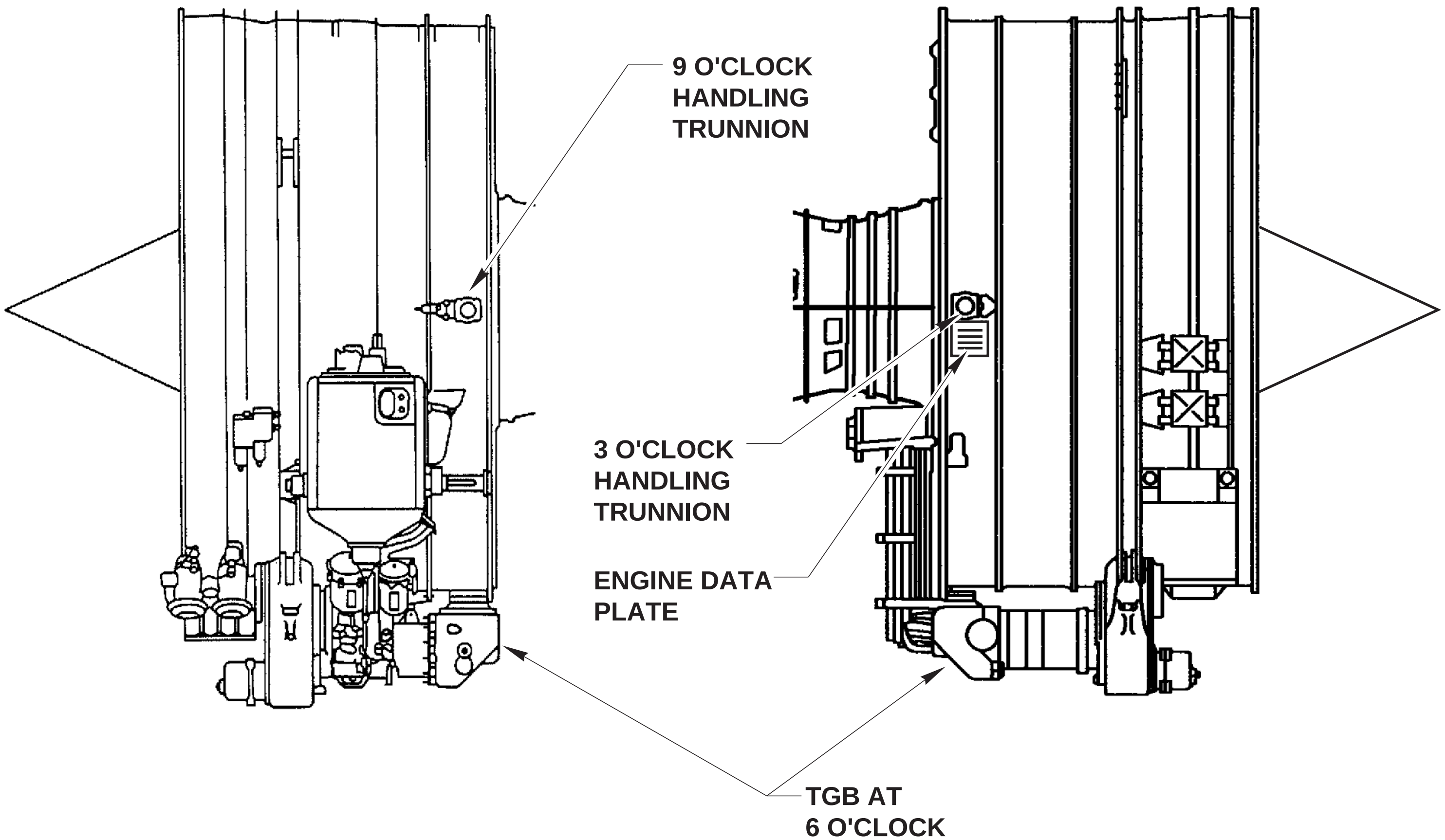
The fan frame outer case

The outer case is a circular welded structure connected to the mid-box structure by the radial struts.

The fan frame outer case surface has :
- 2 ground handling trunnions, at the 3 and 9 o'clock positions.
- the Transfer Gearbox (TGB) mounting pad, at the 6 o'clock position.
- the engine data plate, at the 3 o'clock position.

The outer case front flange supports and centers the fan inlet case. Its rear flange accommodates an adaptor ring for the secondary airflow exhaust system.

The inner surface of the outer case is the outer wall of the secondary airflow and is lined with acoustic panels.



CTC-044-032-00

THE FAN FRAME

FAN FRAME MODULE (CONTINUED)

The mid-box structure

The mid-box structure is located between the primary and secondary airflows.

The structure incorporates 12 struts extending down to the center hub outer surface, an inner contour which limits the primary airflow, a front wall and an aft wall.

The compartments formed between the adjacent struts, house the VBV system, with 11 VBV actuators and a VBV master actuator between struts 10 and 11. The doors and their actuation mechanism are bolted to the front wall and to the inner contour.

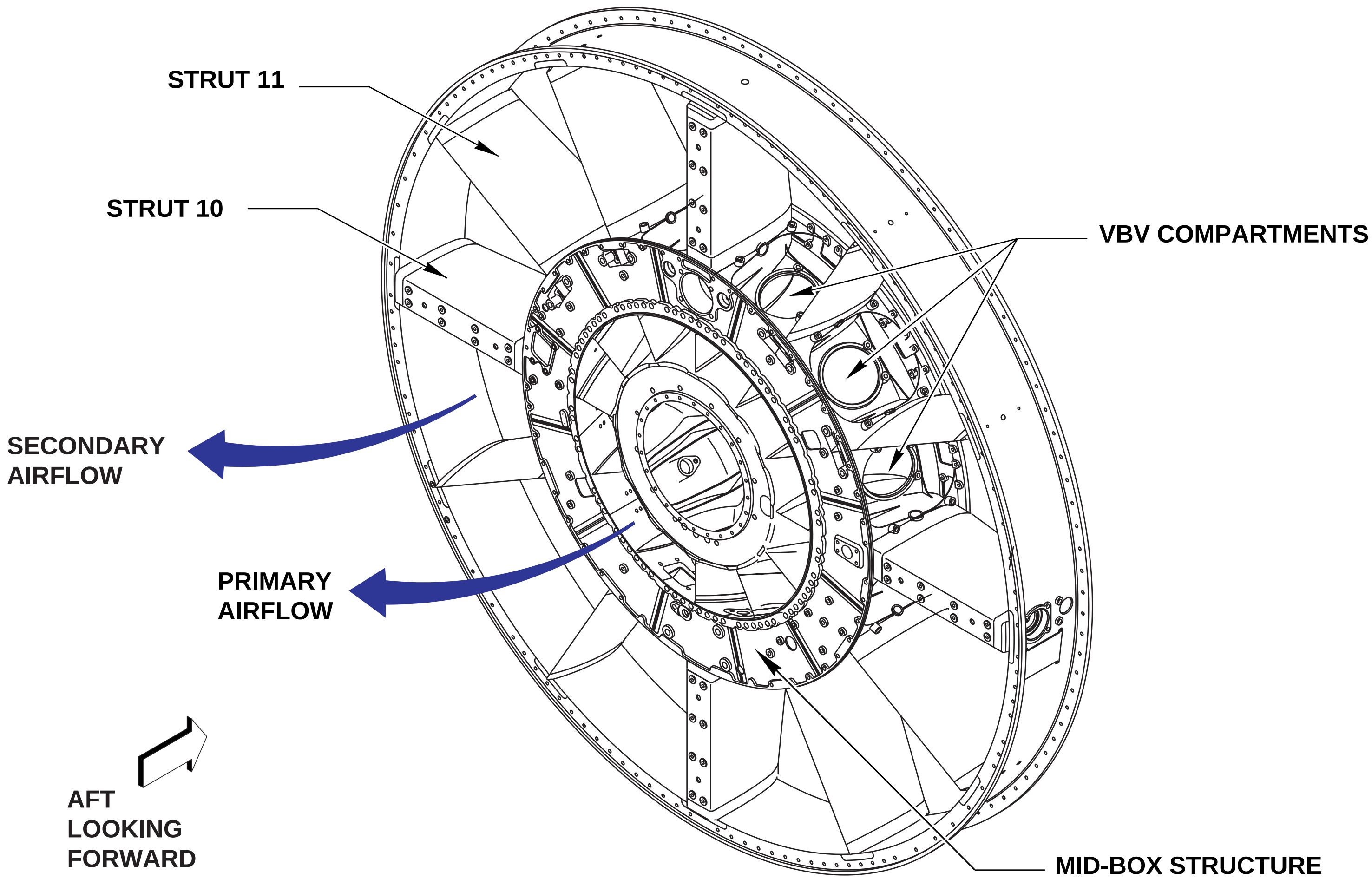
The front wall inner flange provides for attachment of the booster stage 4 stator outer shroud and the outer flange accommodates the OGV inner shrouds.

The front wall also has provisions for the installation of :

- an air scoop elbow, to direct booster air to the ignition leads cooling system.
- a T25 sensor at the 4:30 clock position, to provide compressor inlet temperature to the Fadec system.
- a P25 sensor at the 5:30 clock position, to provide compressor inlet pressure to the Fadec (optional).

The rear wall holds the HPC forward case, the VBV hydraulic gear motor and supplies engine mounting.

The outer contour, ducting the secondary airflow, holds fan duct panels, which are bolted onto the front and aft walls. These panels have a series of cut-outs to redirect primary air into the secondary airflow when the VBV doors are open.



CTC-044-033-00

MID-BOX STRUCTURE

FAN FRAME MODULE (CONTINUED)

The center hub

The center hub front face accommodates the No.1 & 2 bearing support module (inner flange) and the inner shroud of the booster stage 4 stator (outer flange).

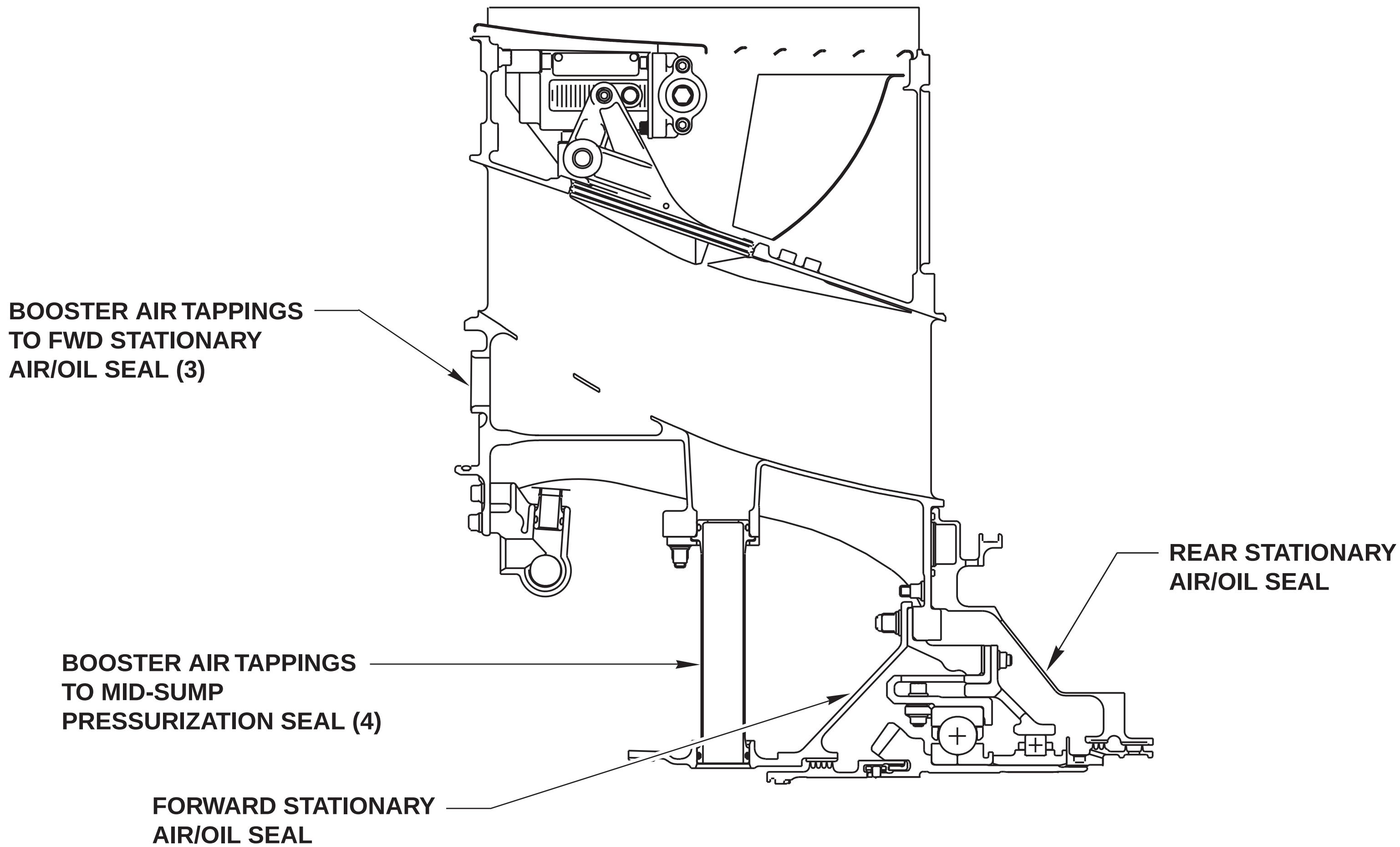
The hub outer contour limits the primary airflow from the booster to the HP compressor inlet and has various apertures :

- 3 air tappings to supply booster air to the pressurizing air tubes for the forward stationary air/ oil seal.
- 4 air tappings to supply booster air to the mid-sump pressurization seals.

The center compartment formed by the hub walls is part of the engine forward sump.

The hub rear wall supports the IGB/No.3 bearing assembly and the No.3 bearing stationary air/oil seals.

Four tubes, which extend radially from the hub outer wall, carry booster discharge air to the mid-sump tube support of the No.3 bearing forward air/oil seal for sump pressurization.



FAN FRAME CENTER HUB

CTC-044-034-00

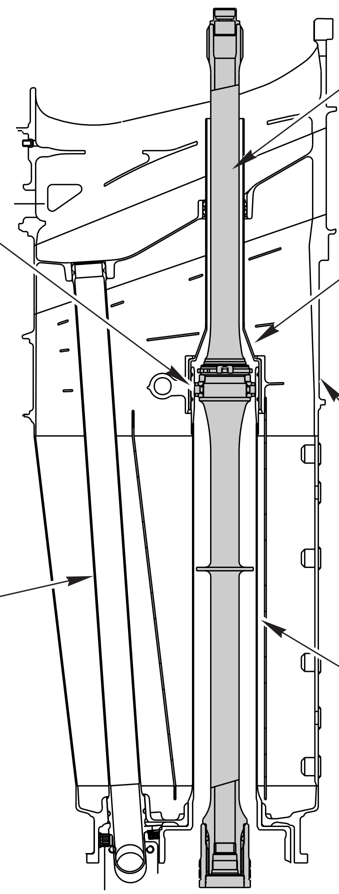
FAN FRAME MODULE (CONTINUED)

The radial drive shaft housing

Strut No 7, at the 6 o'clock position, contains both the forward sump scavenge tube and the Radial Drive Shaft (RDS) housing.

The RDS is the mechanical rotating link between the Inlet Gearbox (IGB) and the Transfer Gearbox (TGB).

At the shaft's center there is a mid-length roller bearing. The outer race of the bearing is brazed to the inside of the outer housing.



CTC-044-035-00

RADIAL DRIVE SHAFT HOUSING

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CORE ENGINE MAJOR MODULE

CORE ENGINE MAJOR MODULE

The core engine is a high pressure, high speed, gas generator that produces the power to drive the engine.

Fan discharge air is compressed in the High Pressure Compressor (HPC), heated and expanded in the combustion chamber. It is then directed by the High Pressure Turbine (HPT) nozzles onto the HPT rotor. Energy not extracted from the gas stream by the HPT rotor is used to drive the Low Pressure Turbine (LPT), fan rotors and booster.

The forward end of the core is supported by the No.3 ball and roller bearings, located in the fan frame.

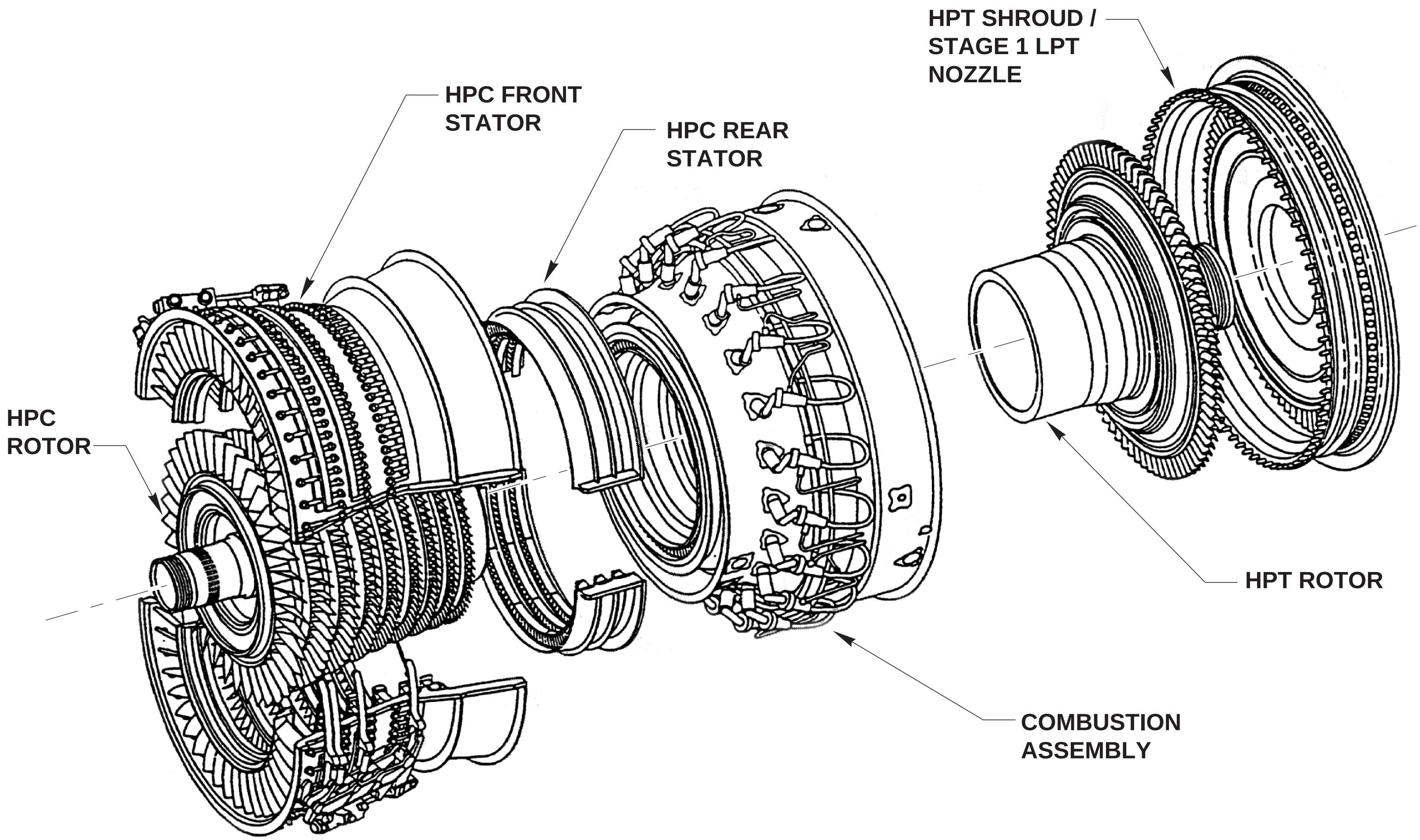
The aft end is supported by the No.4 roller bearing, located in the HPT rotor rear shaft.

The core engine consists of the following :

The HPC.
- HPC rotor.
- HPC front stator.
- HPC rear stator.

The combustion section.
- Combustor casing.
- Combustion chamber.

The HPT.
- HPT nozzle.
- HPT rotor.
- HPT shroud & Stage 1 LPT nozzle.



CTC-044-036-00

CORE ENGINE

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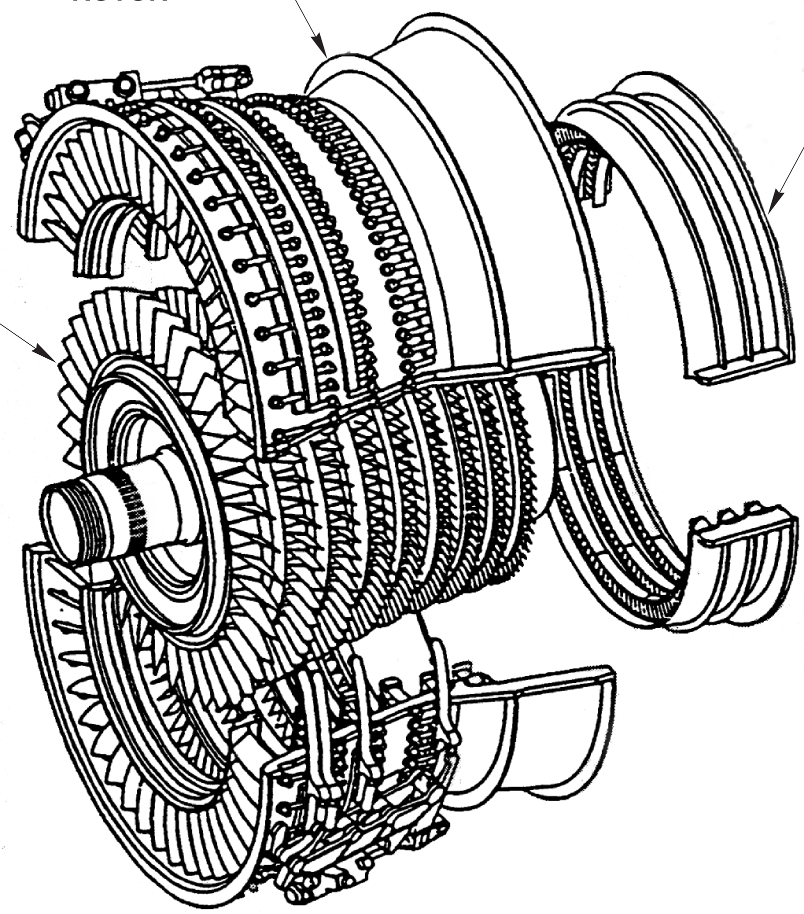
HIGH PRESSURE COMPRESSOR

THE HIGH PRESSURE COMPRESSOR (HPC)

The HPC is a 9-stage compressor and its main purpose is to increase the pressure of the air as it passes from stage to stage, to supply the combustor section.

The HPC is mounted between the fan frame and the combustor case.

It consists of the following modules :
- The compressor rotor
- The compressor front stator
- The compressor rear stator



CTC-044-037-00

HP COMPRESSOR SECTION

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COMPRESSOR ROTOR

The compressor rotor

The compressor rotor increases the velocity of fan booster discharge air, which is pressurized by the stator before entering the combustion section.

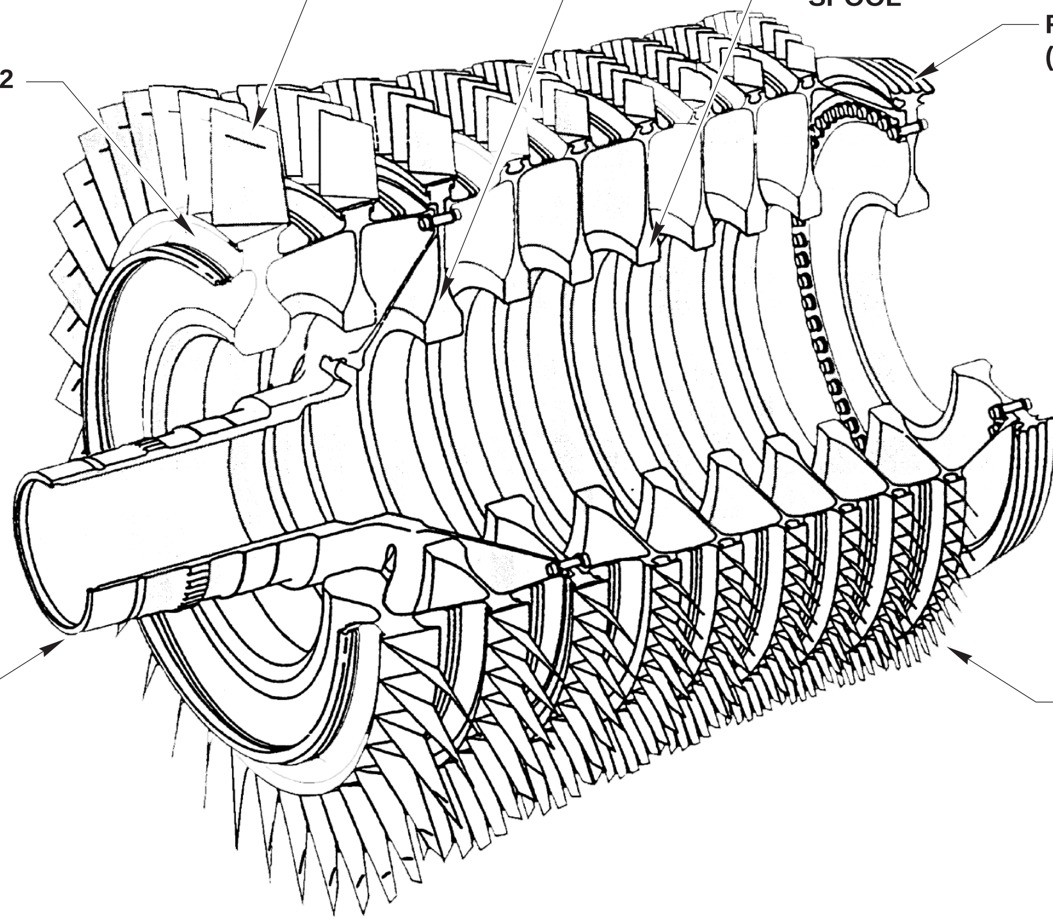
The HPC rotor is a 9-stage, axial flow, high speed, spool-disk structure.

It is housed in the compressor case and the rotor front end is supported by the No.3 bearing.

Its rear end is bolted to the HPT front shaft, through the rear rotating (CDP) air seal.

The rotor has 5 major parts :

- The rotor shaft
- The stage 1-2 spool
- The stage 3 disk
- The stage 4-9 spool
- The rear rotating (CDP) air seal



CTC-044-038-00

HIGH PRESSURE COMPRESSOR ROTOR ASSEMBLY

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

The rotor shaft

The rotor shaft is the forward support for the HPC.

It is made of titanium alloy.

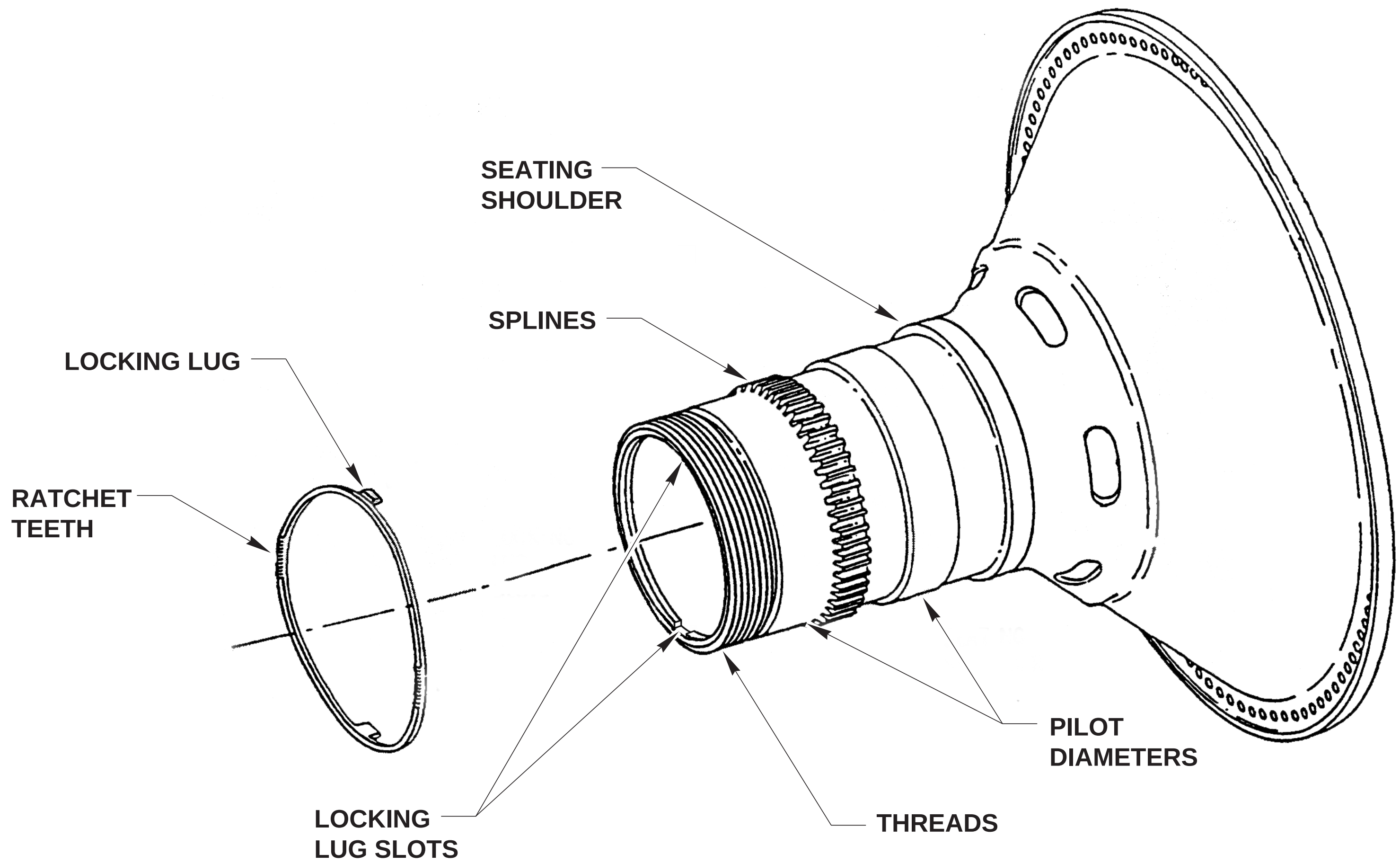
The shaft is splined and attached to the IGB horizontal bevel gear by a coupling nut. The IGB contains the thrust bearing for the core engine.

The shaft forward end is threaded and has 2 machined slots for installation of a retaining ring to provide locking to the coupling nut.

The shaft also has 2 pilot lands to center the IGB bevel gear.

The shaft has 6 oblong orifices to direct air for ventilation and for clearance control inside the rotor cavity. Its bore accommodates the front end of the air duct.

Its rear flange supports the stages 1-2 spool on one side and the stage 3 disk on the other side.



THE ROTOR SHAFT

CTC-044-039-00

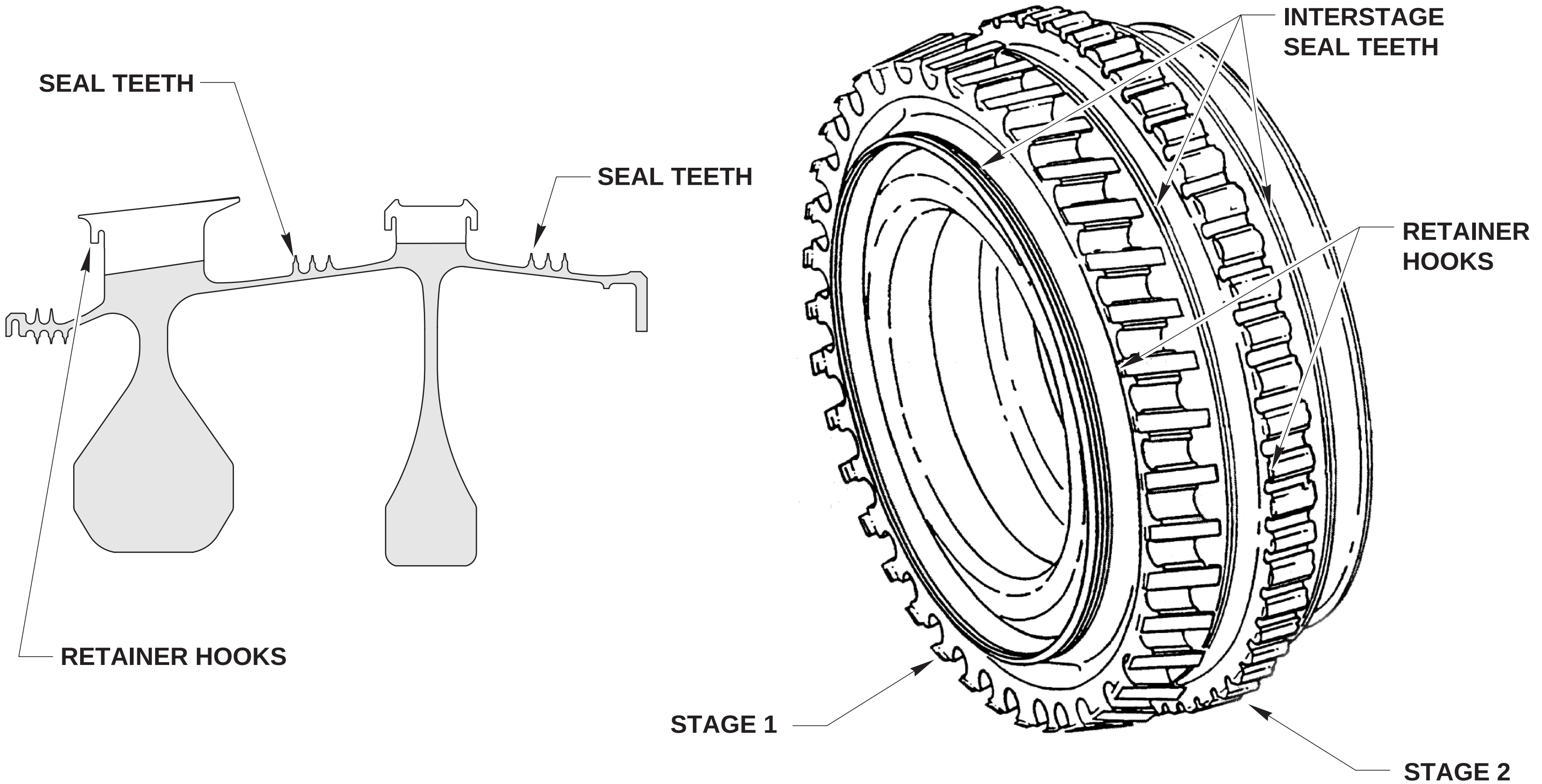
THE HIGH PRESSURE COMPRESSOR (CONTINUED)

The stage 1-2 spool

The stage 1-2 spool is cantilever mounted on the front face of the rotor shaft flange.

The spool is a titanium alloy forging and is assembled by inertia welding and has individual axial slots for blade installation.

There are inter-stage labyrinth seals machined on the spool, which face abradable structures on the stator assembly in order to optimize flow path sealing and HPC performance.



CTC-044-040-00

COMPRESSOR ROTOR SPOOL, STAGE 1 - 2

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

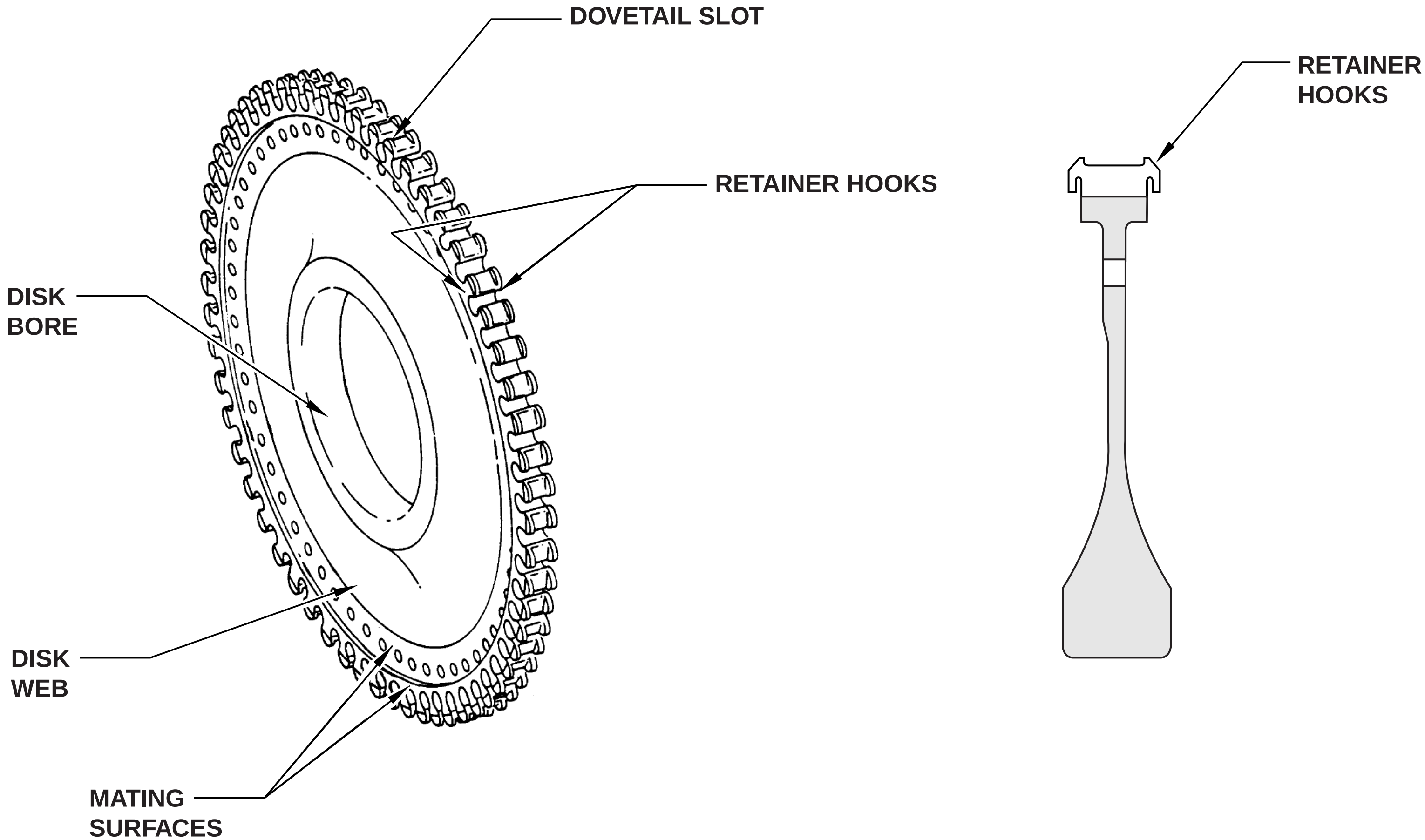
The stage 3 disk

The stage 3 disk mates with the rotor shaft flange and supports the stage 4-9 spool.

It is made of titanium alloy and its web and bore are air fed through the front shaft orifices.

Its outer rim has individual axial dovetail slots for blade installation.

Retainer hooks are machined on either side of the disk to provide a slot for the installation of split-ring type blade retainers.



CTC-044-041-00

HPC STAGE 3 DISK

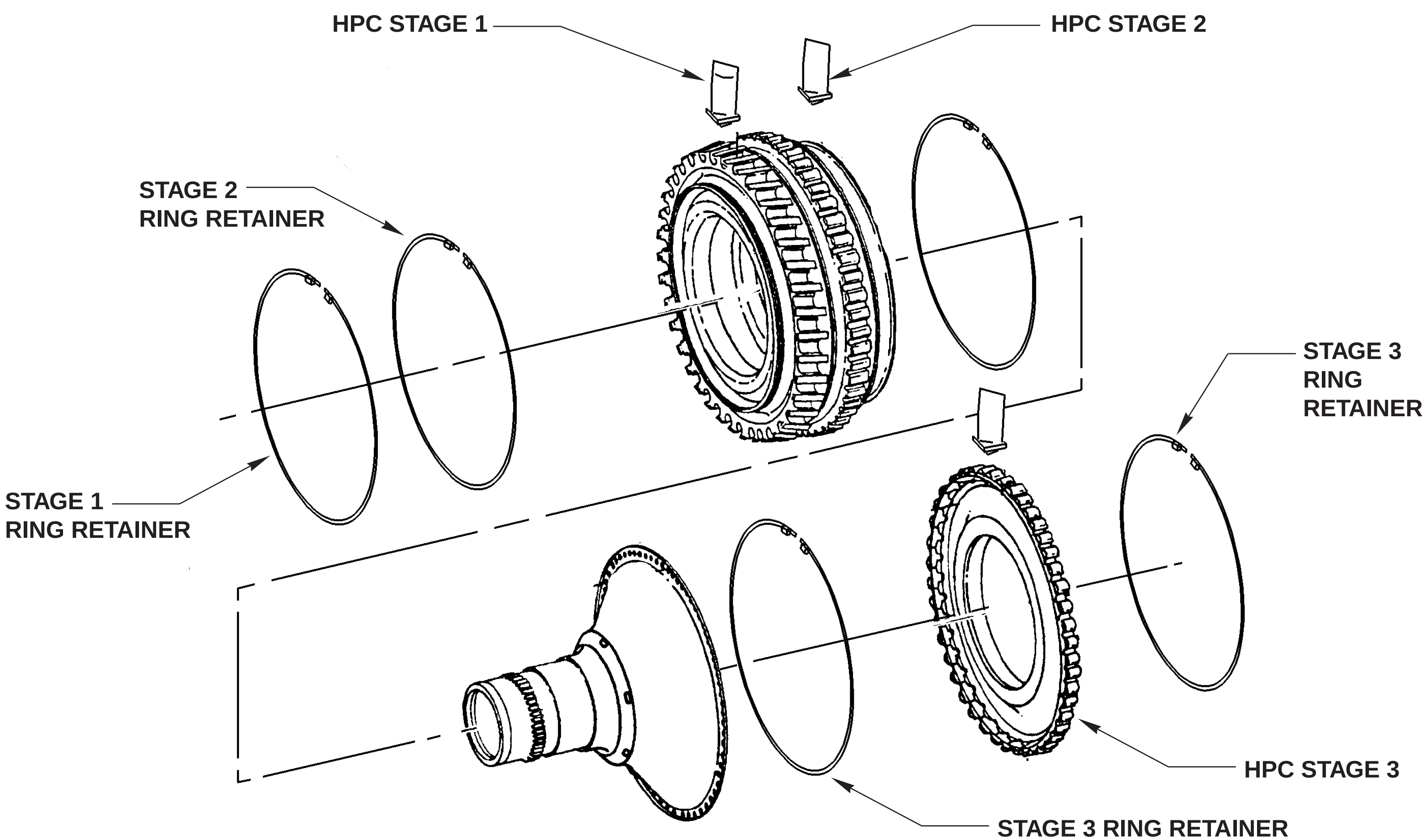
THE HIGH PRESSURE COMPRESSOR (CONTINUED)

Blade retention

The blade retention system for the front spool and disk is similar for all three stages.

The blades all have dovetail roots that slide into individual dovetail slots.

The blades are held in place by a ring blade retainer that engages into retainer slots.



CTC-044-042-00

HPC FRONT SPOOL BLADE RETENTION SYSTEM

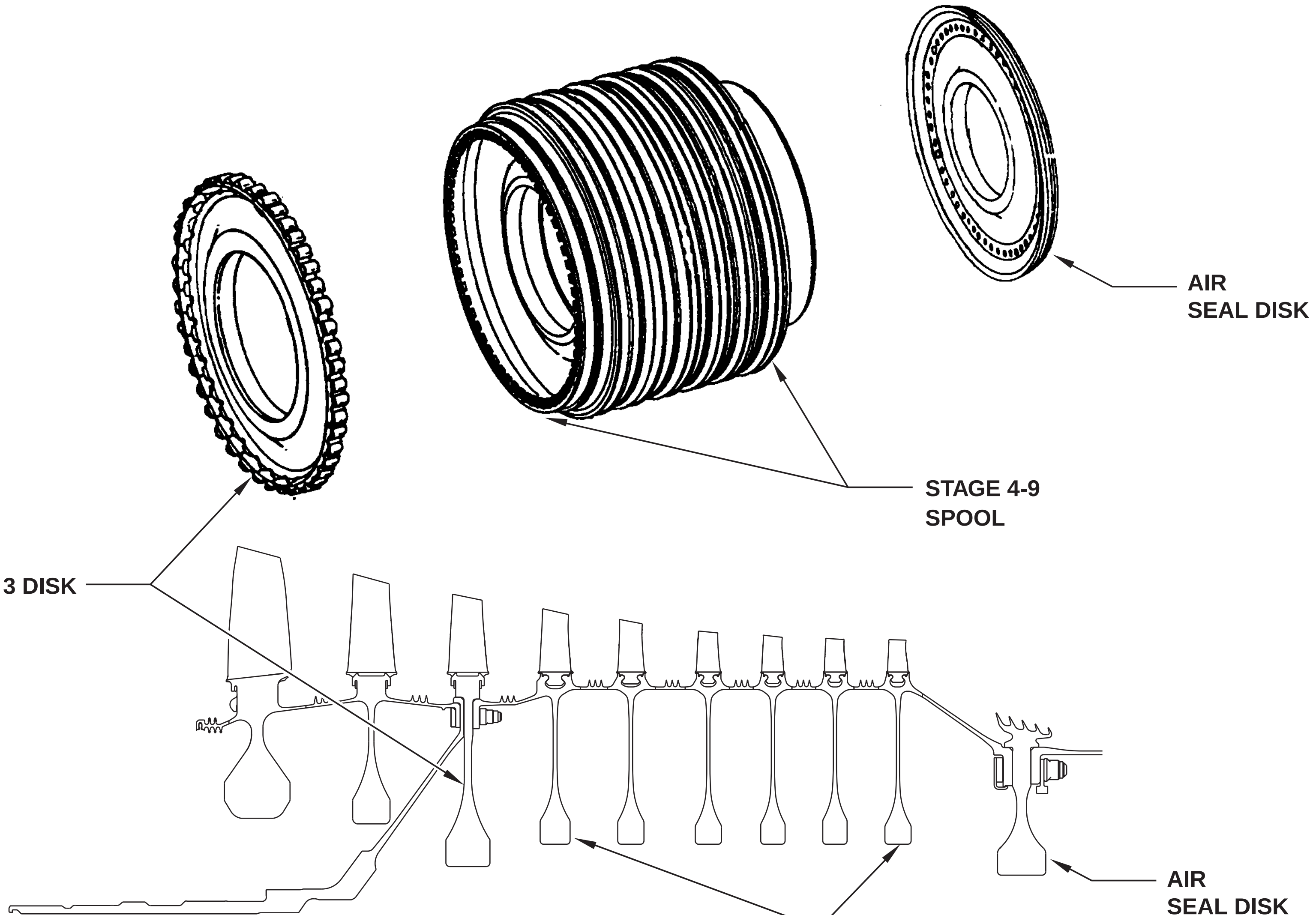
THE HIGH PRESSURE COMPRESSOR (CONTINUED)

The stage 4-9 spool

The HPC stage 4-9 spool is bolted onto the stage 3 disk rear face and its aft flange accommodates the rear rotating air seal disk.

It is made from a nickel alloy.

There are a series of labyrinth seal teeth on the spool outer structure, between each stage, which face an abradable structure on the stator assembly.



HPC STAGE 4-9 SPOOL

CTC-044-043-00

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

The stage 4-9 spool (continued)

The outer surface of the 4-9 spool has 6 circumferential dovetail grooves for installation of the blades.

Each groove has:

- a loading slot for blade installation.
- 2 slots for the installation of locking lugs used to immobilize the blades.

For balancing purposes, the position of the locking lugs is shifted between stages :

- stages 4 and 5	180° apart.
- stages 5 and 6	60° apart.
- stages 6 and 7	180° apart.
- stages 7 and 8	60° apart.
- stages 8 and 9	180° apart.

2 seal wires are installed forward and aft of the groove and make contact with the underside of the blade platforms at installation.

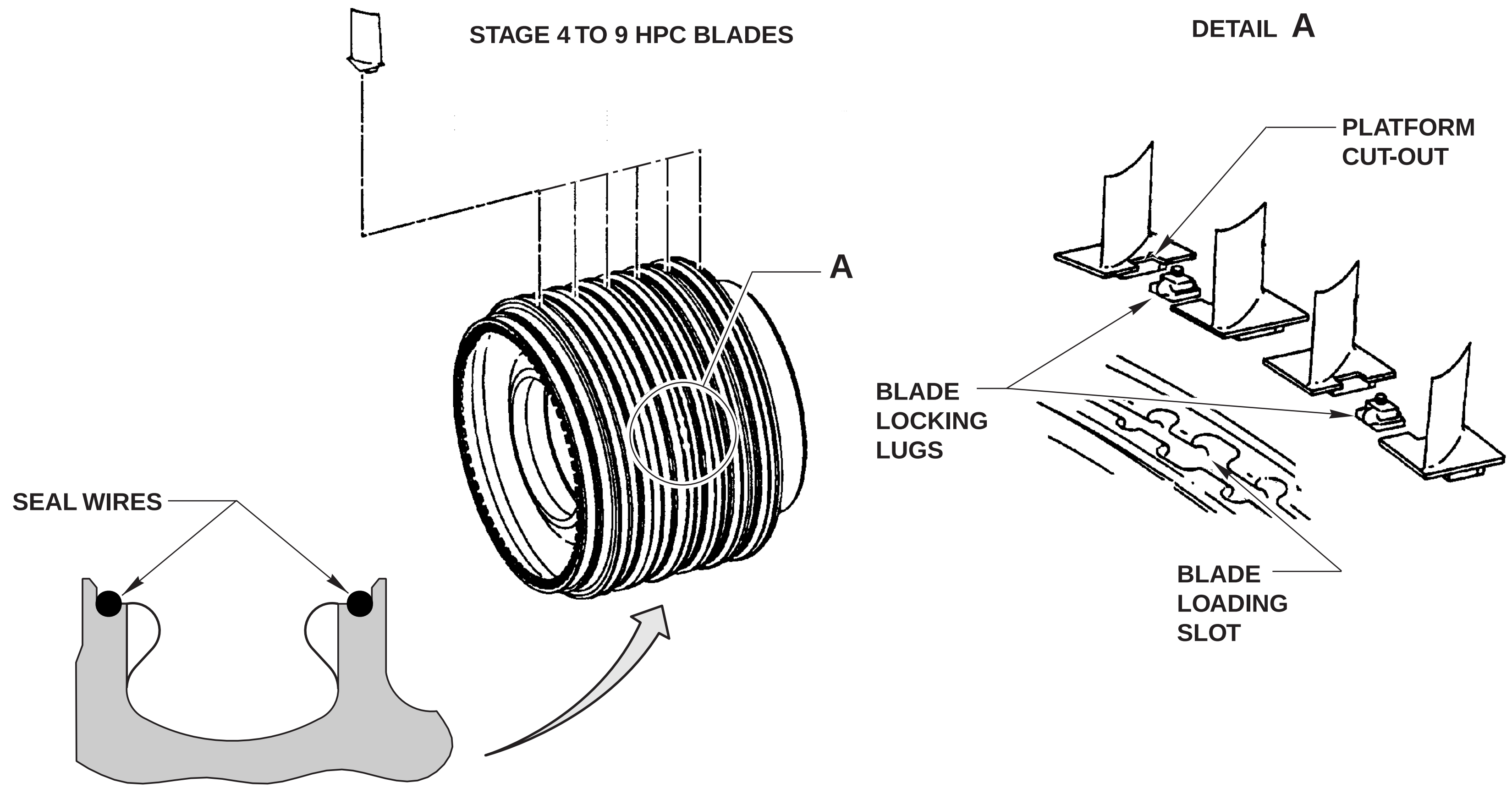
These seal wires ensure flow path sealing.

The stage 4-9 blades fit into the circumferential dovetail grooves on the spool :

- Stage 4 has 68 blades
- Stage 5 has 75 blades
- Stages 6 & 7 have 82 blades
- Stage 8 has 80 blades
- Stage 9 has 76 blades

The blade tips are machined to reduce contact surface rubbing (squealer tip) and their platforms can be either wide or narrow to adjust circumferential clearance.

On each stage there are 4 blades, which have cut-outs on their platforms to accommodate the blade locking lugs.



CTC-044-044-00

HPC REAR SPOOL BLADE RETENTION SYSTEM

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

Rotor blades design

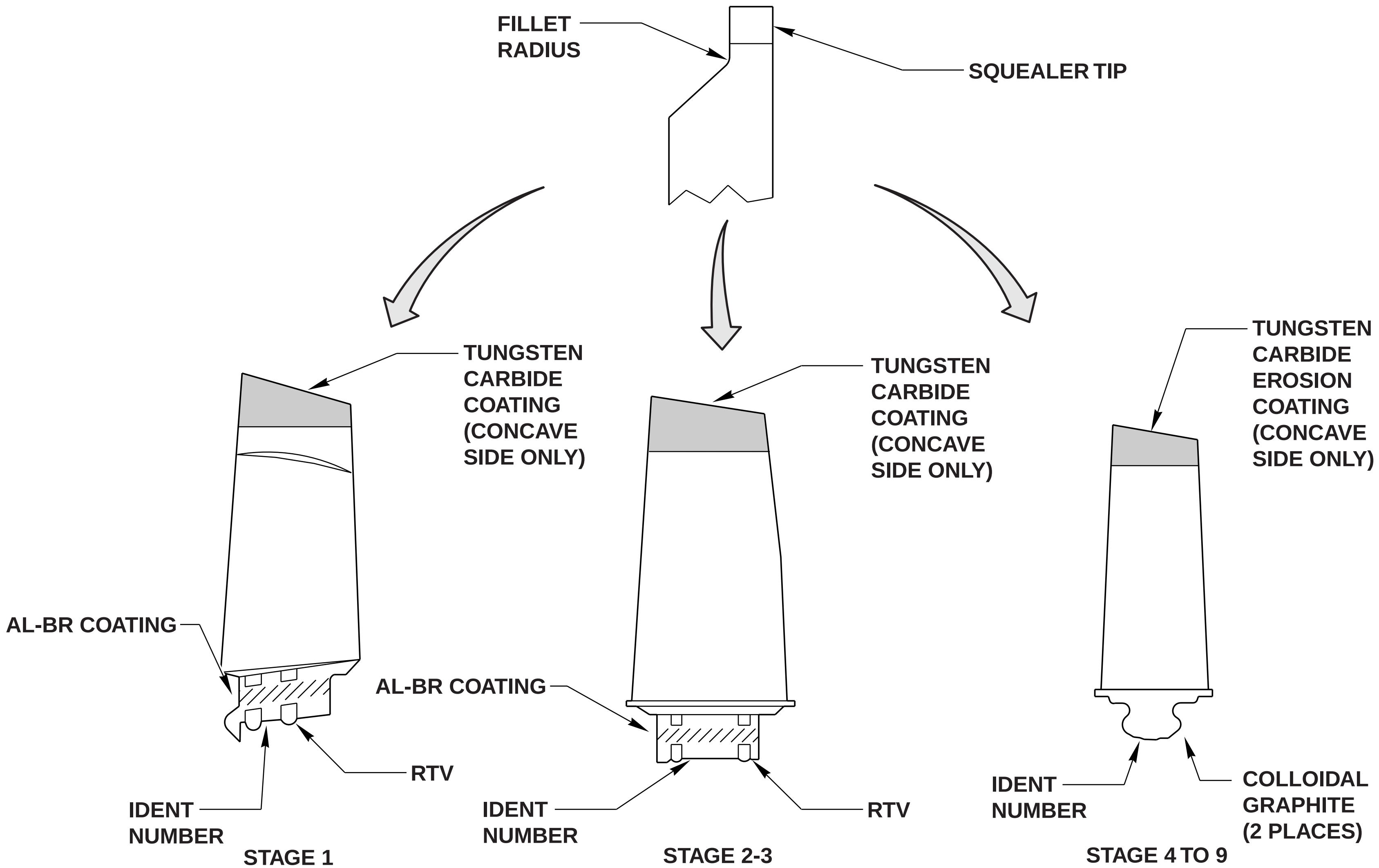
All the blades are squealer tip types and stage 1 blades have an integral stiffener.

Stage 1-3 blades are made of titanium alloy.

Stage 4-9 blades are made of nickel alloy.

The upper portion of the airfoil is coated with tungsten carbide, on its concave side, to limit erosion.

The blade roots have an aluminum bronze (Al-Br) coating on their mating faces.



ROTOR BLADES DESIGN

CTC-044-045-00

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

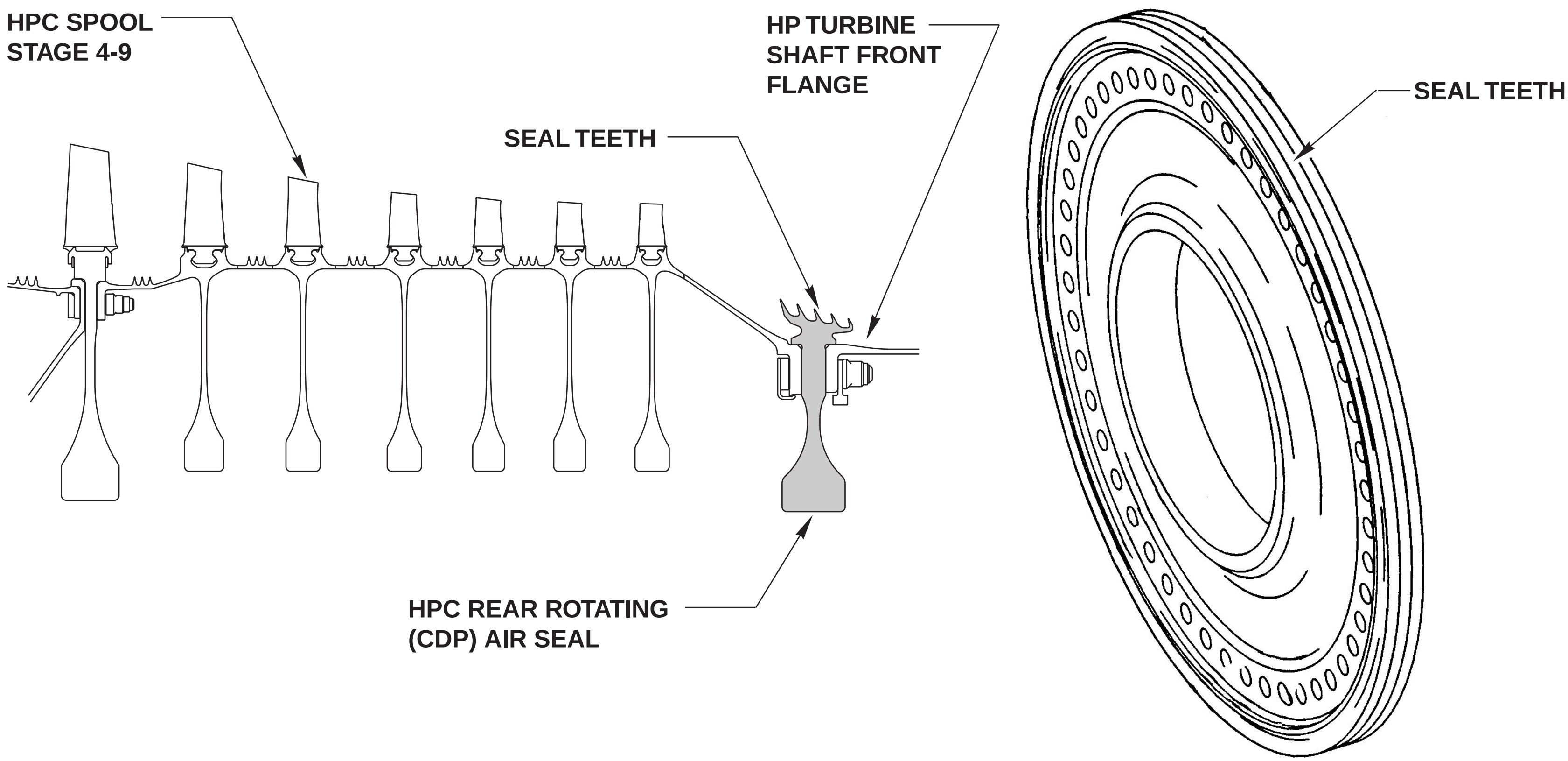
The rear rotating air seal

The compressor rotor rear rotating (CDP) air seal is a one-piece nickel alloy forged part, with abrasive protection-coated labyrinth seal teeth.

The CDP seal is attached to the aft flange of the stage 4-9 spool by a tight-fitting rabbeted diameter.

The seal is axially clamped by the bolts and nuts which hold the forward flange of the HPT shaft to the compressor.

Its outer rim has labyrinth teeth to control CDP air supply to a downstream compartment for HP rotor axial balancing.



HPC REAR ROTATING AIR SEAL

CTC-044-046-00

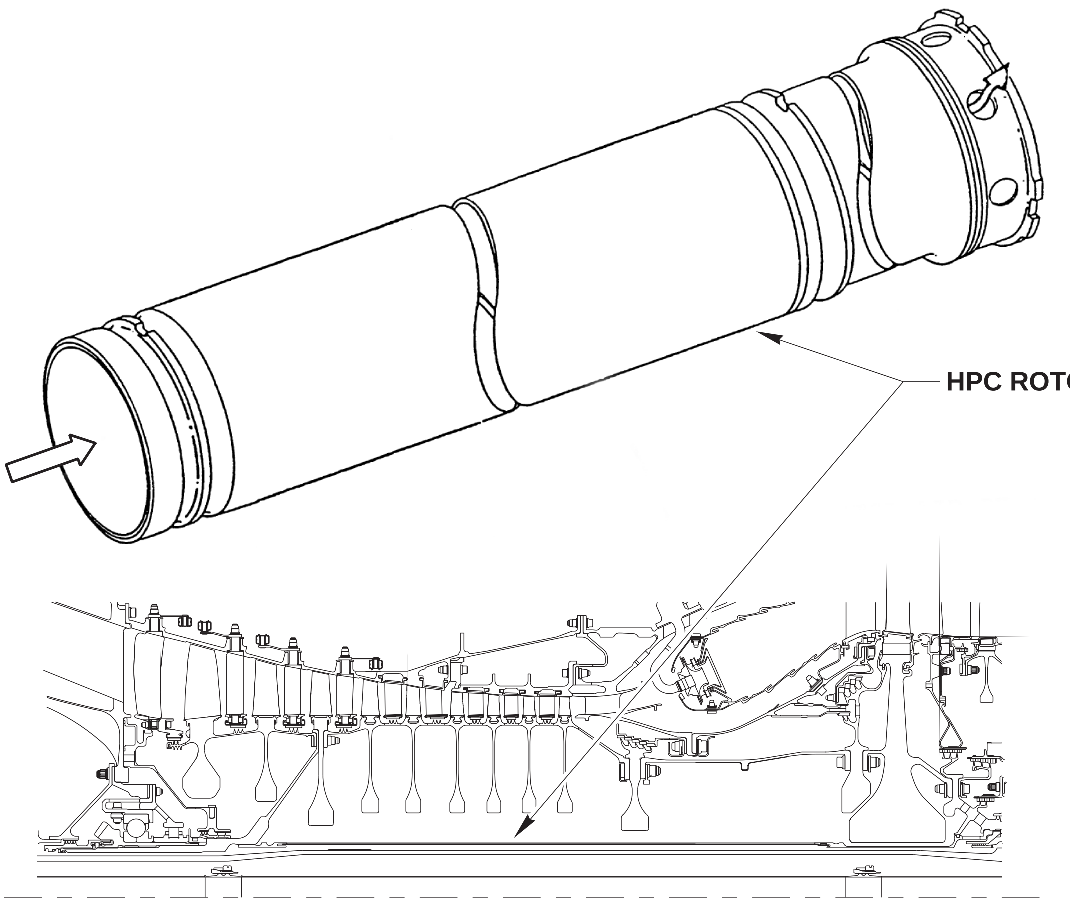
THE HIGH PRESSURE COMPRESSOR (CONTINUED)

The rotor air duct

The rotor air duct is a titanium alloy sleeve running through the entire length of the HP rotor assembly to isolate the LP Turbine shaft from HP rotor cavity.

The tungsten carbide coated front end fits into the bore of the compressor front shaft and the aft end fits into the center bore of the HP Turbine rotor assembly, forward of the No.4 bearing.

The aft end is designed to control airflow circulation in the No.4 bearing vicinity. An aluminium bronze split ring fits in a circumferential groove, for local sealing, and a series of circular apertures is provided to route aft sump pressurization air through the HP rotor assembly.



CTC-044-047-00

THE ROTOR AIR DUCT

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COMPRESSOR FRONT STATOR

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

The front stator

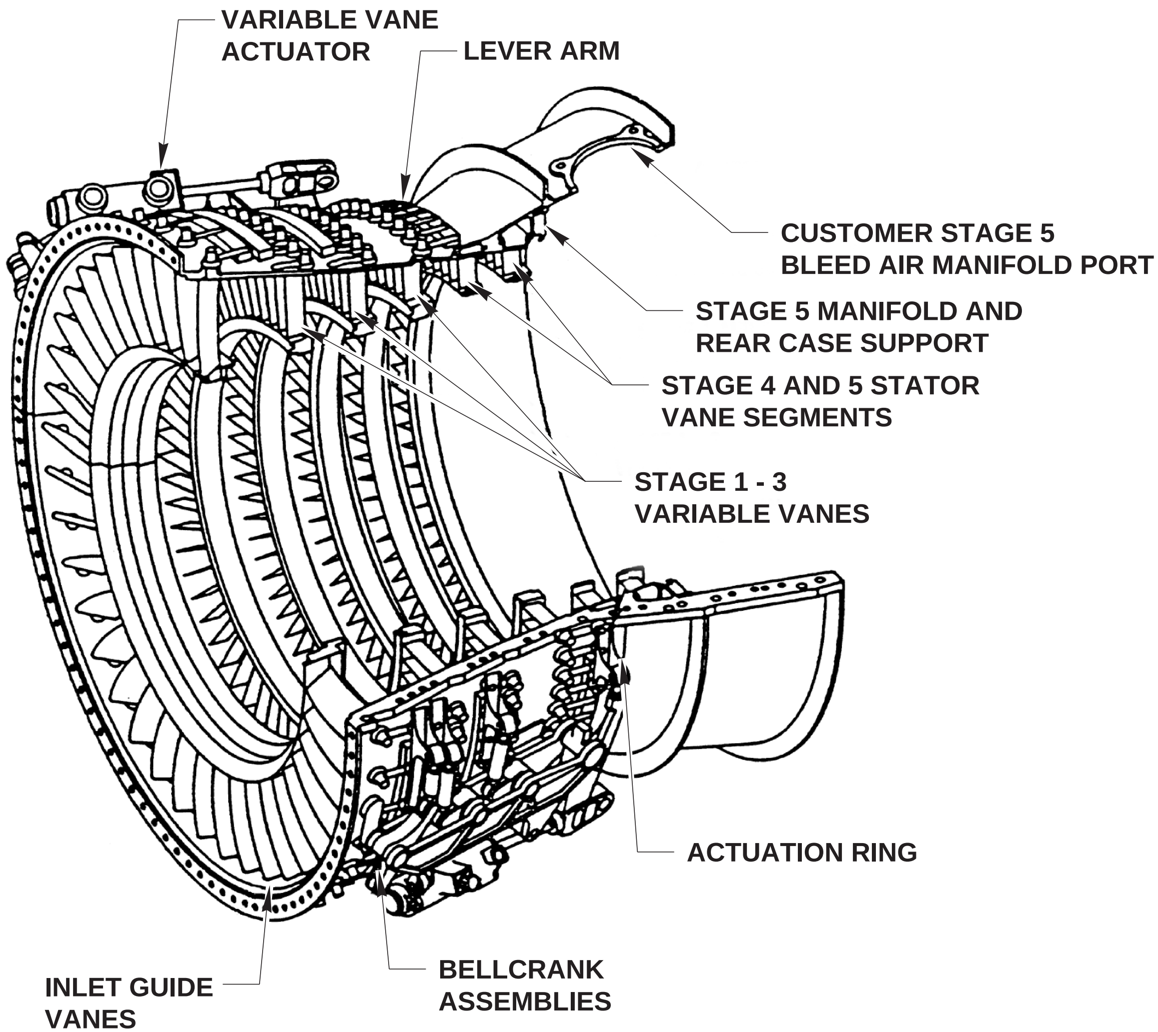
The compressor stator changes the air velocity produced by the rotor into pressure.

The front case forms the load carrying structure between the fan frame and the combustion case.

The front case is made up of two halves with horizontal split-line flanges that are machined as a matched set from a steel forging.

The front stator assembly consists of :
- the stator case halves
- the inlet guide vanes (IGV)
- the variable stator vanes (VSV), stages 1, 2 and 3
- the fixed stator vanes stages 4 and 5
- the VSV actuation system

The inner surface is machined to provide a smooth air flowpath through stages 1 to 5.



COMPRESSOR FRONT STATOR ASSEMBLY

CTC-044-048-00

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

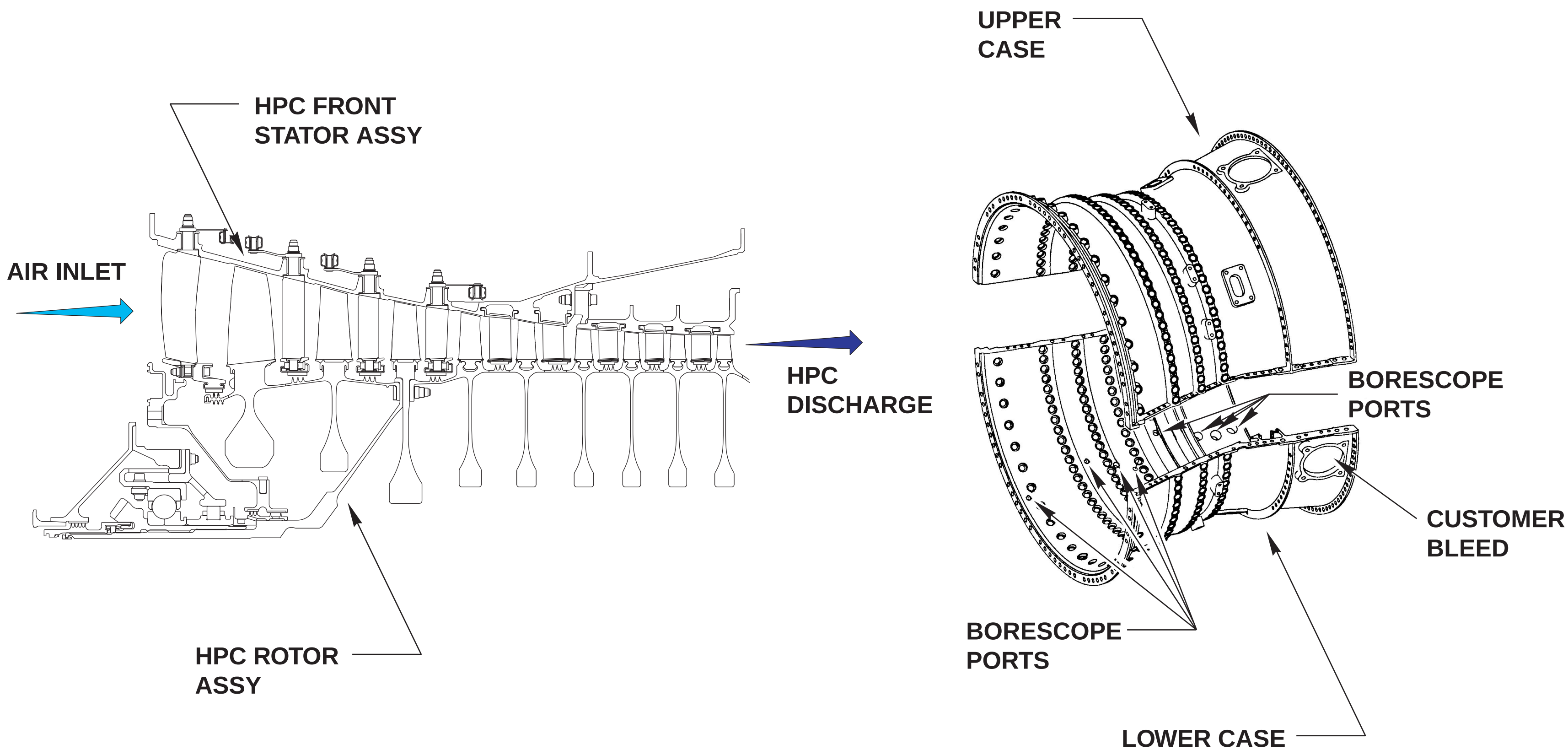
The front stator case

The upper and lower cases of the HPC front stator are bolted together.

They have ports at the 5th stage to accommodate pipes that supply bleed air for both engine and aircraft use.

There are also a series of plugged ports alongside the casing, at approximately the 5 o'clock position, for borescope inspection of the rotor blades (one port per stage) and the 2 stator vanes adjacent to the port.

The outer case has individual raised bosses at the IGV and stages 1, 2 and 3. The outer case is thin to save weight, so the bosses add extra depth to accommodate the variable vane trunnions.



CTC-044-049-00

HPC FRONT STATOR DESIGN

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

Variable stator vane stages outer end connection.

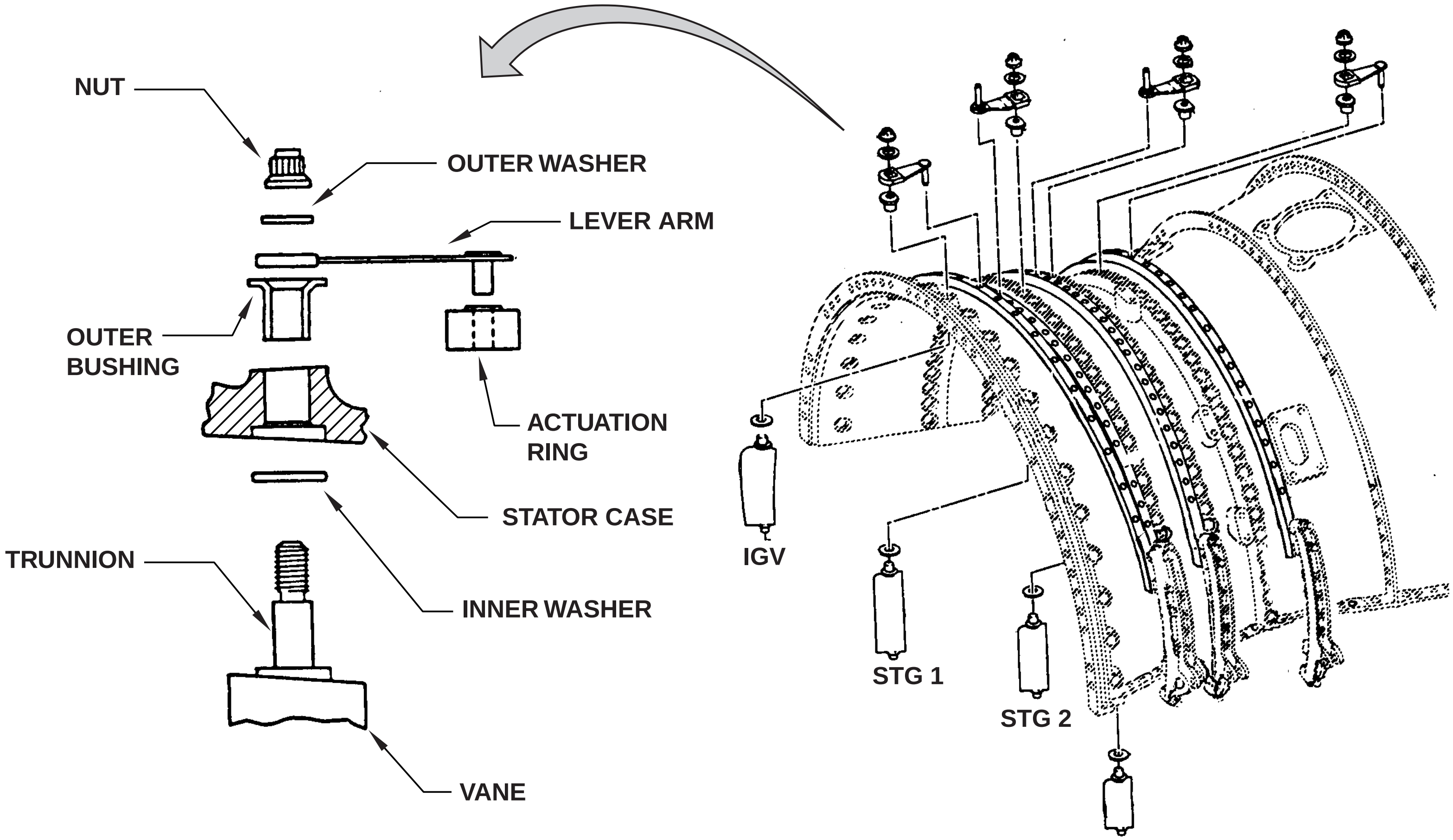
The IGV and stages 1, 2 and 3 are variable vanes installed individually through the HPC front case.

The vanes are made of a steel alloy.

The vane’s outer trunnion passes through the bosses in the outer case.

Its radial position is adjusted by an inner washer and the upper pivot is protected by an outer bushing.

It is then connected to a lever arm and secured by a washer and nut. The lever arm connects to actuation rings around the outer surface of the front case.



CTC-044-050-00

VSV UPPER END CONNECTION

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

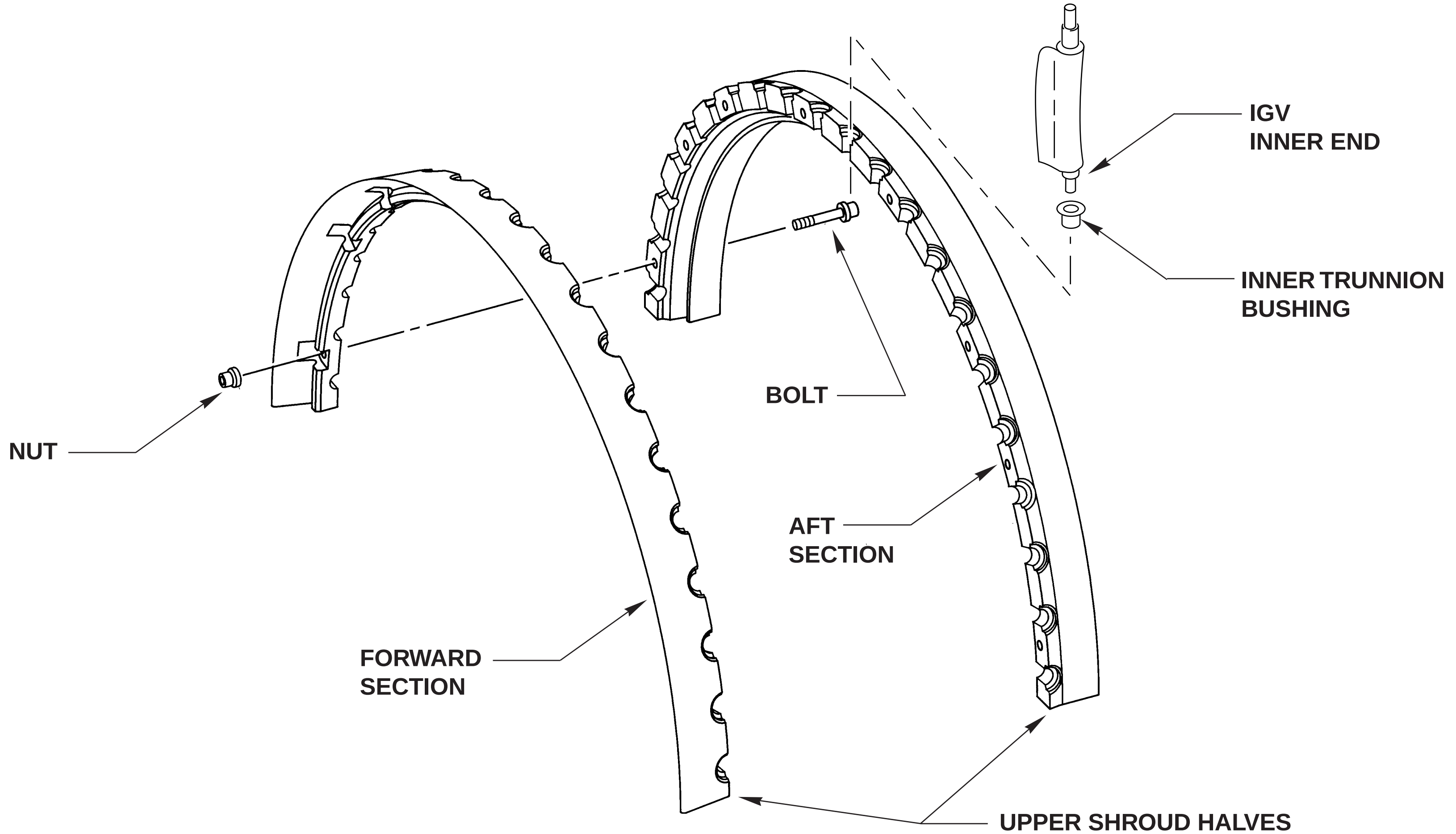
Variable stator vane stages inner end connection

All stages of vanes have a shroud on their inner diameter.

There are 2 IGV shroud segments, the upper and the lower, which can be separated into forward and aft halves.

The forward and aft IGV shroud sections are a matched set bolted together to form a segment.

The inner end of the inlet guide vane fits into an inner trunnion bushing installed in holes in the shroud segments.



CTC-044-051-00

INLET GUIDE VANE INNER END CONNECTION

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

Variable stator vane stages inner end connection

Stages 1, 2 and 3 vanes are mounted in a similar way to the IGV's, but the shroud segments are smaller.

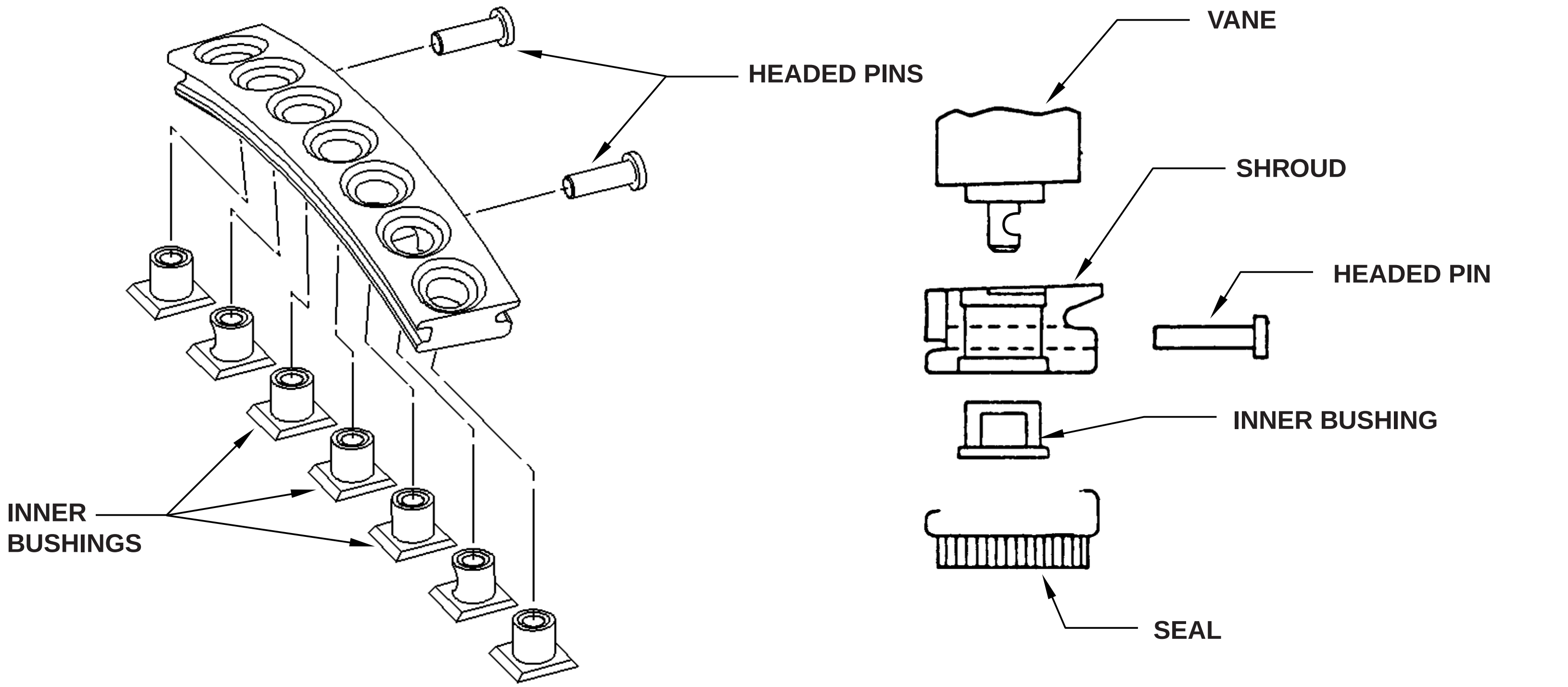
Stages 1 and 2 hold seven vanes each and stage 3 holds eight vanes.

Two bushings fitted at the outer ends of the segments have a small cutout to allow insertion of headed pins, which lock the shroud segments in position.

At the pins location, the vanes have a machined slot on their inner pivot which allows their rotation and also pin insertion.

The bushings and pins are held in place by the installation of a honeycomb seal, which slides into slots machined on the shroud.

The honeycomb seals face the rotor teeth to make interstage seals that prevent air leakage from the flowpath.



CTC-044-052-00

VSV SHROUD SEGMENTS INSTALLATION

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

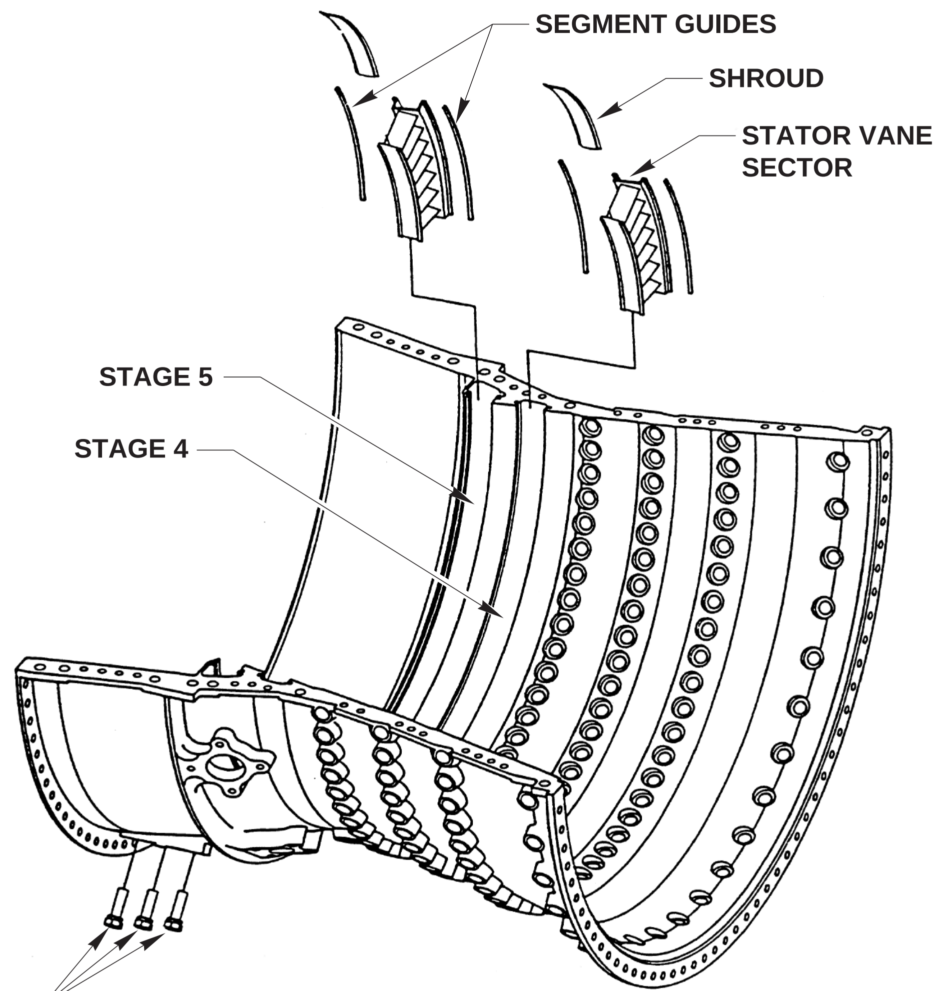
Fixed stator vane stages 4 and 5

There are 2 circumferential grooves machined inside the front stator case to accommodate stator vane sectors at stages 4 and 5.

The stator vane sectors slide into the circumferential grooves on their outer platform rail with segment guides.

The sectors inner platform rail accommodates a honeycomb shroud, which faces labyrinth seal teeth to prevent air leakage from the flowpath.

Slots are machined at the end of the circumferential grooves to accommodate an anti-rotation stop for sector retention.



COMPRESSOR FRONT STATOR CASE

CTC-044-053-00

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

The VSV actuation system

Actuation of the variable vanes is achieved through hydro-mechanically actuated bellcrank assemblies.

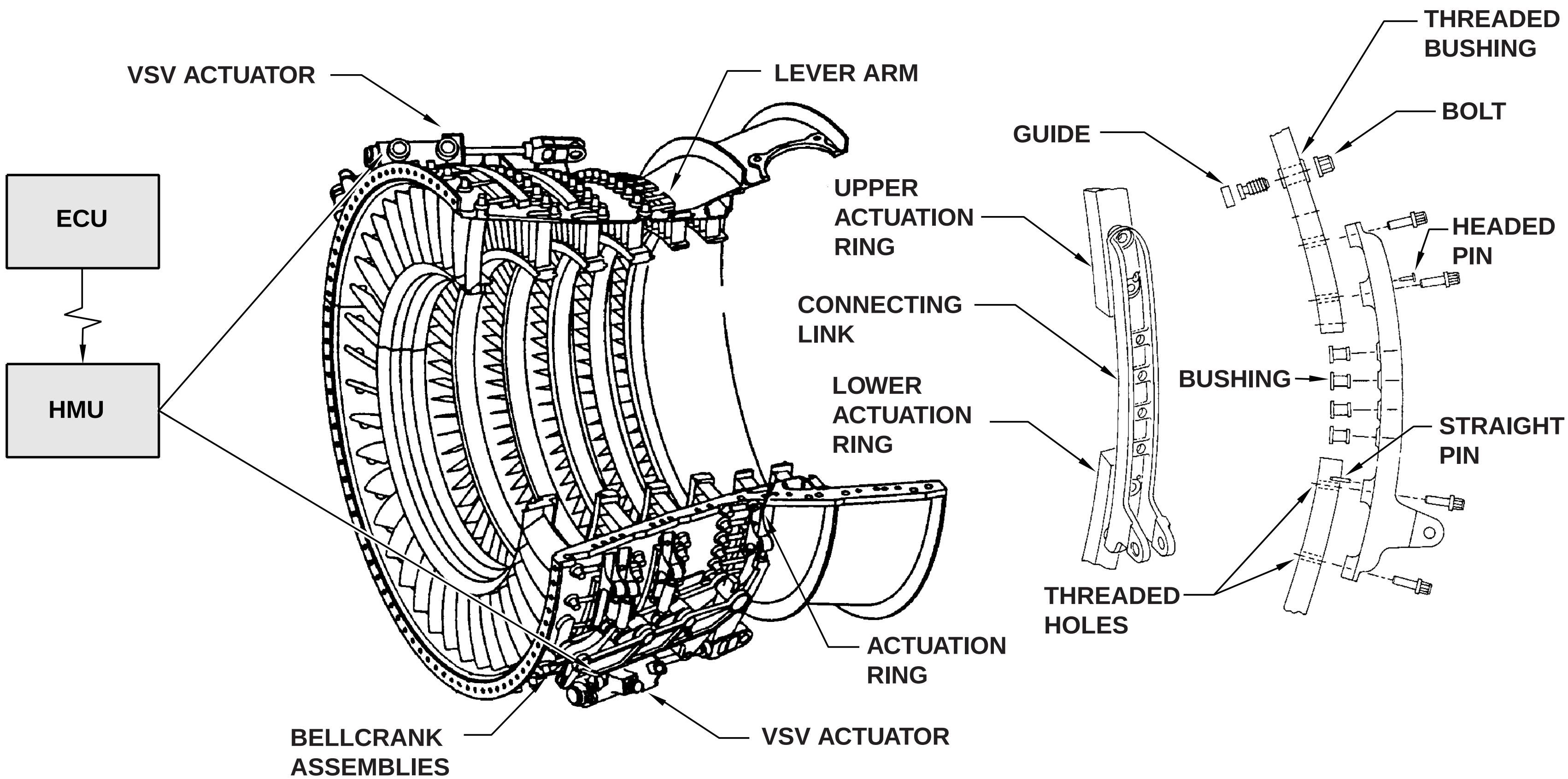
The bellcrank assemblies are installed on the front compressor stator at the 2 and 8 o'clock positions.

Fixed links, which are bolted to upper and lower actuation rings, form the connection to the bellcrank assemblies.

The upper and lower actuation rings are connected to the lever arms on the variable vanes.

A guide installed on the actuation rings makes contact with a polished surface on the stator case and ensures a smooth gliding action of the rings movement.

Fuel pressures from the Hydromechanical Unit (HMU) operate the hydraulic actuators on command from the Electronic Control Unit (ECU).



CTC-044-054-00

VSV ACTUATION SYSTEM

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COMPRESSOR REAR STATOR

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

The rear stator

The HPC rear stator plays a role in increasing the air pressure delivered to the combustion section.

The rear stator houses three fixed vanes stages 6-8 and is installed inside the front stator casing.

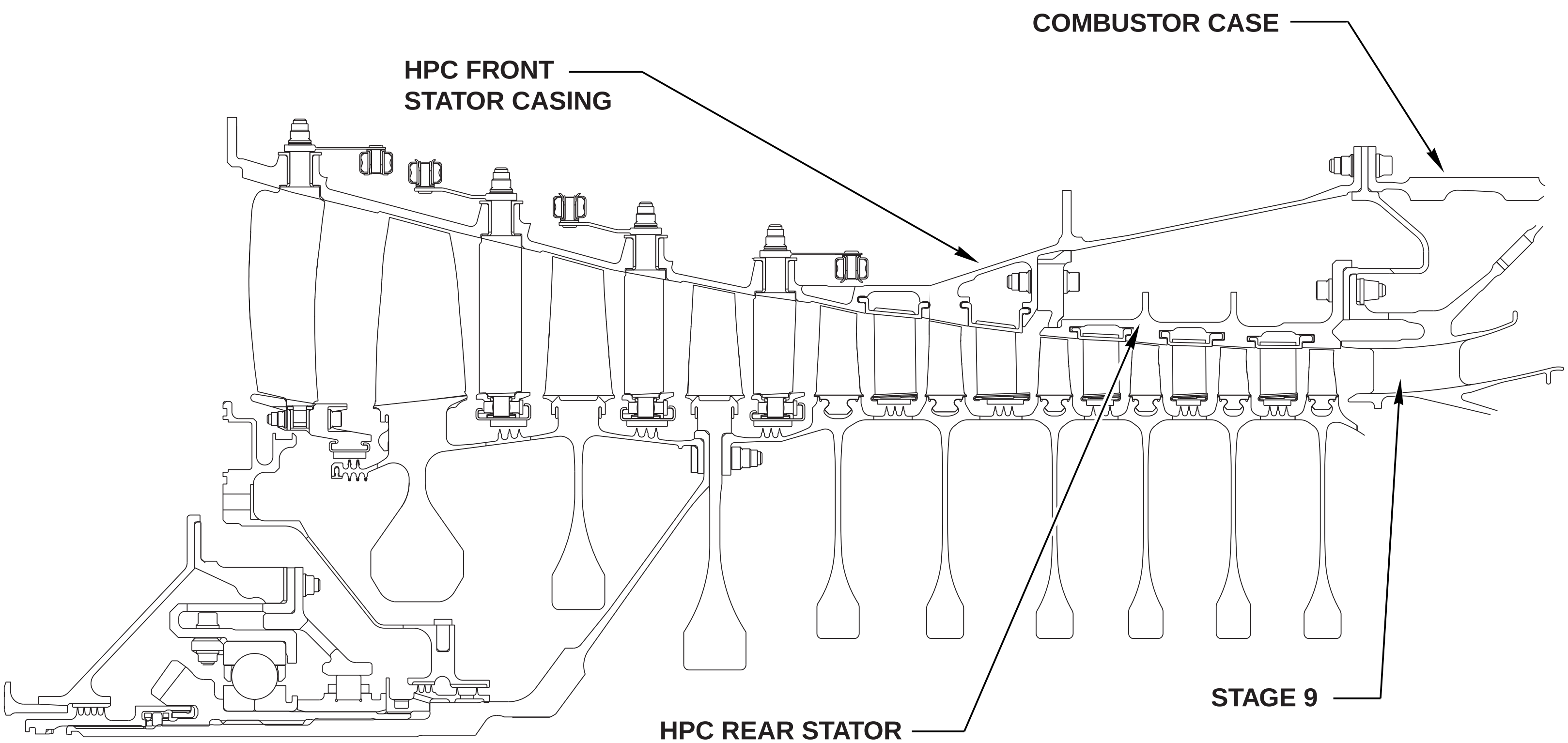
The HPC fixed vane stage 9 is part of the combustion case.

The rear stator aft flange is cantilever installed to the inner flange of the compressor discharge pressure (CDP) bulkhead and the combustor case.

The CDP bulkhead is installed between the front stator extension and combustor case.

All flanges are bolted, close-tolerance rabbeted diameters making a strong assembly, with accurate concentricity with the combustor case.

The forward end of the rear stator assembly is radially held by stage 5 manifold brackets installed on the front stator case.



CTC-044-055-00

REAR STATOR LOCATION

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

The rear stator (continued)

The rear stator case is made up of two halves bolted together at their 3 and 9 o'clock split-line flanges.

The casing halves are a matched set machined from a zinc-nickel-cobalt alloy forging.

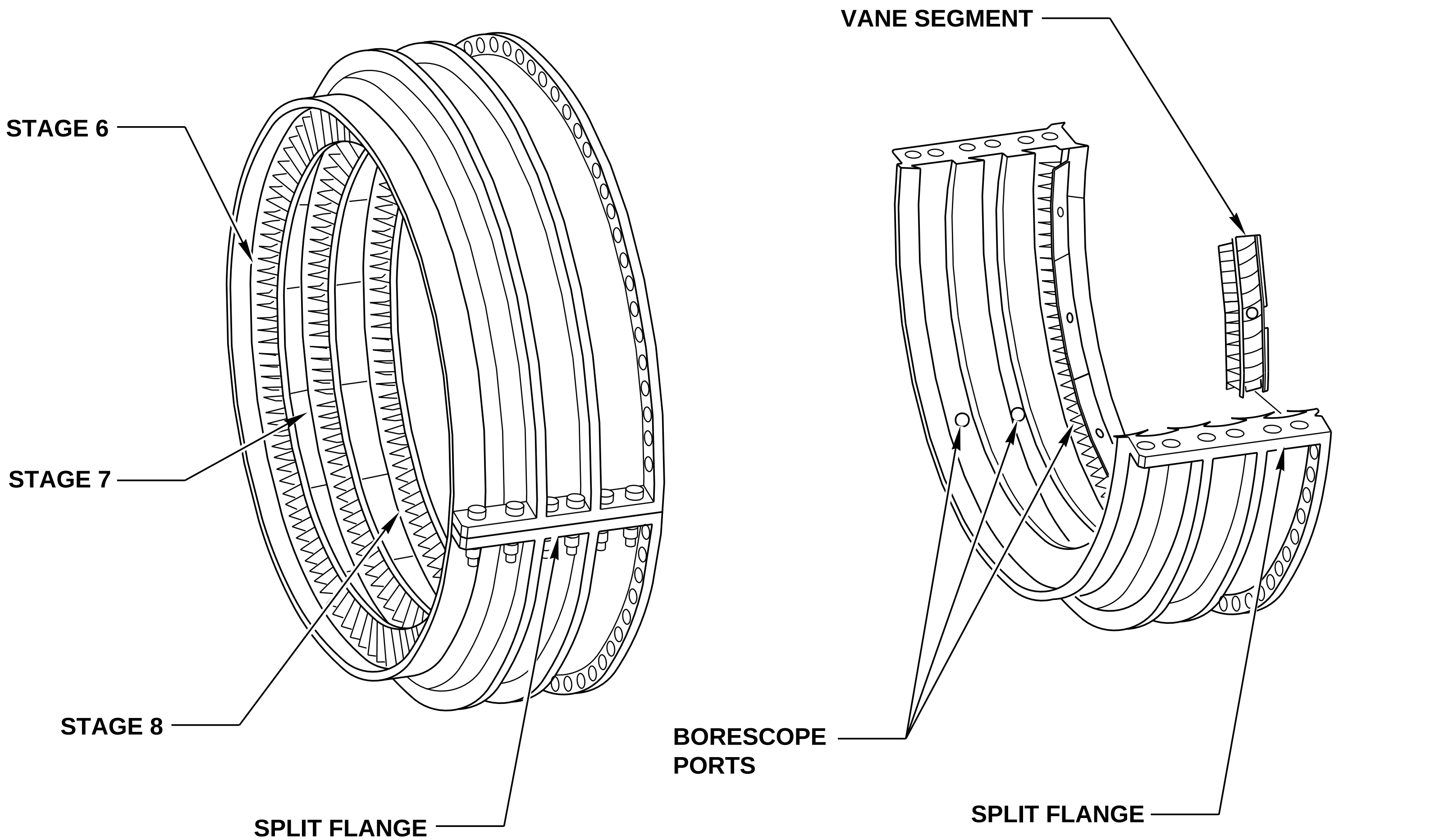
The casings have internal machined circumferential slots that hold the fixed vanes of stages 6, 7 and 8.

The vanes are assembled into segments and each stage has 10 segments.

Each casing half is equipped with an anti-rotation stop, which keeps the segments in position.

All stages of vanes have a honeycomb shroud on their inner diameter that faces rotor seal teeth to make inter-stage air seals.

The casing has borescope ports for inspection of internal areas.



HPC REAR STATOR ASEMBLY

CTC-044-056-00

THE HIGH PRESSURE COMPRESSOR (CONTINUED)

Borescope ports

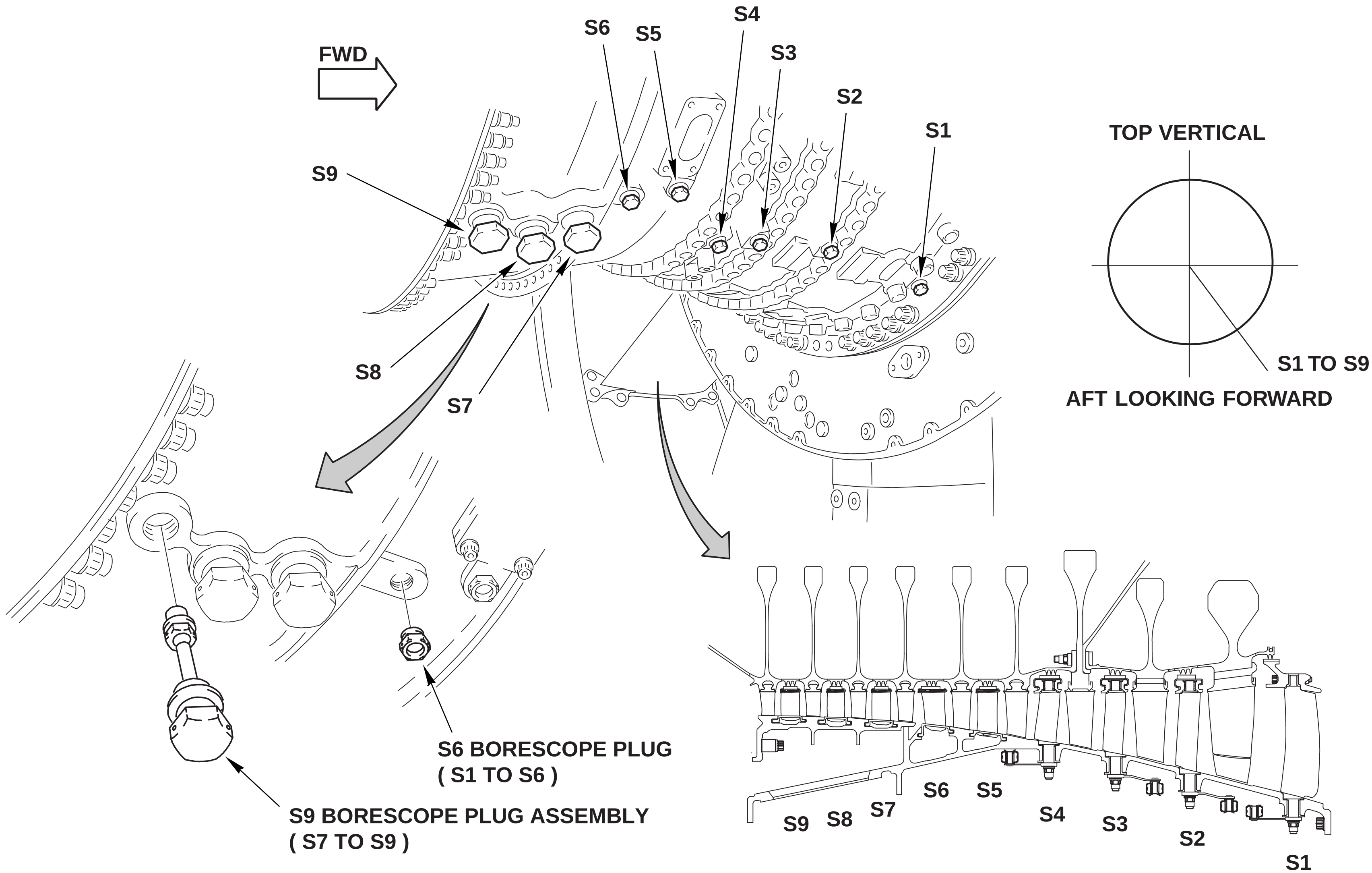
There are 9 plugged borescope ports on the lower stator case, at approximately the 5 o'clock position, and they are numbered S1 thru S9, where S1 is the most forward.

S7, S8 and S9 plugs have a particular design. They are double plugs.

The inner thread engages the HPC rear stator case, while the outer thread is tightened on the HPC case.

A spring-loaded system enables the outer plug to drive the inner plug.

Both the inner and outer plugs have specific torque values.



HPC BORESCOPE PORTS

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COMBUSTION SECTION

THE COMBUSTION SECTION

The combustion section is located between the High Pressure Compressor (HPC) and the Low Pressure Turbine (LPT).

Air from the HPC is mixed with fuel, supplied by 20 fuel nozzles.

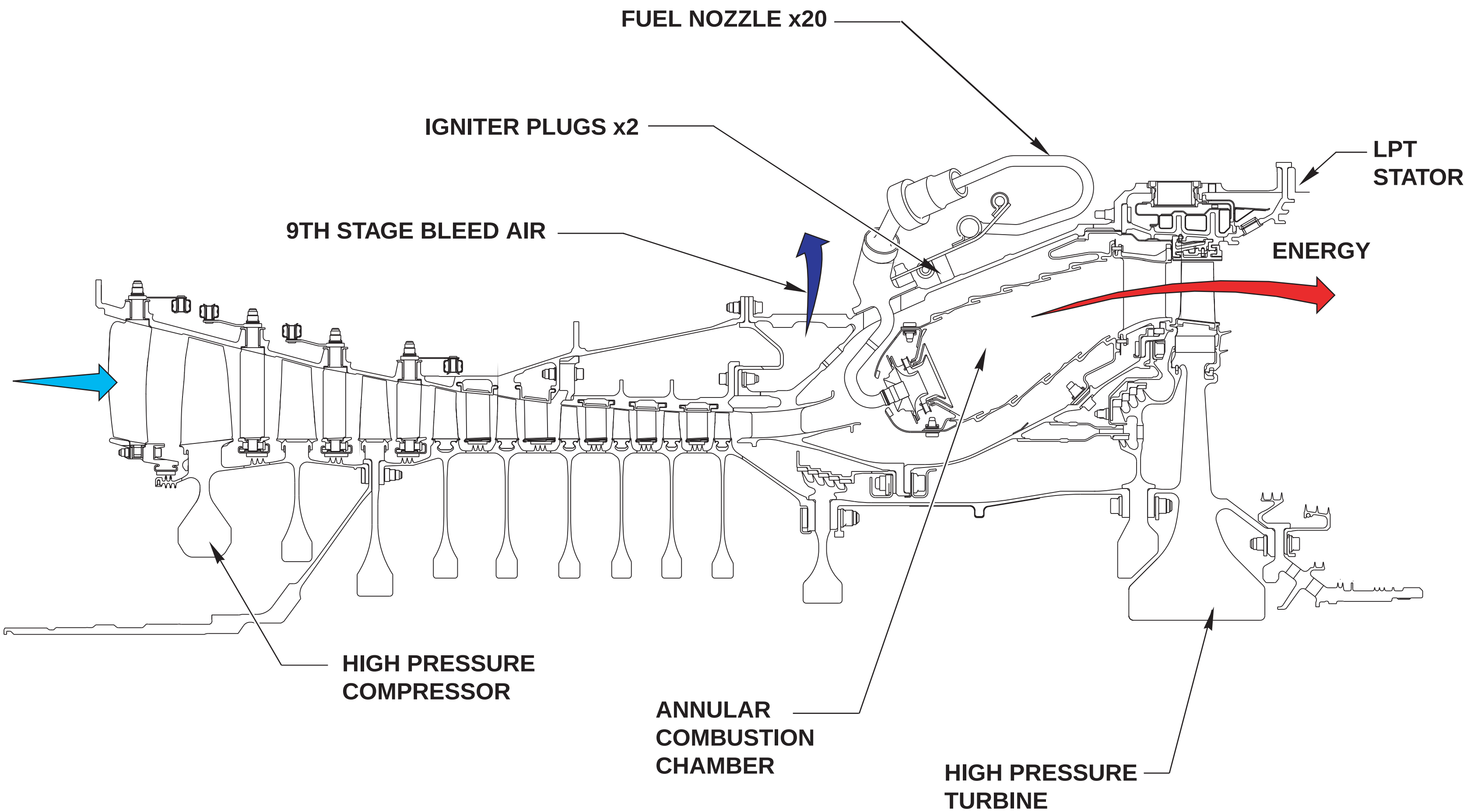
During the starting sequence, or when required, the mixture is ignited by 2 igniter plugs, in order to produce the necessary energy to drive the turbine rotors. Residual energy is converted into thrust.

The combustion section also supplies HPC 9th stage bleed air for both aircraft and engine use.

The front face of the combustor is attached to the rear of the HPC and its rear face is bolted onto the LPT module front flange.

The rear part of the combustor houses the High Pressure Turbine (HPT) module and stage 1 LPT nozzle.

The combustion section consists of :
- the combustion case
- the combustion chamber



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COMBUSTOR DESIGN

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COMBUSTION CASE

THE COMBUSTION SECTION (CONTINUED)

The combustion case

The combustion case is a weldment structure, which provides the structural interface between the HPC, the combustor and the LPT and transmits the engine axial loads.

It provides 9th stage bleed air for both engine and aircraft use.

It incorporates the compressor Outlet Guide Vanes (OGV) and a diffuser, which slows down HPC airflow prior to delivering it into the combustion area, thus improving combustion efficiency.

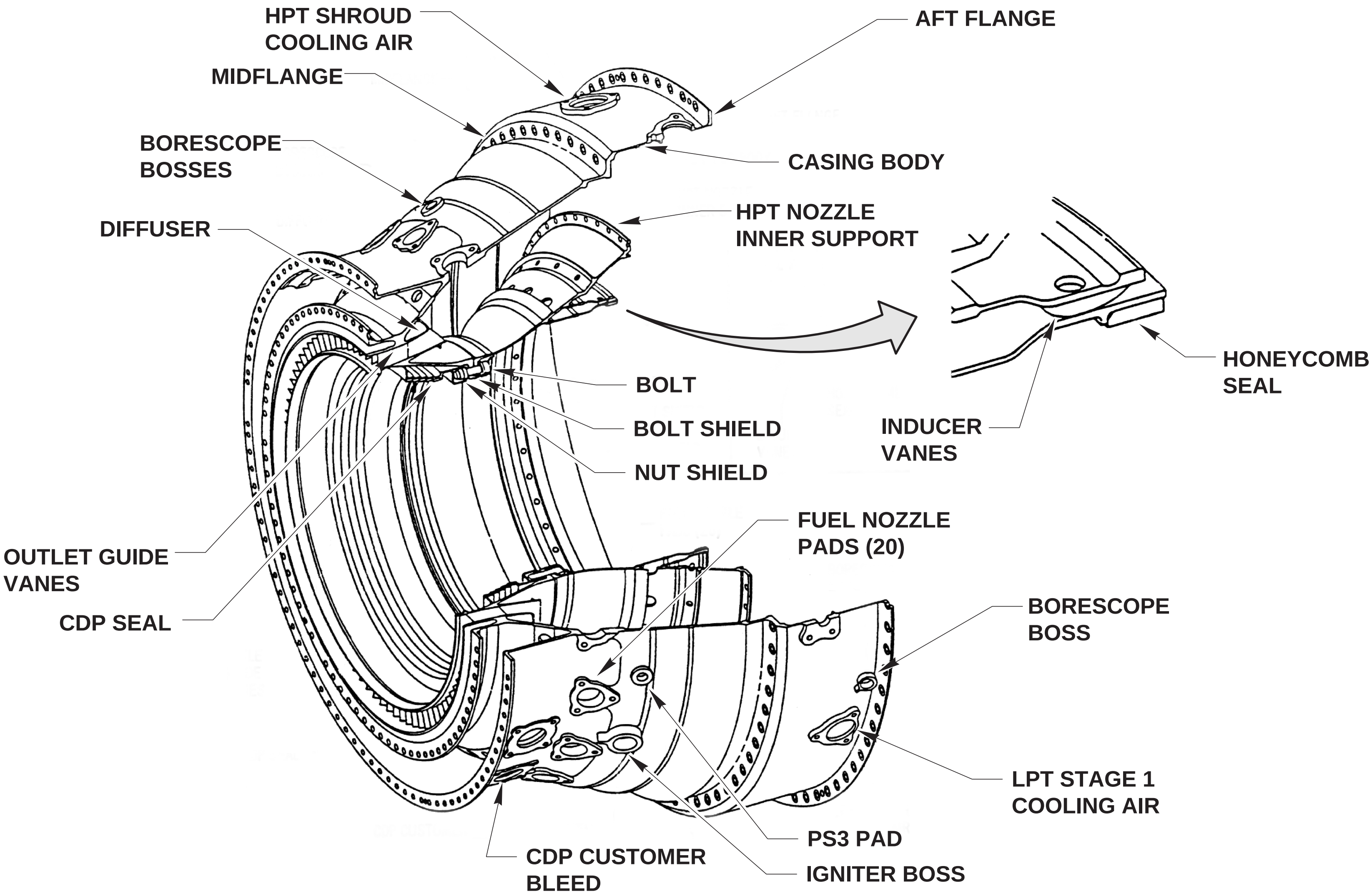
The mounting pads accommodate 20 fuel nozzles around the outer surface and 2 igniters, which are at the 4 and 8 o'clock positions.

The fuel nozzles are supplied by the following equipment, which is attached to the case :

- a fuel supply manifold (Y-tubes).
- 4 fuel manifold halves.

The combustion case also has :

- 6 borescope ports.
- 4 customer bleed ports.
- 4 ports for LPT stage 1 cooling.
- 3 ports for HPT clearance control air, 1 for source air and 2 for the introduction of air to the shrouds.
- Mounting pads for pressure and temperature sensors.



COMBUSTION CASE

CTC-044-059-00

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COMBUSTION CHAMBER

THE COMBUSTION SECTION (CONTINUED)

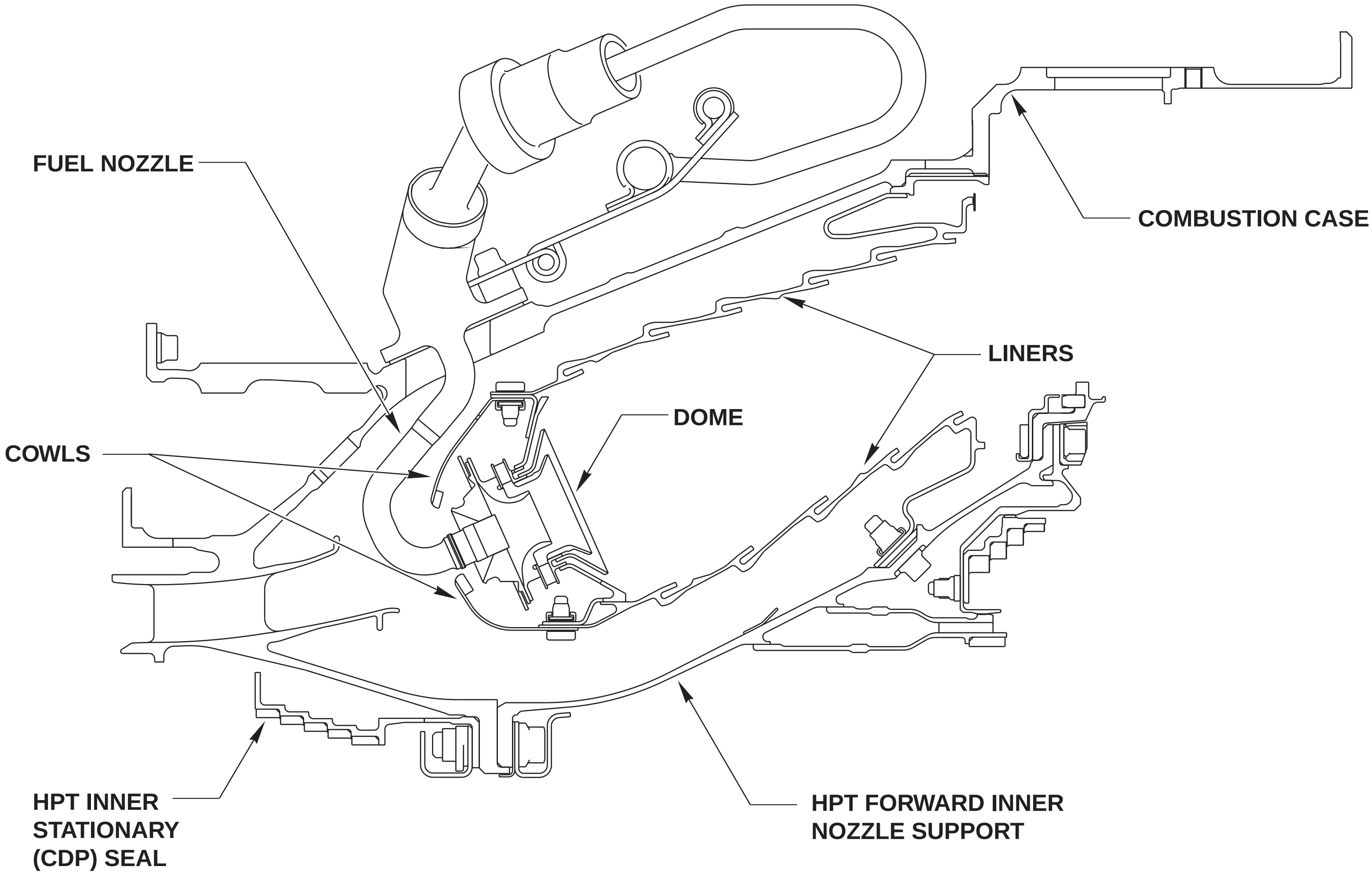
The combustion chamber

The combustion chamber is a short annular structure housed in the combustion case.

It is installed between the HPC stator stage 9 and the HPT nozzle.

The swirl nozzles and the liners, which provide additional combustion and cooling air, produce an efficient fuel/air mixture providing a uniform combustion pattern and low thermal stresses.

It consists of :
- the swirl fuel nozzles and deflectors (the dome)
- the outer and inner cowls
- the outer and inner liners



COMBUSTION CHAMBER

CTC-044-060-00

THE COMBUSTION SECTION (CONTINUED)

The swirl nozzles and dome

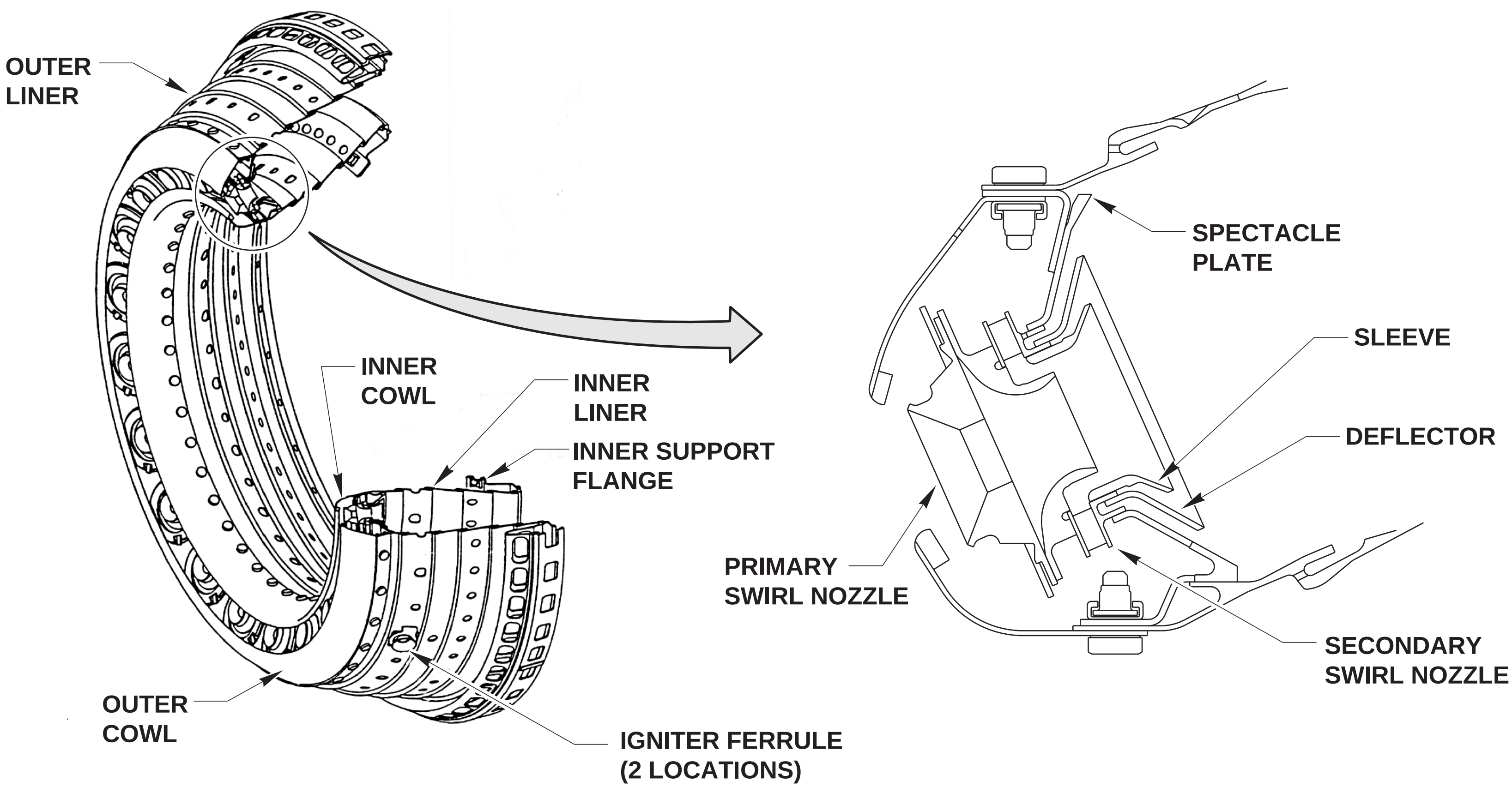
The dome is made of both cast and machined components.

It is bolted at its inner and outer ends to the liners and cowls.

The dome contains the spectacle plate, which supports 20 primary swirl nozzles, 20 secondary swirl nozzles, sleeves and deflectors.

The swirl nozzles, sleeves and deflectors mix air and fuel.

The surface of the dome is cooled by a layer of air from the HPC discharge (CDP) airflow.



CTC-044-061-00

SWIRL NOZZLES AND DOME

THE COMBUSTION SECTION (CONTINUED)

The outer and inner liners

The outer and inner liners are of an integral design with overhung panels which contain closely spaced holes for cooling purposes.

To lower turbine inlet gas temperature, the liners have dilution holes, which produce additional combustion and cooling air.

The outer liner has 2 ferrules for installation of the spark igniters.

The inner liner rear flange is bolted on the combustion case inner casing. There are holes in the rear flange to duct HPT nozzle cooling air.

The outer liner rear flange is S-shaped and mechanically secured to the HPT nozzle vanes outer platform and to the combustion chamber outer casing. Holes in the flange duct HPT nozzle cooling air.

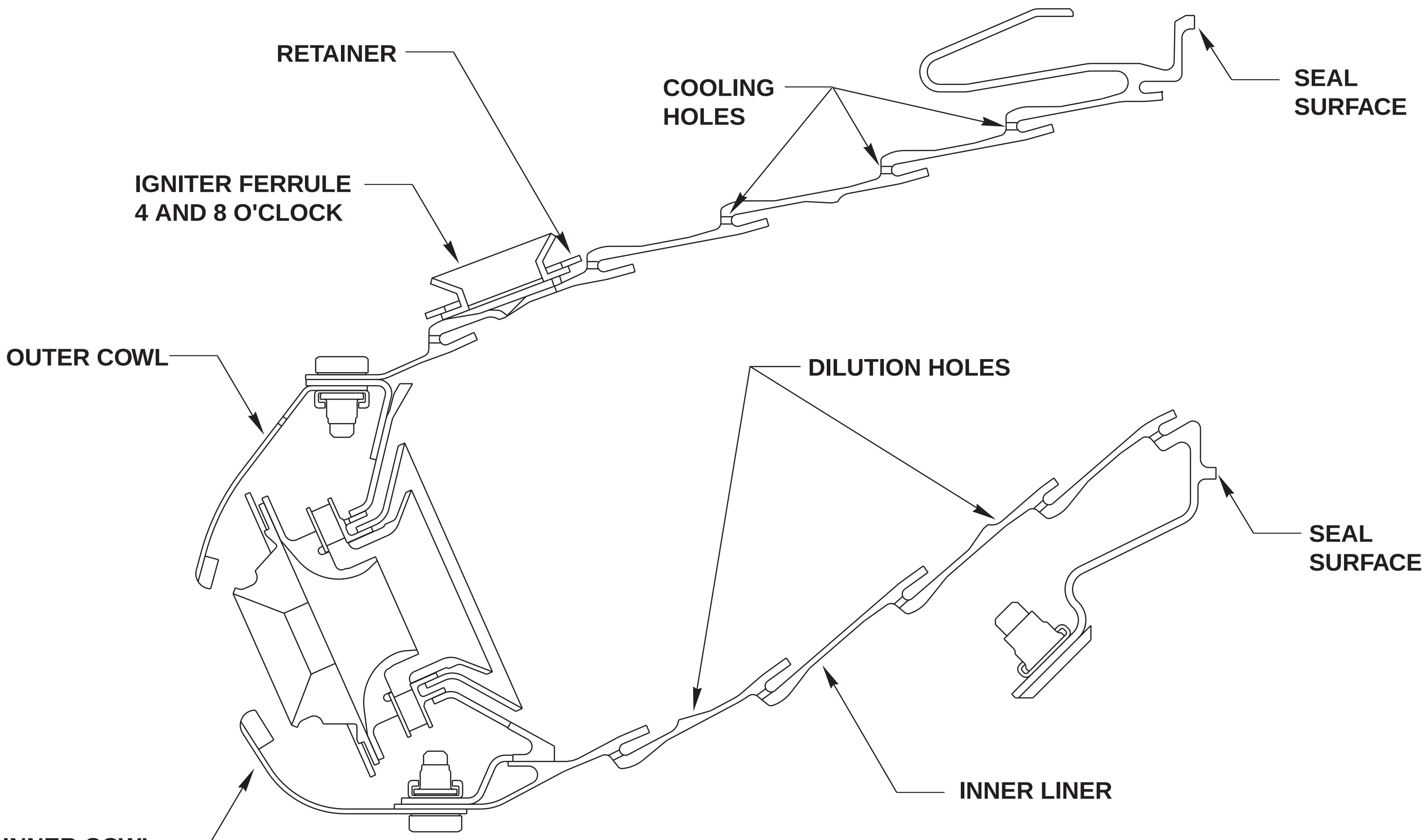
Both inner and outer liners have a thermal barrier coating on their inner surfaces.

The outer and inner cowls

The outer and inner cowls form the front end of the combustor and are designed to give a constant and stable airflow to the combustion chamber.

They are made from a nickel-chrome alloy.

The outer and inner cowls are bolted to the forward end of the outer and inner liners and the dome.



CTC-044-062-00

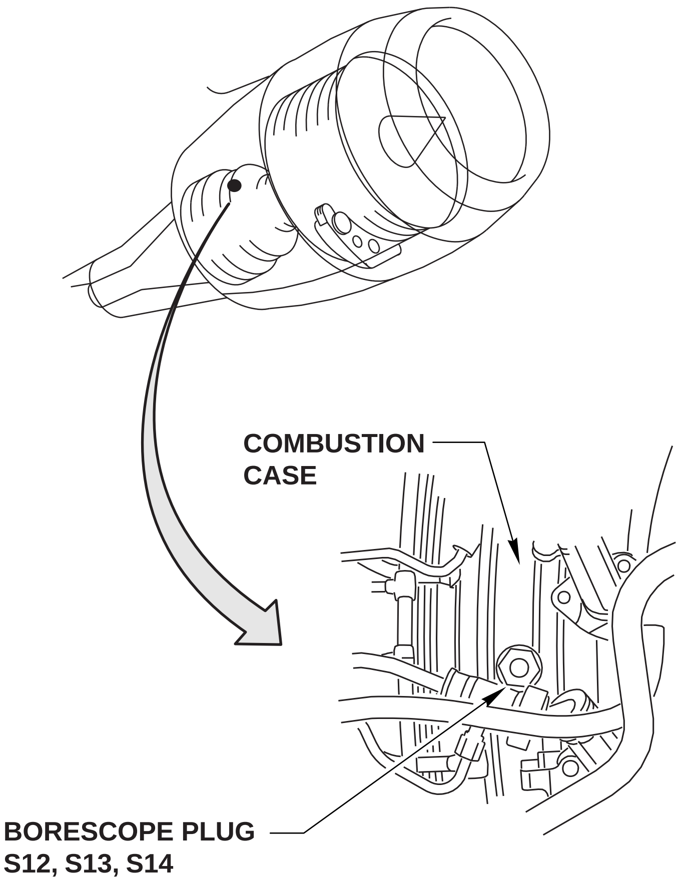
OUTER AND INNER COWLS AND LINERS

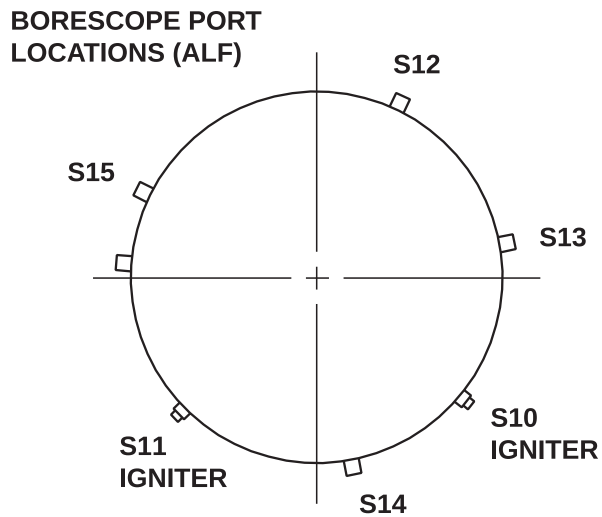
THE COMBUSTION SECTION (CONTINUED)

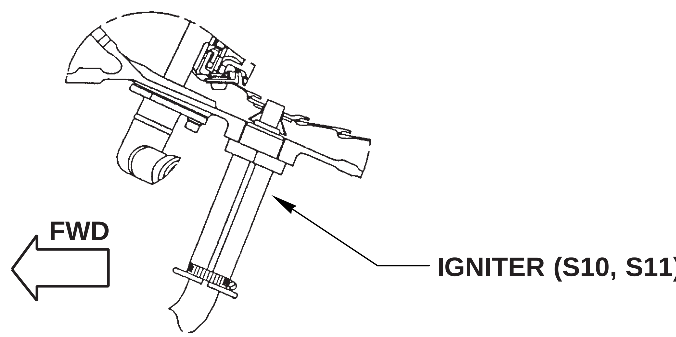
Borescope ports

There are 4 plugged borescope ports (S12, S13, S14, S15) around the combustion case, which enable inspection of the combustion chamber.

Two other ports are available, using the spark igniter ports S10 and S11, which can also be used to inspect the High Pressure Turbine (HPT) blades.







COMBUSTION CHAMBER BORESCOPE PORTS

CTC-044-063-00

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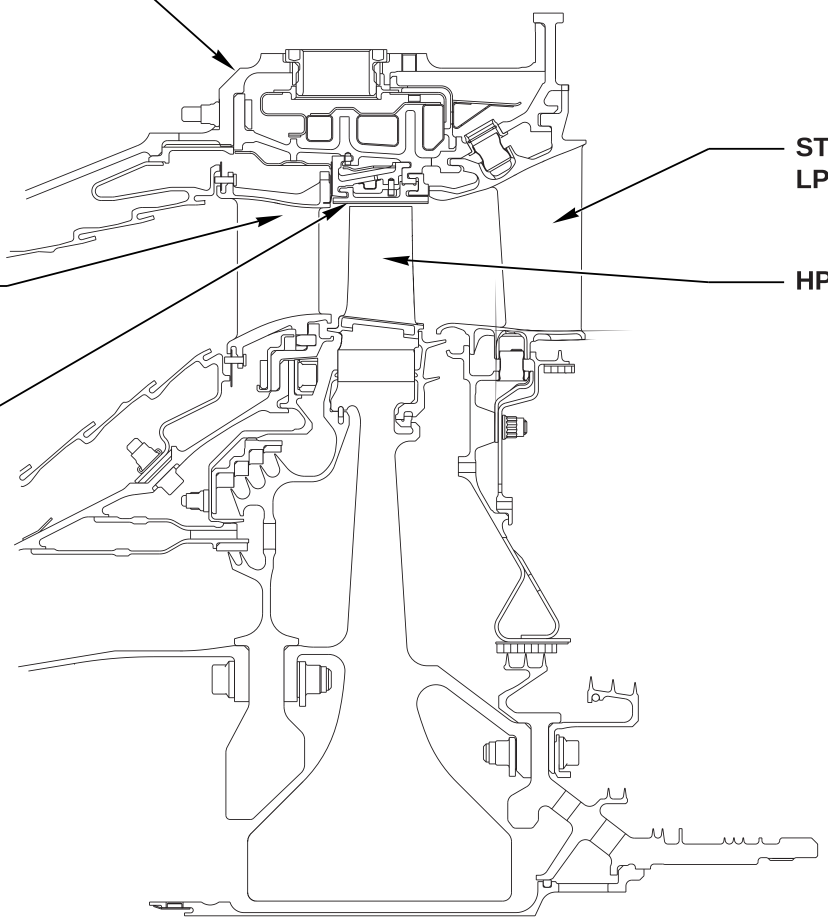
HIGH PRESSURE TURBINE

THE HIGH PRESSURE TURBINE (HPT)

The HPT converts the kinetic energy of gasses from the combustion chamber into torque to drive the HPC.

It is housed in the combustion case and is a single-stage air cooled assembly that consists of :

- the HPT nozzle
- the HPT rotor
- the HPT shroud and stage 1 LPT nozzle



CTC-044-064-00

THE HIGH PRESSURE TURBINE

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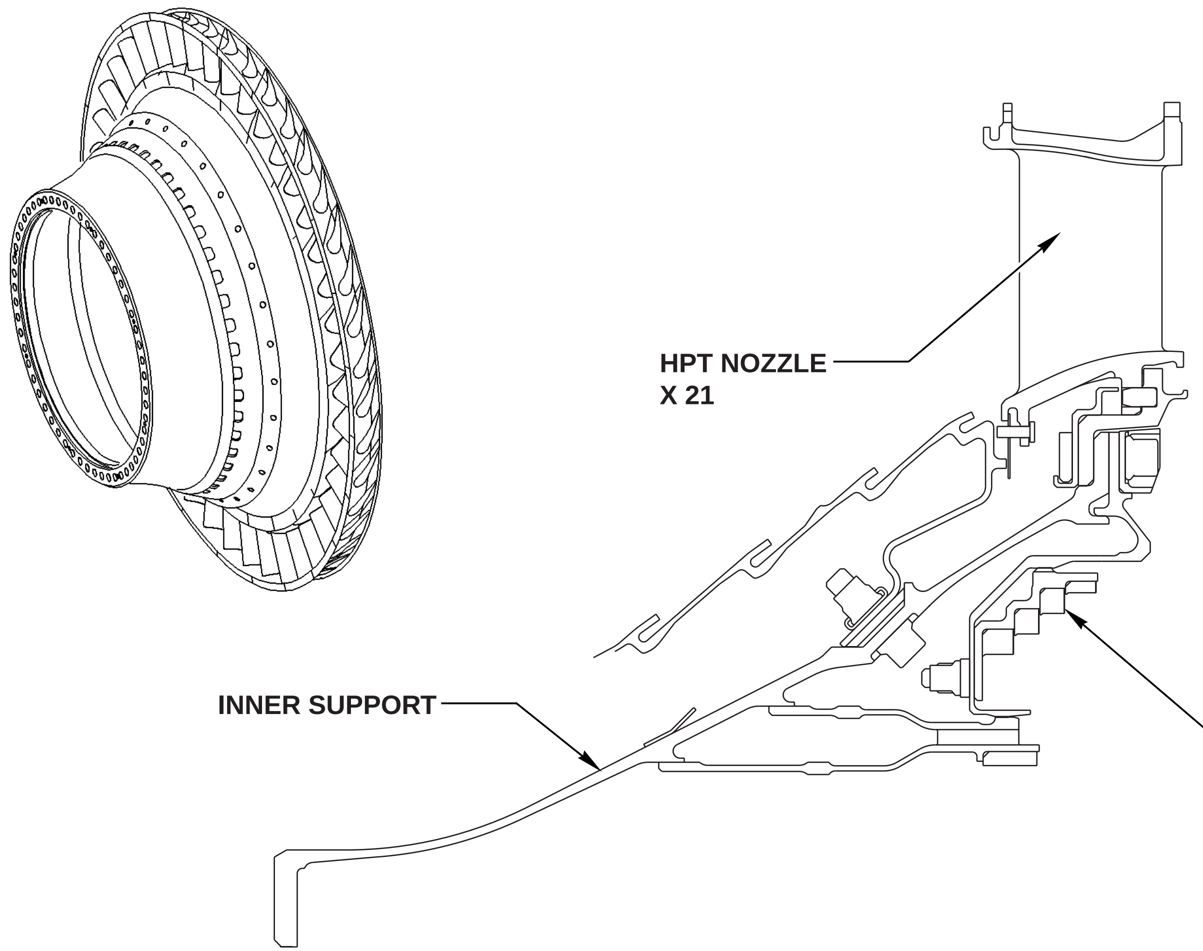
HIGH PRESSURE TURBINE NOZZLE

THE HIGH PRESSURE TURBINE

The HPT nozzle

The HPT nozzle directs the gas flow from the combustion chamber onto the blades of the HPT rotor at an angle that will give the greatest performance during all operating conditions.

The HPT nozzle consists of :
- 21 nozzle segments of 2 vanes each
- the inner support
- the aft support and seal



CTC-044-065-00

HIGH PRESSURE TURBINE NOZZLE ASSEMBLY

THE HIGH PRESSURE TURBINE (CONTINUED)

The nozzle segments

The 21 HPT nozzle segments are assemblies made up of 2 vanes brazed onto inner and outer platforms.

Each vane is a cast shell divided into forward and aft cooling compartments by an inner rib.

The vanes and platforms are cooled by CDP air, which enters the vane compartments through inserts in the inner and outer ends of the vanes.

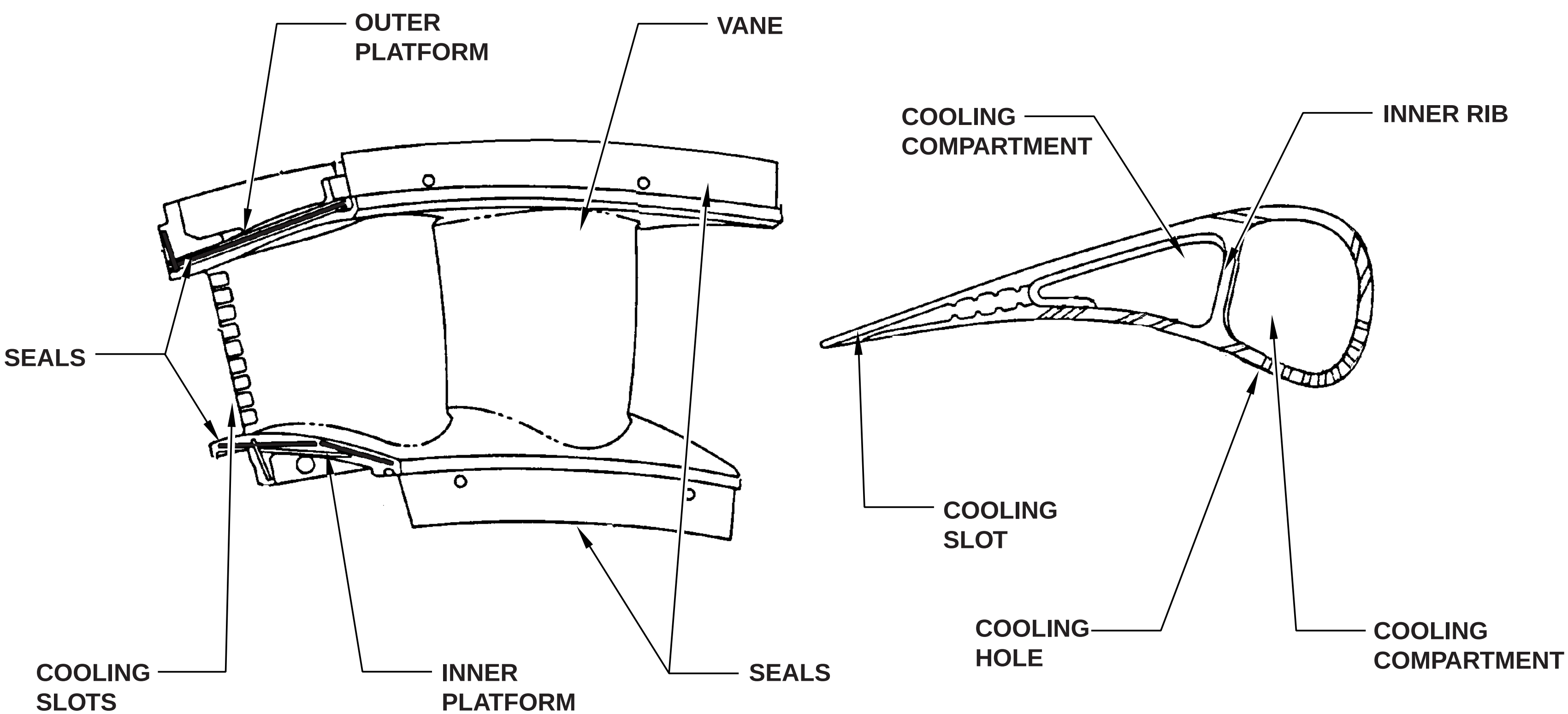
The air exits through holes in the vane's leading edge and slots in the trailing edge.

The vanes and platforms are made of a high strength nickel base alloy, with a protective coating on the vane airfoils and the platform flowpath surfaces.

The nozzle inner and outer platform sides have metal seals, held in place by grease at installation, to prevent air leakage.

The forward inner and outer platform seals are pushed against the combustion case inner and outer liners by springs. The vanes rear outer platform seal is pushed against the shroud support by spring-loaded clips.

The vanes rear inner platforms are supported by forward and aft inner supports.



CTC-044-066-00

HP TURBINE NOZZLE SEGMENTS

THE HIGH PRESSURE TURBINE (CONTINUED)

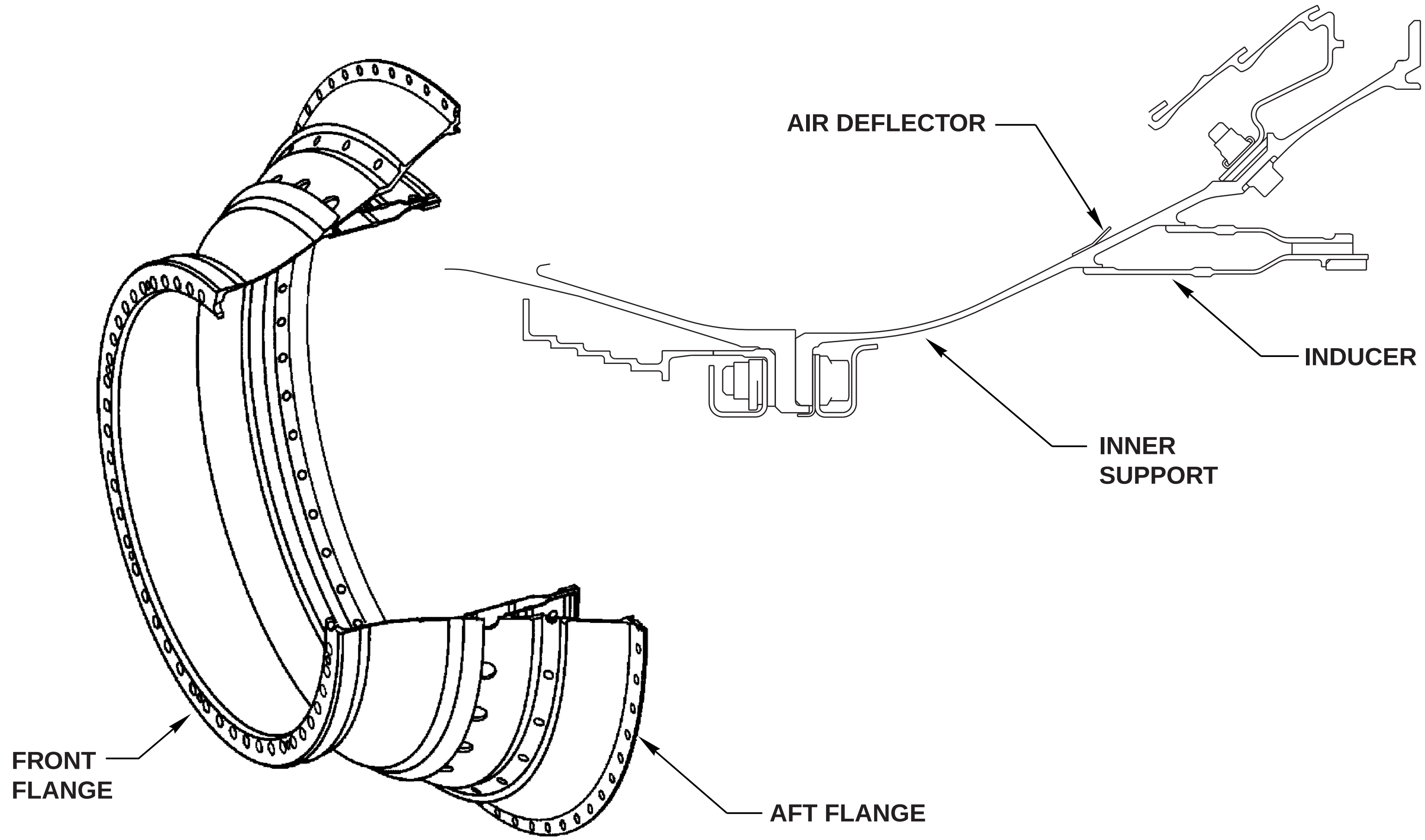
The nozzle inner support

The HPT nozzle inner support is made of a nickel base alloy and carries much of the nozzle load.

The nozzle forward inner support forward flange is bolted on the combustion case inner casing rear flange.

An integral part of the forward inner support is the inducer that provides HPT rotor cooling air.

An air deflector enables air to enter the inducer and at the same time prevents contaminants from entering.



CTC-044-067-00

HPT NOZZLE FORWARD INNER SUPPORT

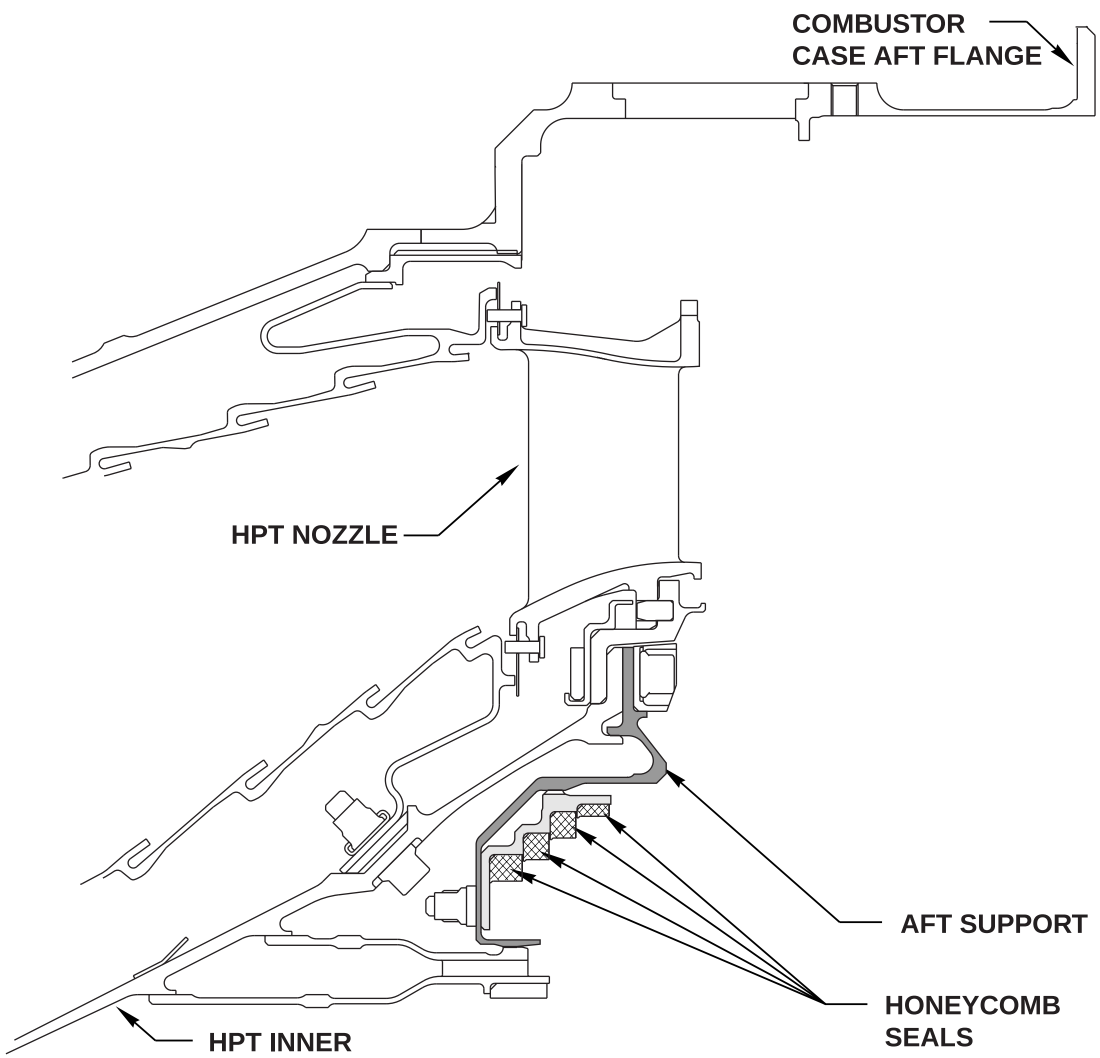
THE HIGH PRESSURE TURBINE (CONTINUED)

The aft support and seal

The aft seal assembly is a one-piece ring that is made of a nickel base alloy.

It has a 4-step honeycomb seal that mates with the HPT rotor seal teeth. This helps to maintain the proper amount of cooling airflow and rotor thrust.

The aft support is bolted on the inner support at its upper flange. The honeycomb seal is bolted on the aft support at its lower flange.



AFT SUPPORT AND SEAL

CTC-044-068-00

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HIGH PRESSURE TURBINE ROTOR

THE HIGH PRESSURE TURBINE (CONTINUED)

The HPT rotor

The HPT rotor receives gas flow from the combustion chamber through the HPT nozzle. The nozzle and rotor convert the kinetic energy into the necessary torque for the HPT rotor to drive the HPC rotor.

The HPT rotor is a single stage assembly cooled by CDP air and is housed in the combustion case at the rear of the core engine.

It consists of :

- the front shaft
- the forward rotating air seal
- the disk
- the blades
- the rear shaft

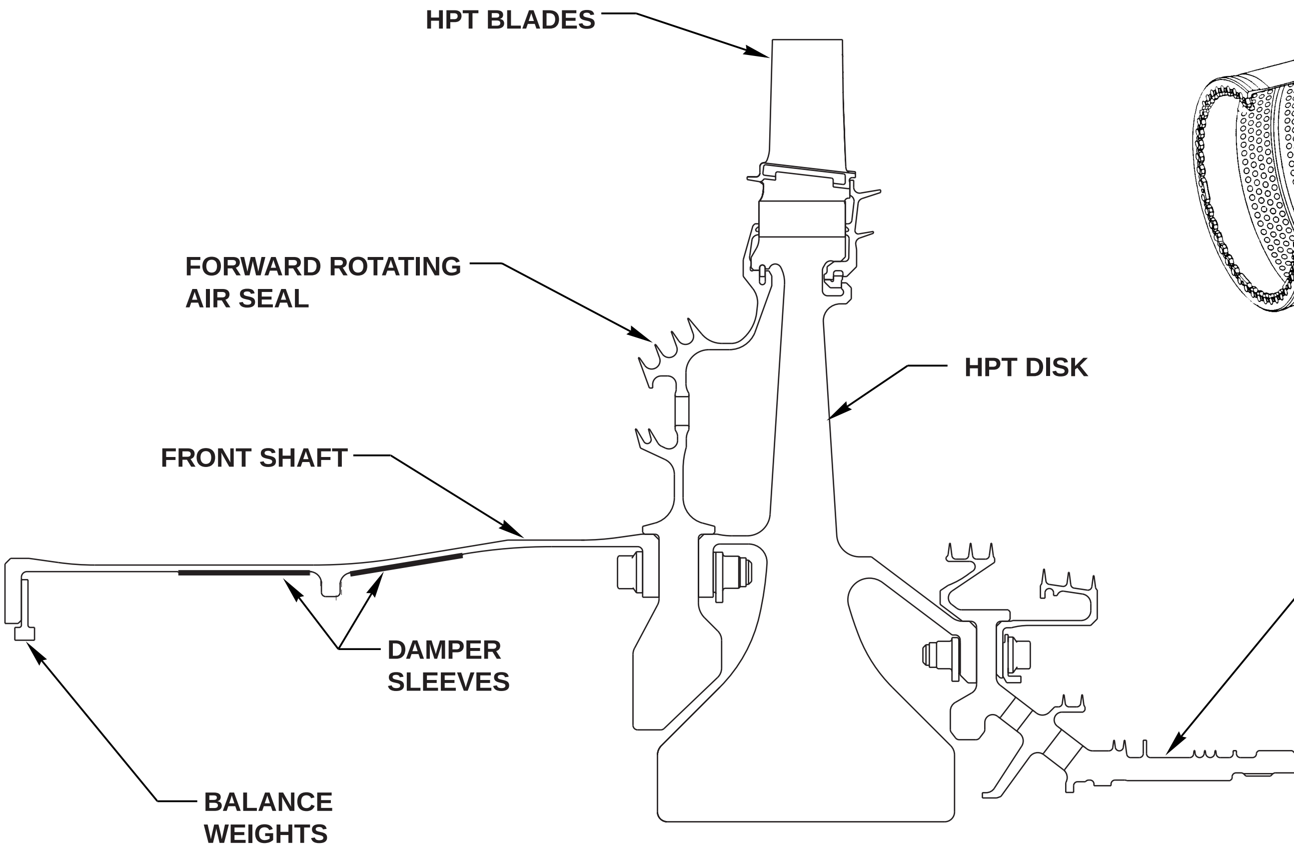
The front shaft

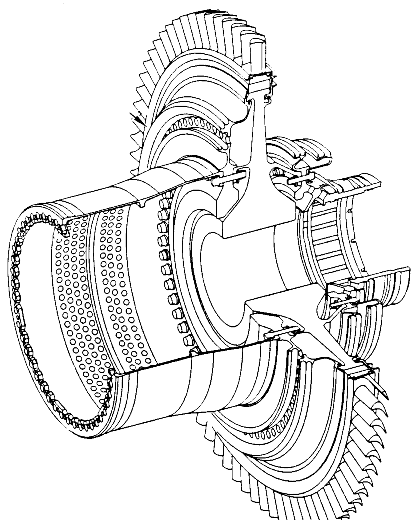
The rotor front shaft forms the structural connection between the compressor rotor and the HPT rotor. It also supports the aft end of the compressor rotor.

The front shaft front flange is bolted to the HPC stages 4-9 spool at the CDP rotating air seal to form a single core rotor.

It accommodates a damper sleeve on its inner surface to change vibration frequency.

Weights are also installed, at assembly line and module maintenance level, for balancing purposes.





HPT ROTOR DESIGN

CTC-044-069-00

THE HIGH PRESSURE TURBINE (CONTINUED)

The forward rotating air seal

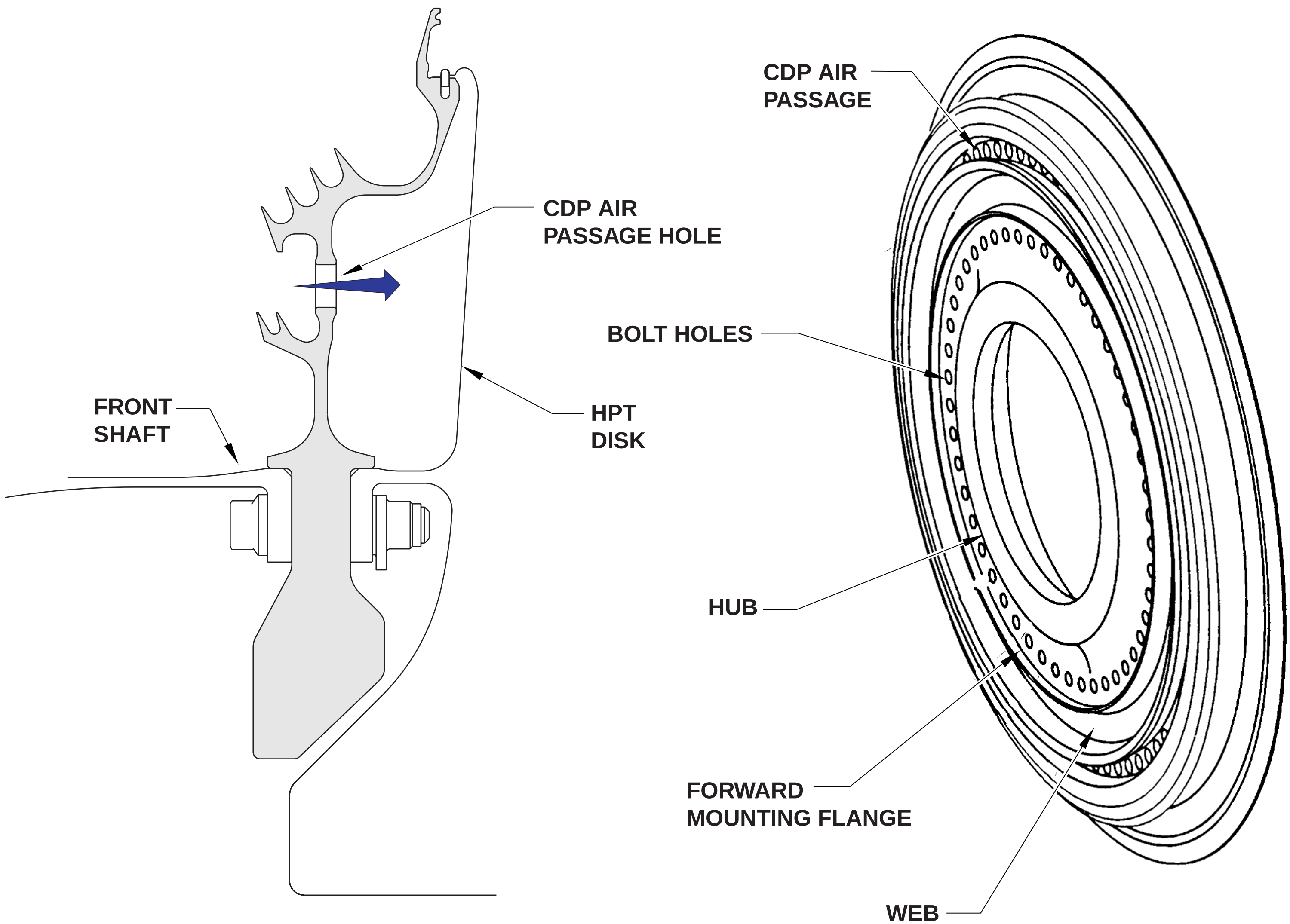
The forward rotating air seal provides a closed cavity to direct CDP air toward the disk and out through the turbine rotor blades for cooling purposes.

It is bolted between the rotor front shaft and the disk.

Two labyrinth seals reduce air leakage of CDP air from the inducer.

The outer inclined seal teeth are coated with a ceramic material to improve cutting ability into the stationary seal. The inner seal teeth have a plasma wear coating.

Axial holes between the two seals allow cooling air to enter the disk web cavity formed by the seal and the disk. The cooling air is directed against the disk web and radially out to the turbine blades. Air enters the blade roots through the disk slots.



FORWARD ROTATING AIR SEAL

CTC-044-070-00

THE HIGH PRESSURE TURBINE (CONTINUED)

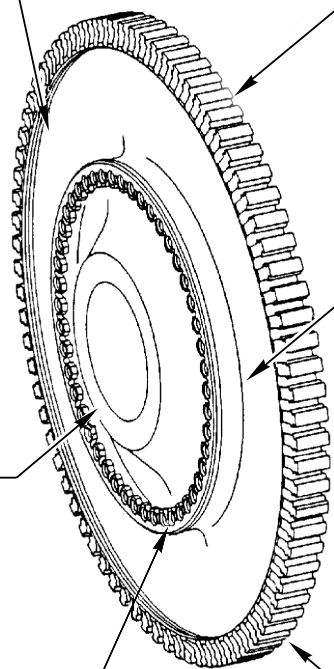
The disk

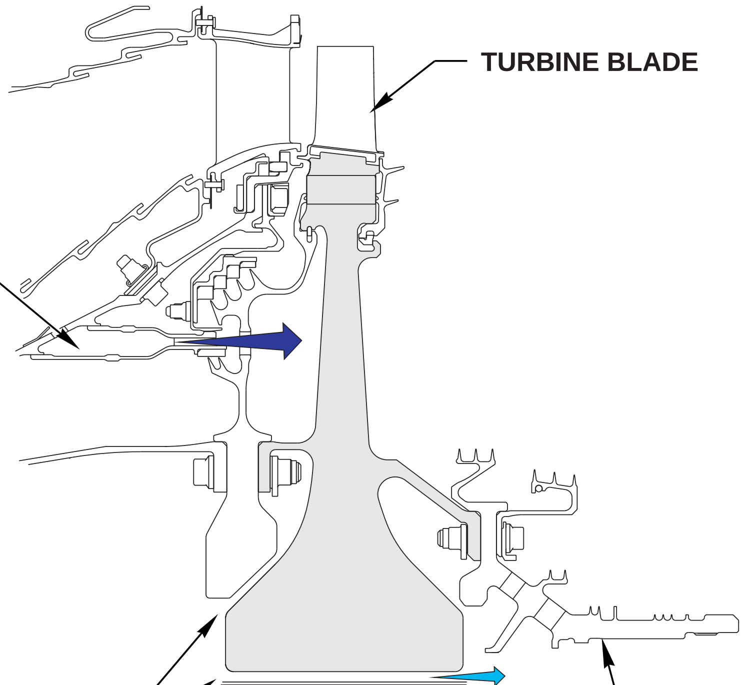
The HPT disk is a forged and machined part that retains the turbine blades in individual axial dovetail slots.

The inner part of the disk is cooled by booster discharge air and HPC 5th stage air (when RACC system is operational).

Its outer front face is cooled by CDP air passing through the forward rotating air seal.

It is bolted to the forward rotating air seal on its forward face and the rear shaft on its rear face.





HP TURBINE DISK

CTC-044-071-00

THE HIGH PRESSURE TURBINE (CONTINUED)

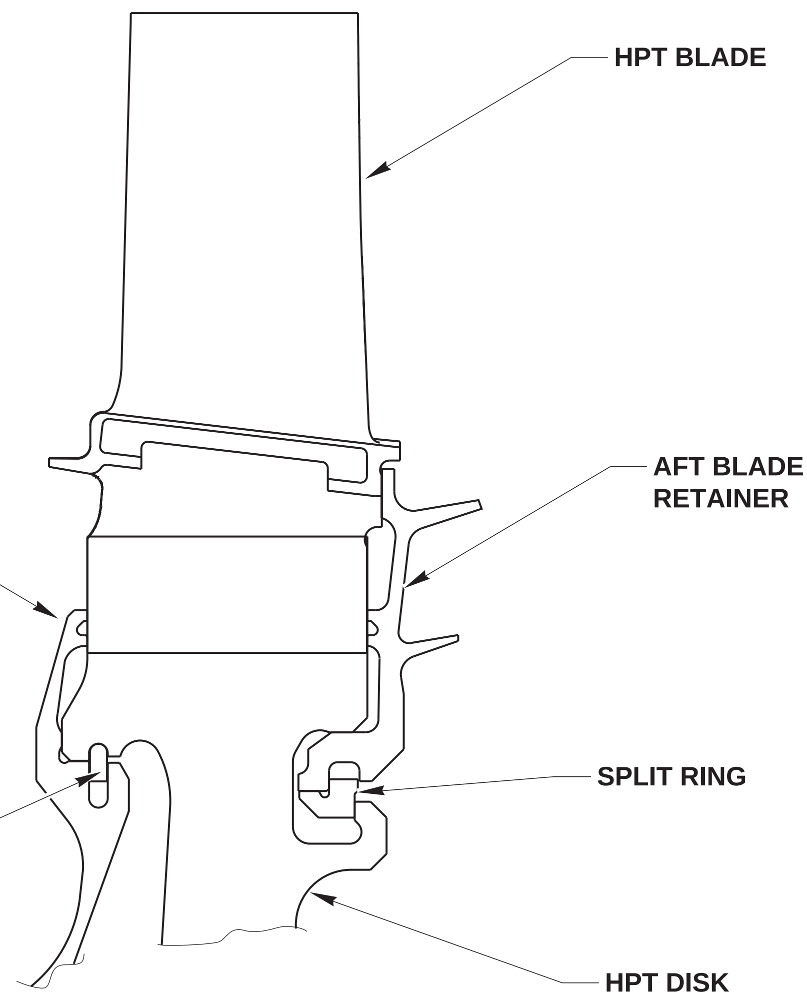
The blade retainers

The HPT rotor blades are installed into individual dovetail slots on the disk.

They are held in position at the front by the outer arm of the forward rotating air seal. The arm is installed on the disk with a press fit and held in place by a split ring.

The forward rim cavity is pressurized by CDP air leakage across the front seal teeth to prevent hot gas path air from entering.

At the rear, the blades are held in place by a blade retainer installed onto the HPT disk with an interference fit and held in place axially by a split ring.



BLADE RETAINERS

CTC-044-072-00

THE HIGH PRESSURE TURBINE (CONTINUED)

The rotor blades

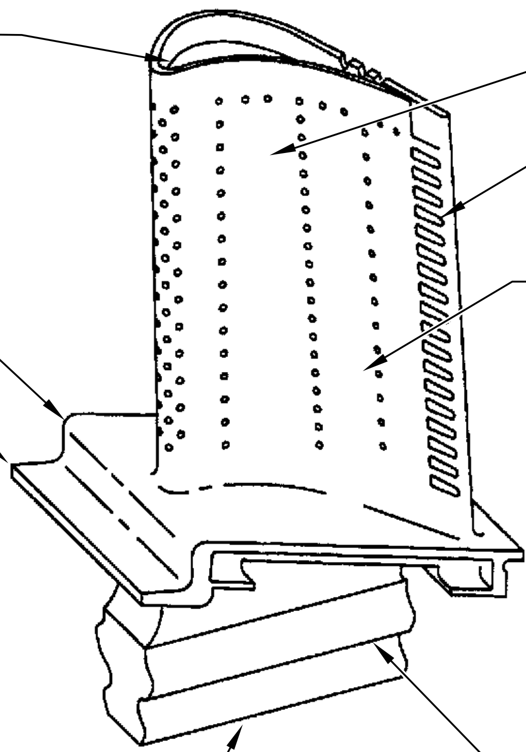
The HPT rotor blades are made of a high temperature nickel alloy that is directionally solidified for a high strength to weight ratio.

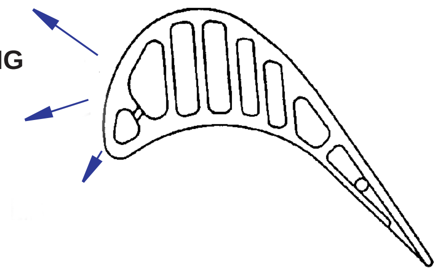
There are 80 individually replaceable blades. 4 blades have notches machined on their convex side at installation in order to indicate wear levels and help in borescope inspection.

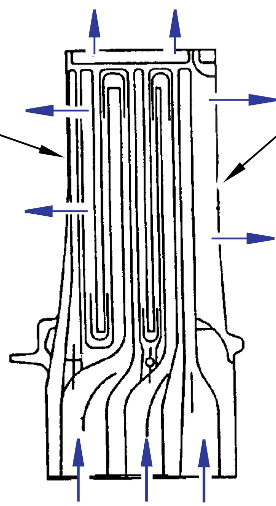
They are internally cooled by CDP air which enters through the blade root and exits through holes in the leading edge, tip and trailing edge.

The blades have dovetail roots that slide into slots on the disk.

Blade damper seals are installed in the cavity underneath the blade platforms and held in place by two lobes. They prevent hot gasses from entering the cavity and provide vibratory damping to the blade.







HP TURBINE BLADE

CTC-044-073-00

THE HIGH PRESSURE TURBINE (CONTINUED)

The rear shaft

The rear shaft provides aft support for the HPT rotor through the No.4 bearing.

It is installed with bolts to the aft side of the disk at a rabbeted flange. An aft air seal is attached at the same point.

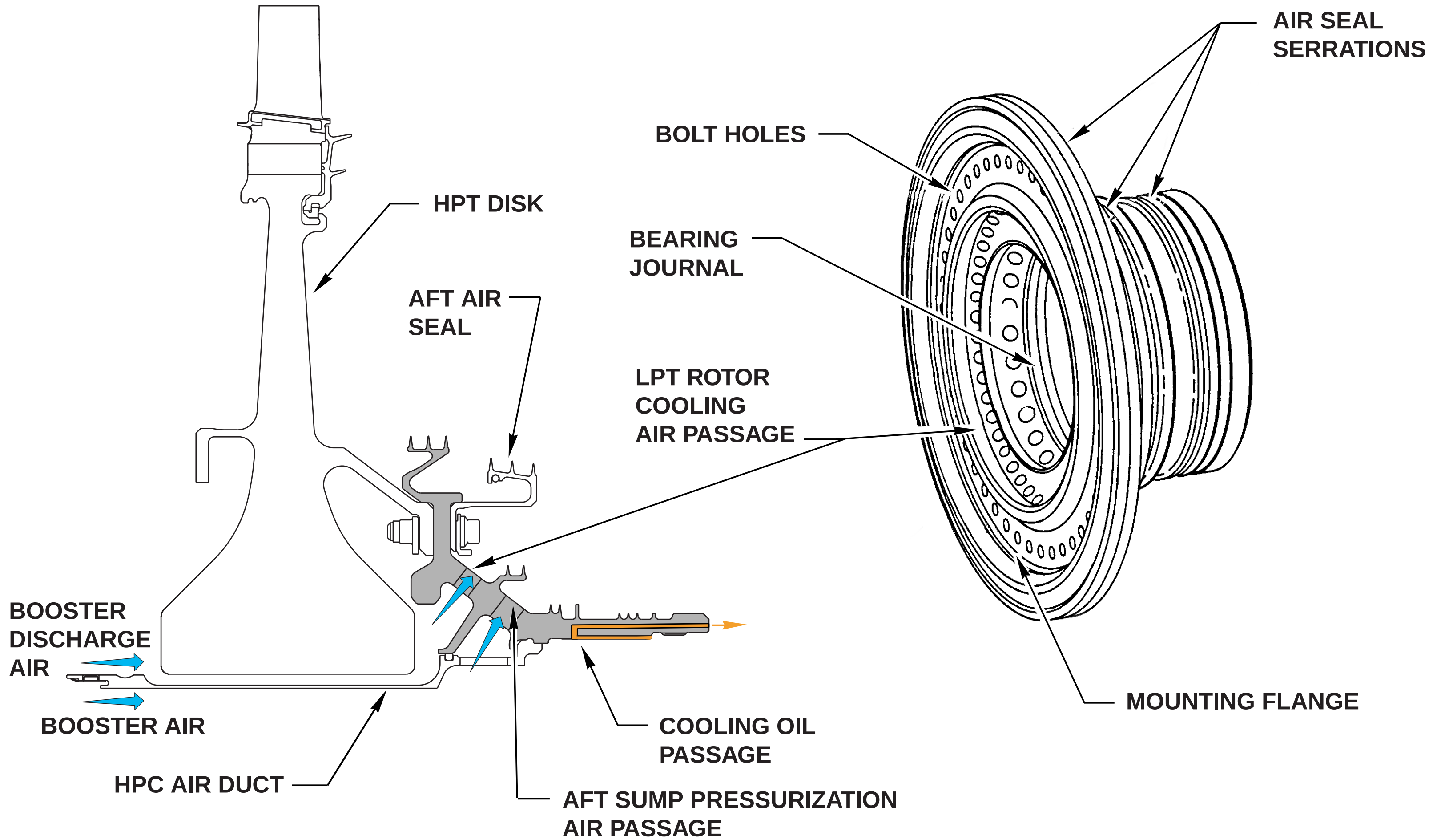
The shaft is supported by the No.4 roller bearing that rides on the low pressure shaft.

An integral 3-tooth seal separates the HPT rotor aft cavity from the LPT forward cavity.

A separate 3-tooth seal is bolted onto the rear shaft flange. It separates the LPT forward cavity cooling air from the aft cavity pressurizing air.

The teeth of both seals are coated with a ceramic material to improve cutting ability into the stationary seal.

Access holes in the conical section of the shaft allow pressurization air to pass to the LPT and rear sump areas.



HP TURBINE REAR SHAFT

CTC-044-074-00

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HIGH PRESSURE TURBINE SHROUD AND STAGE 1 NOZZLE

THE HIGH PRESSURE TURBINE (CONTINUED)

The shroud and stage 1 LPT nozzle

The HPT shroud and stage 1 LPT nozzle assembly forms the connection between the core section and the LPT module of the engine.

It is located inside the aft end of the combustion case and performs 2 main functions :

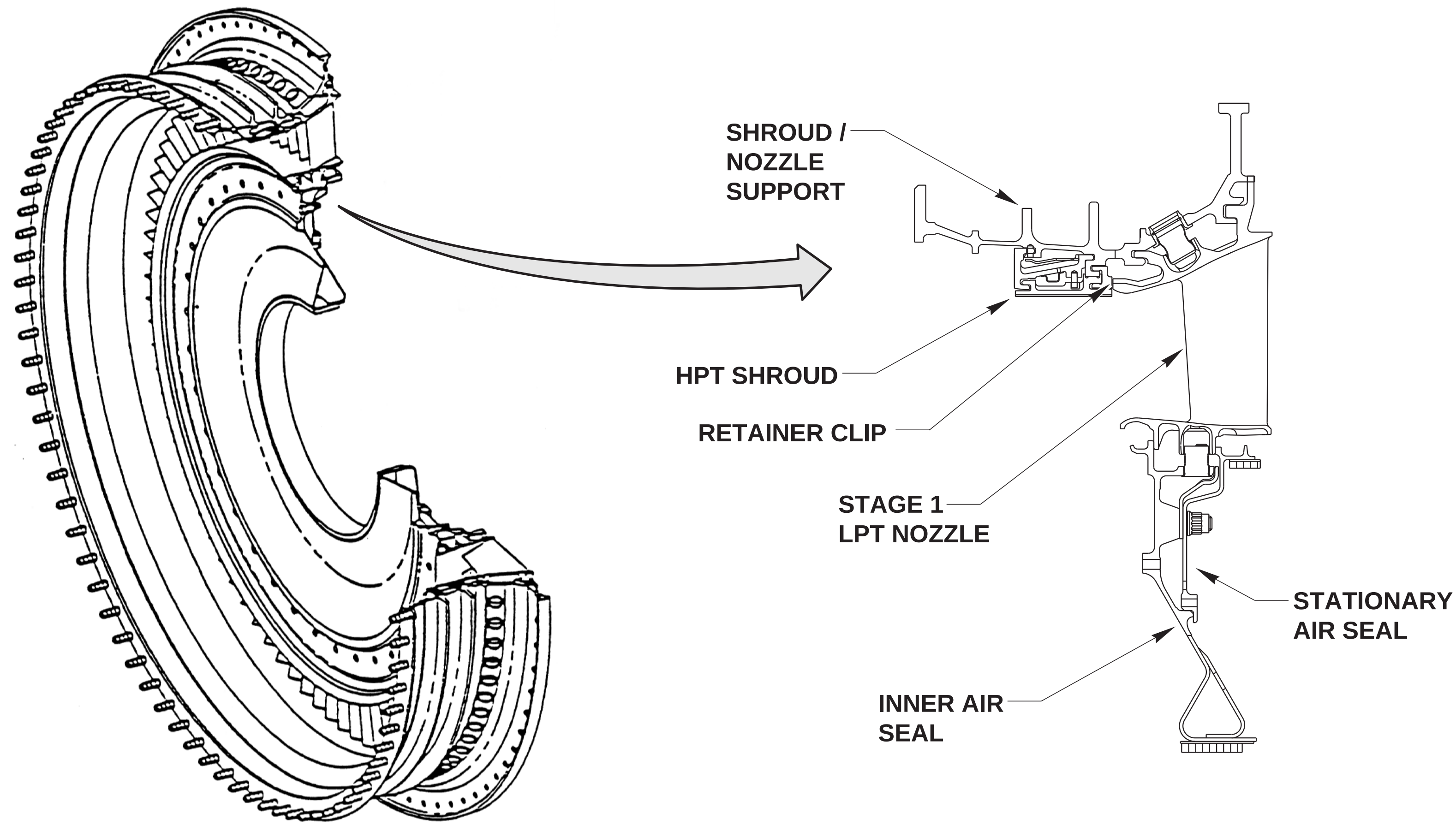
- The HPT shroud is part of the HPT clearance control mechanism and uses HPC bleed air to maintain close clearances with the HPT rotor blades throughout flight operations.
- The stage 1 LPT nozzles direct the core engine exhaust gas onto the stage 1 LPT blades.

The forward flange of the assembly is bolted to the inner surface of the combustion case.

The aft flange is rabbeted and bolted between the combustion case aft flange and the LPT stator forward flange.

The HPT shroud and stage 1 LPT nozzle assembly consists of :

- an air impingement manifold, to circulate 5th and 9th stage bleed air for HPT clearance control.
- shroud/nozzle support.
- HPT shroud hangers & shrouds.
- the stage 1 nozzle.
- the inner and stationary air seals.



CTC-044-075-00

HPT SHROUD AND STAGE 1 NOZZLE ASSEMBLY

THE HIGH PRESSURE TURBINE (CONTINUED)

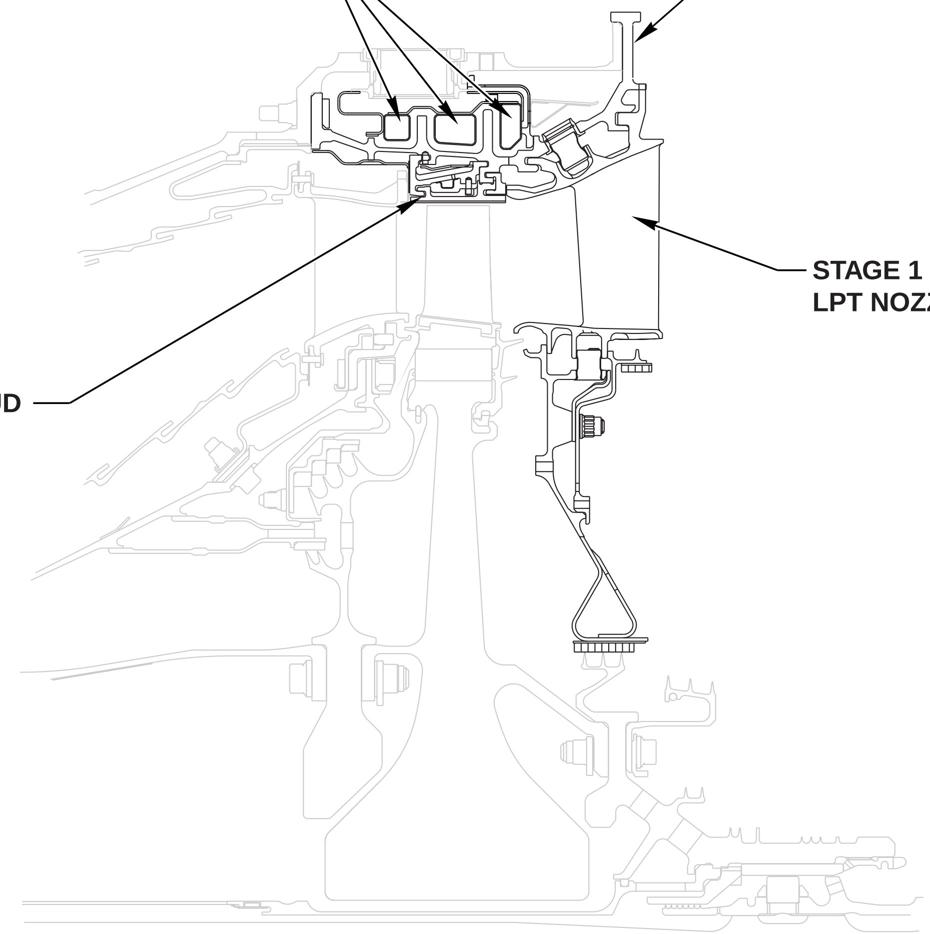
The shroud/nozzle support

The shroud/nozzle support assembly forms the outer shell of the HPT shroud and stage 1 LPT nozzle assembly.

It provides the area for the air impingement manifold on its outer surface and supports the HPT shrouds and the outer platforms of the LPT nozzle segments on its inner surface.

The support's front flange is bolted to the combustion case with slab-head bolts and its rear flange is pinched between the combustion case rear flange and the LPT stator case front flange.

There are borescope ports, at approximately the 5:30 and 8:30 clock positions, to enable inspection of the nozzle area.



CTC-044-076-00

HPT SHROUD AND NOZZLE SUPPORT

THE HIGH PRESSURE TURBINE (CONTINUED)

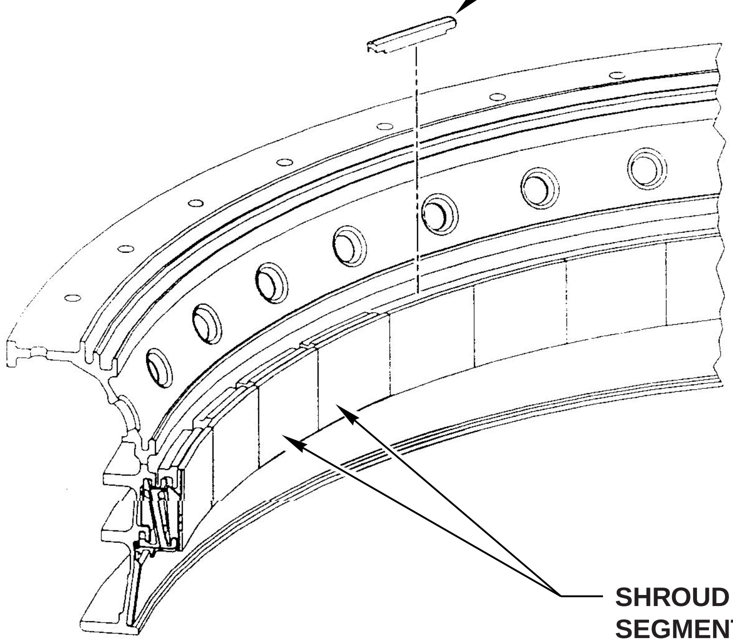
The shrouds

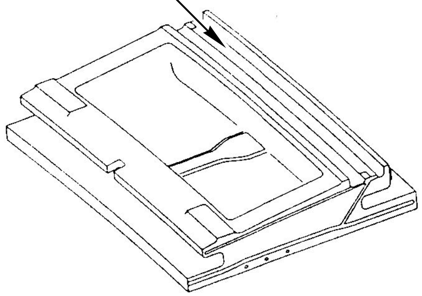
The HPT shrouds have a smooth abradable surface that can endure blade tip rub and prevent erosion from hot exhaust gasses.

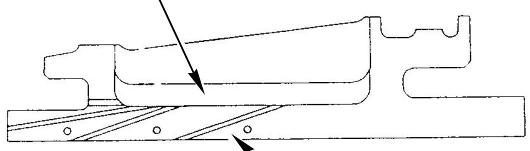
The HPT shroud segments are carried by hangers. The hangers provide a cooling area between the segments and the shroud/nozzle support reducing the risk of damage to the support due to thermal stresses.

Shroud expansion is controlled throughout engine operation to increase HPT efficiency.

CDP air passes between the shroud/nozzle support and the shroud segments for cooling purposes. It exits through holes drilled in the shroud and goes back into the primary flow to the LPT nozzles.







CTC-044-077-00

HP TURBINE SHROUD

THE HIGH PRESSURE TURBINE (CONTINUED)

The Low Pressure Turbine (LPT) nozzle

The LPT nozzle directs high velocity gasses from the HPT rotor onto the blades of the LPT rotor stage 1.

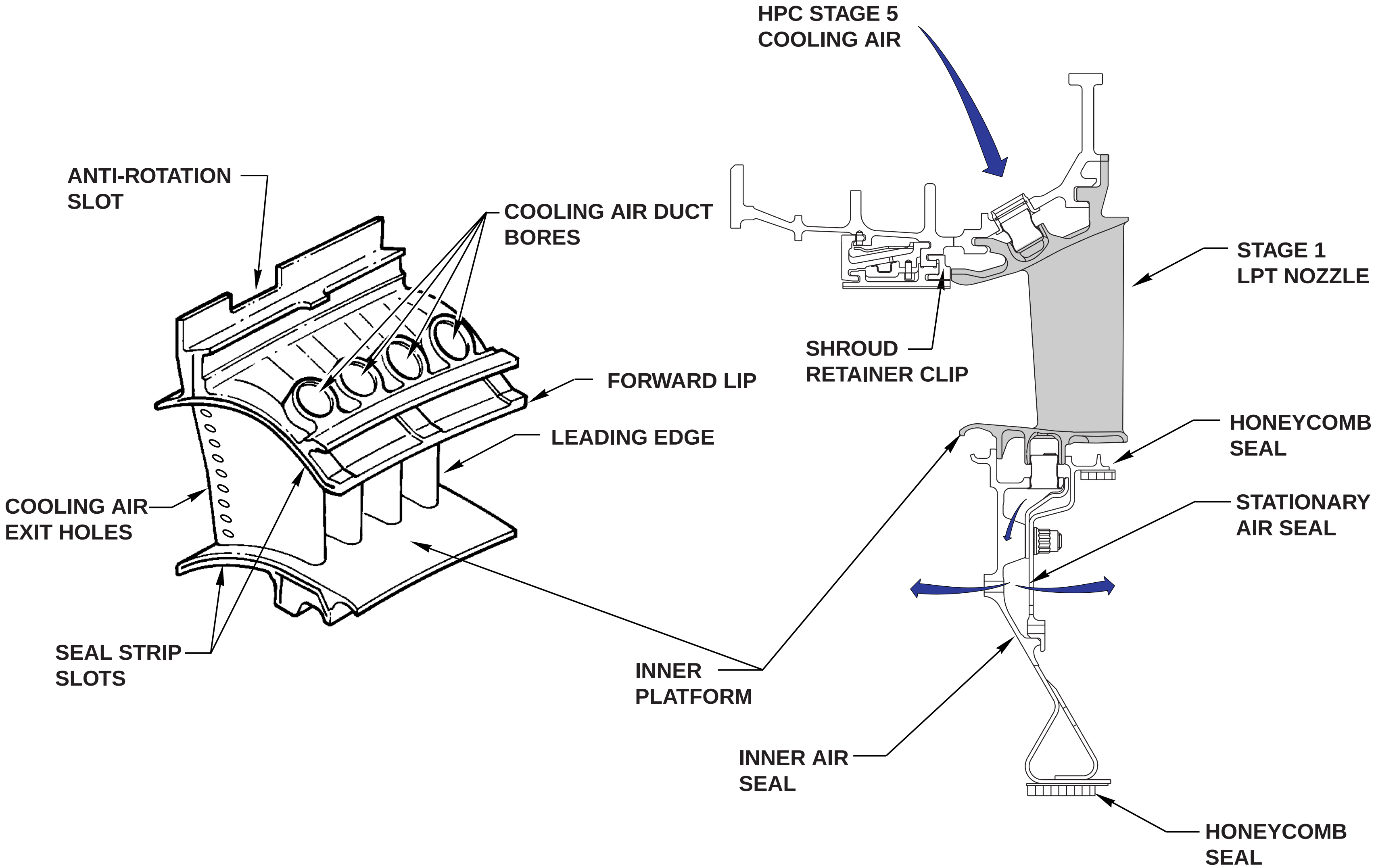
The assembly consists of 28 nozzle segments of 4 vanes each and the nozzle segments outer and inner locating lips are mechanically locked into the shroud/nozzle support.

The forward lip prevents axial movement of the HPT shroud retainer clips.

The inner air seal and the stationary air seal are bolted together and held in place on the inner platforms of the LPT nozzle.

HPC 5th stage cooling air is directed into cooling air duct bores in the nozzle segments and seals are installed between the segments to avoid air leakage.

The cooling air exits through holes in the vane’s trailing edge and through the vane roots and inner seal to cool the HPT disk rear face. The air also passes through the stationary air seal to cool down the LPT rotor.



STAGE 1 LPT NOZZLE SEGMENT

CTC-044-078-00

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LOW PRESSURE TURBINE MAJOR MODULE

LOW PRESSURE TURBINE (LPT) MAJOR MODULE

The purposes of the LPT major module are :

- to transform the pressure and velocity of gasses coming from the High Pressure Turbine (HPT), into mechanical power to drive the fan and booster module.

- to provide a rear support for the HP and LP rotors.

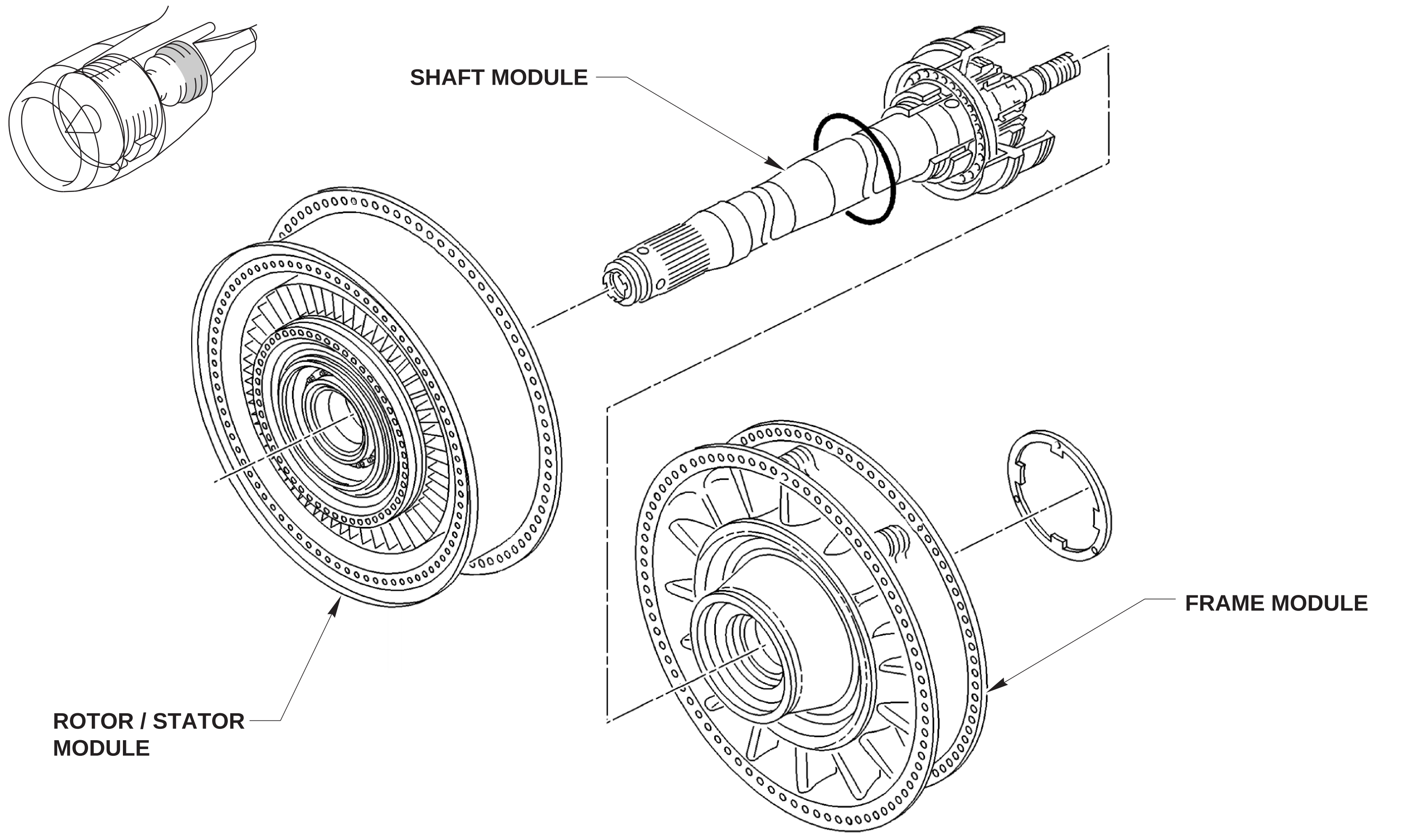
- to provide rear mounts for engine installation on the aircraft.

The LPT major module is located at the rear of the engine, and consists of :

- The LPT rotor/stator module

- The LPT shaft module

- The turbine frame module



LPT MAJOR MODULE

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LPT ROTOR / STATOR MODULE

LPT ROTOR/STATOR MODULE

The purpose of the LPT rotor/stator module is to convert the kinetic energy of gasses coming from the HPT, into mechanical power to drive the fan and booster rotor.

The LPT rotor/stator is located between the HPT and the turbine frame.

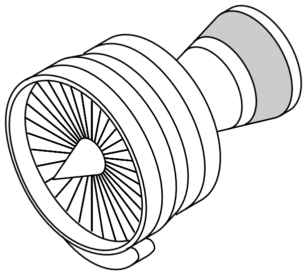
Its front flange is mounted on the rear flange of the combustion module.

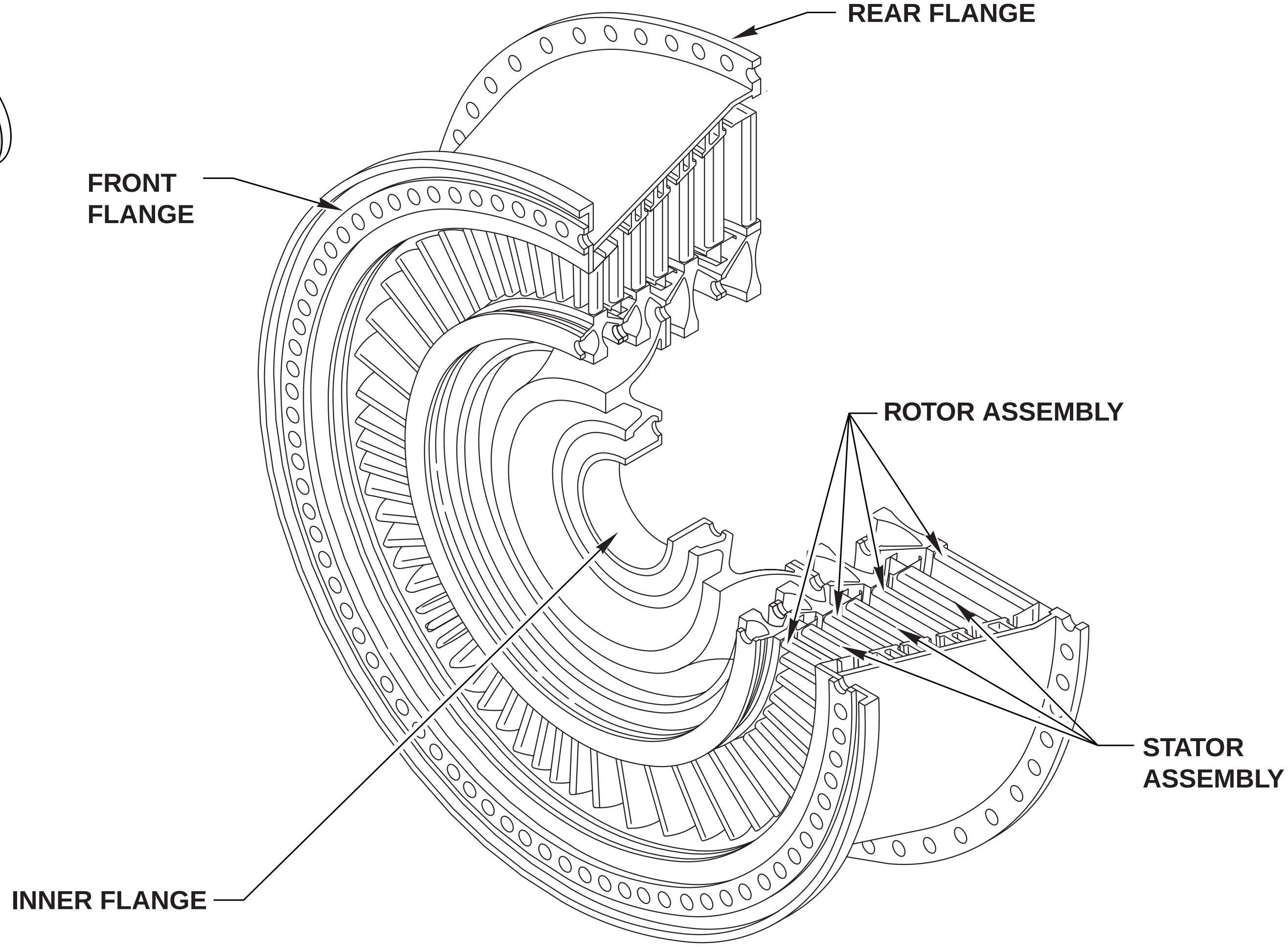
Its rear flange provides attachment for the turbine frame.

Its inner flange is secured onto the LPT shaft.

It is a 4-stage axial flow turbine, and consists of :

- a stator assembly
- a rotor assembly





LPT ROTOR / STATOR MODULE

CTC-044-080-00

LPT STATOR ASSEMBLY

The stator assembly increases the speed of gasses coming from the combustion chamber.

It consists of the following components :

- An air cooling tubes and manifolds assembly

- The LPT case

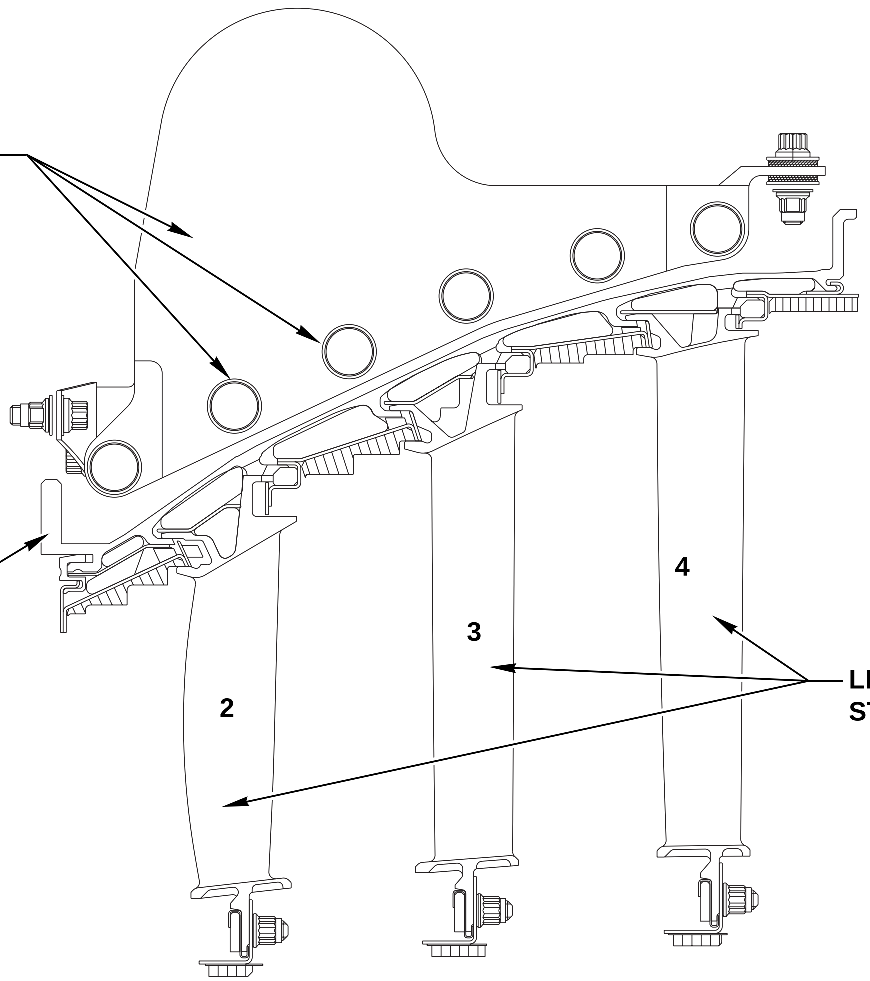
- Stages 2 to 4 nozzle assemblies

<u>Air cooling tubes and manifolds assembly</u>

The purpose of the air cooling tubes and manifolds assembly is to blow cooling air onto the outer surface of the LPT case, for rotor clearance control.

It is installed on supports, held by brackets located around the LPT case, and consists of 6 tubes which surround the case.

Fan discharge air is ducted to the tubes, which have holes drilled in them to direct cooling air onto the outer case.



CTC-044-081-00

LPT STATOR ASSEMBLY

LPT STATOR ASSEMBLY (CONTINUED)

LPT case

The LPT case provides support for the stator assembly and is made of nickel-chrome alloy.

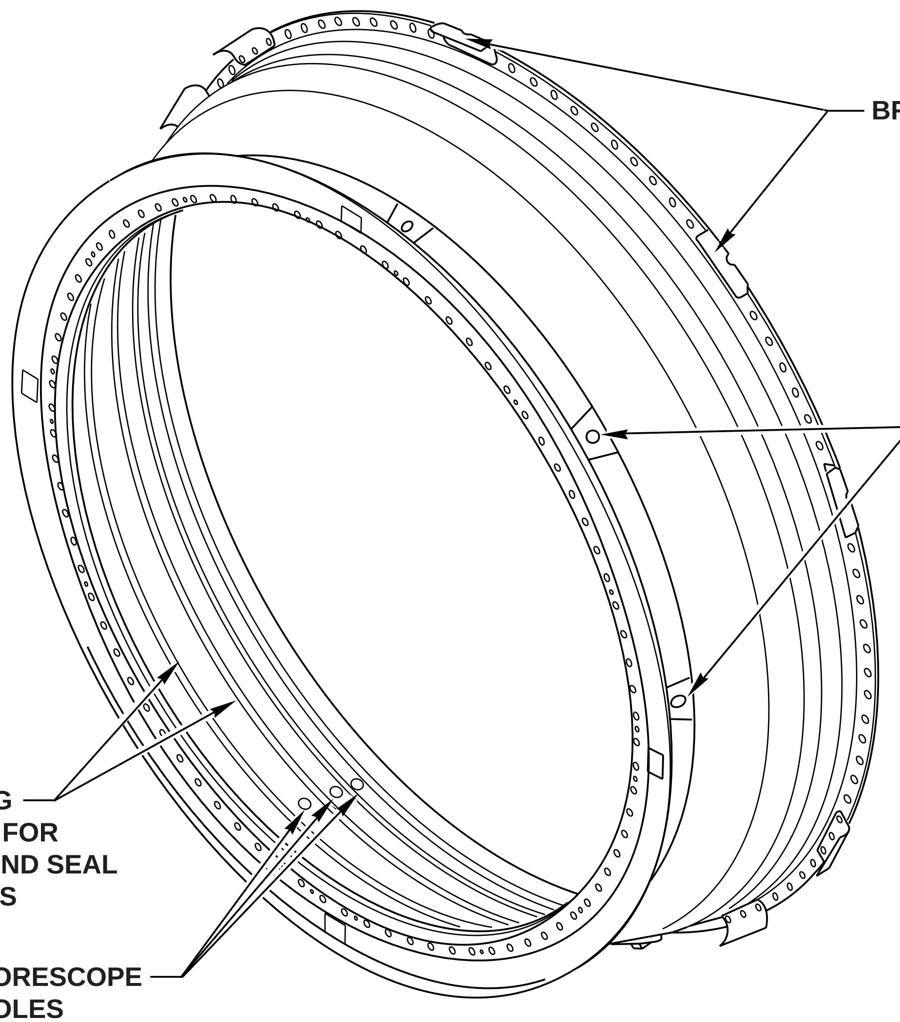
Its front flange is bolted to the rear flange of the combustion case, through the HPT shroud/nozzle support flange (also called T-flange).

Its rear flange provides attachment for the outer front flange of the turbine frame.

The outer surface of the LPT case is fitted with angle brackets to hold air cooling tube supports and cooling manifolds.

It also has 9 thermocouple mounting pads for EGT measurement, and 3 borescope ports at the 5 o'clock position.

The inner surface of the LPT case houses thermal insulation blankets and also has flanges for the installation of nozzle and seal segments.



LPT CASE

CTC-044-082-00

STATOR ASSEMBLY (CONTINUED)

Stages 2 to 4 nozzles

The purpose of the LPT stages 2 to 4 nozzles is to increase the speed of the air coming from the HPT, and to direct it onto the LPT rotor assembly.

Each nozzle stage is made up of segments. The number of segments and the number of vanes in each segment vary from stage to stage.

The segments are installed on the flanges inside the LPT case and their retention is obtained through a stacking system, which is basically the same for all stages.

Three sectors of insulation blankets are installed between the case and the nozzle. The insulation blanket sectors are held in position by a pre-loaded ring.

The segments inner platforms are retained by the inner stationary air seal.

Nine vanes of the stage 2 nozzle accommodate EGT thermocouples that are inserted through the LPT case.

Inner stationary air seal.

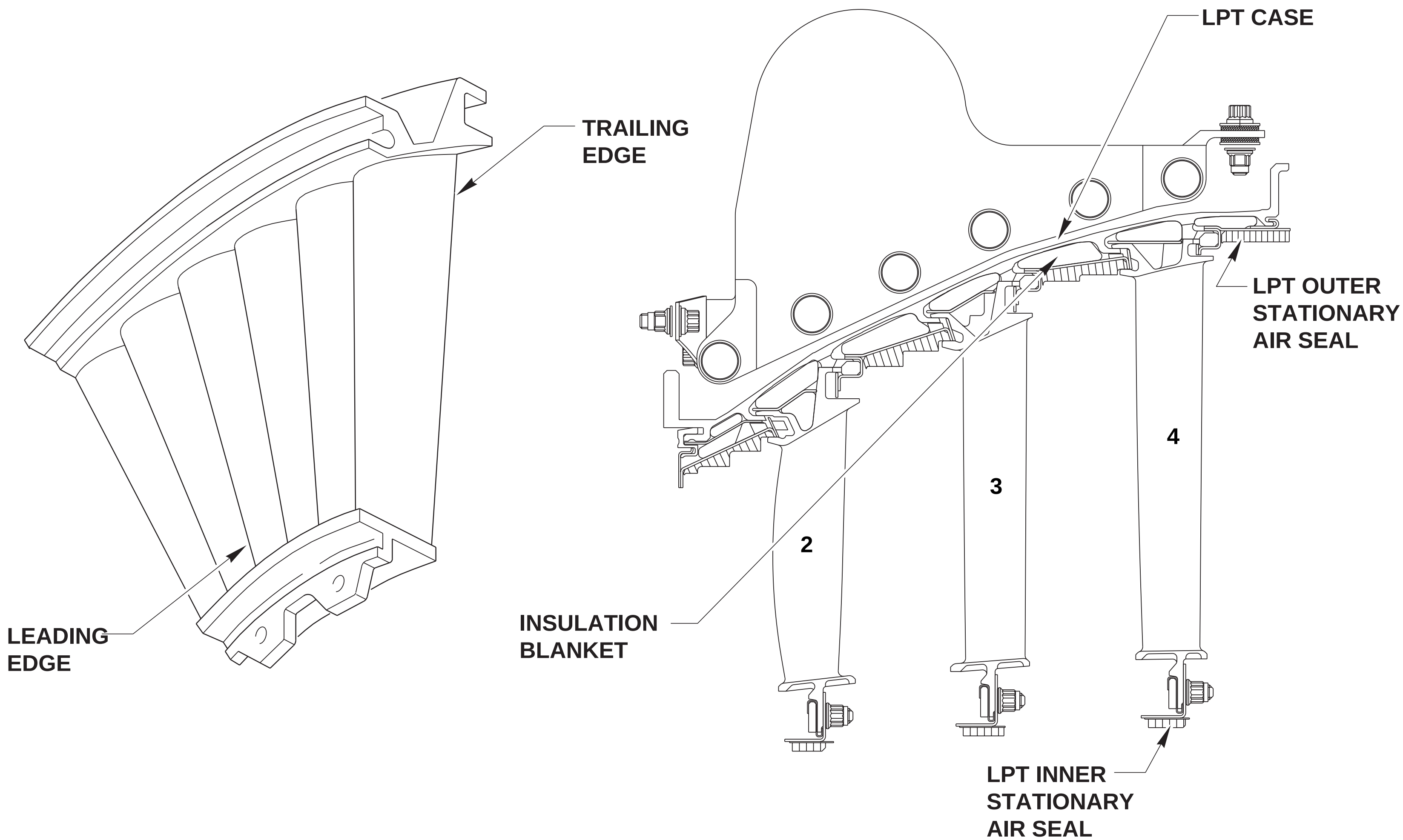
The inner stationary air seal of each nozzle stage consists of a ring of honeycomb abradable brazed on a support.

Each ring is made in several segments secured by screws on the nozzle inner platform. The seals match the teeth of the rotating labyrinth.

Outer stationary air seal.

The outer stationary air seal consists of honeycomb rings brazed on a support and divided into segments. The outer seal is positioned between two consecutive nozzle stages and faces the LPT rotor blades.

Each segment forward end engages into a recess in the LPT case and features a lug, locked into a matching slot.



STAGES 2 TO 4 NOZZLES

CTC-044-083-00

ROTOR ASSEMBLY

The rotor assembly is housed inside the LPT case and has four stages.

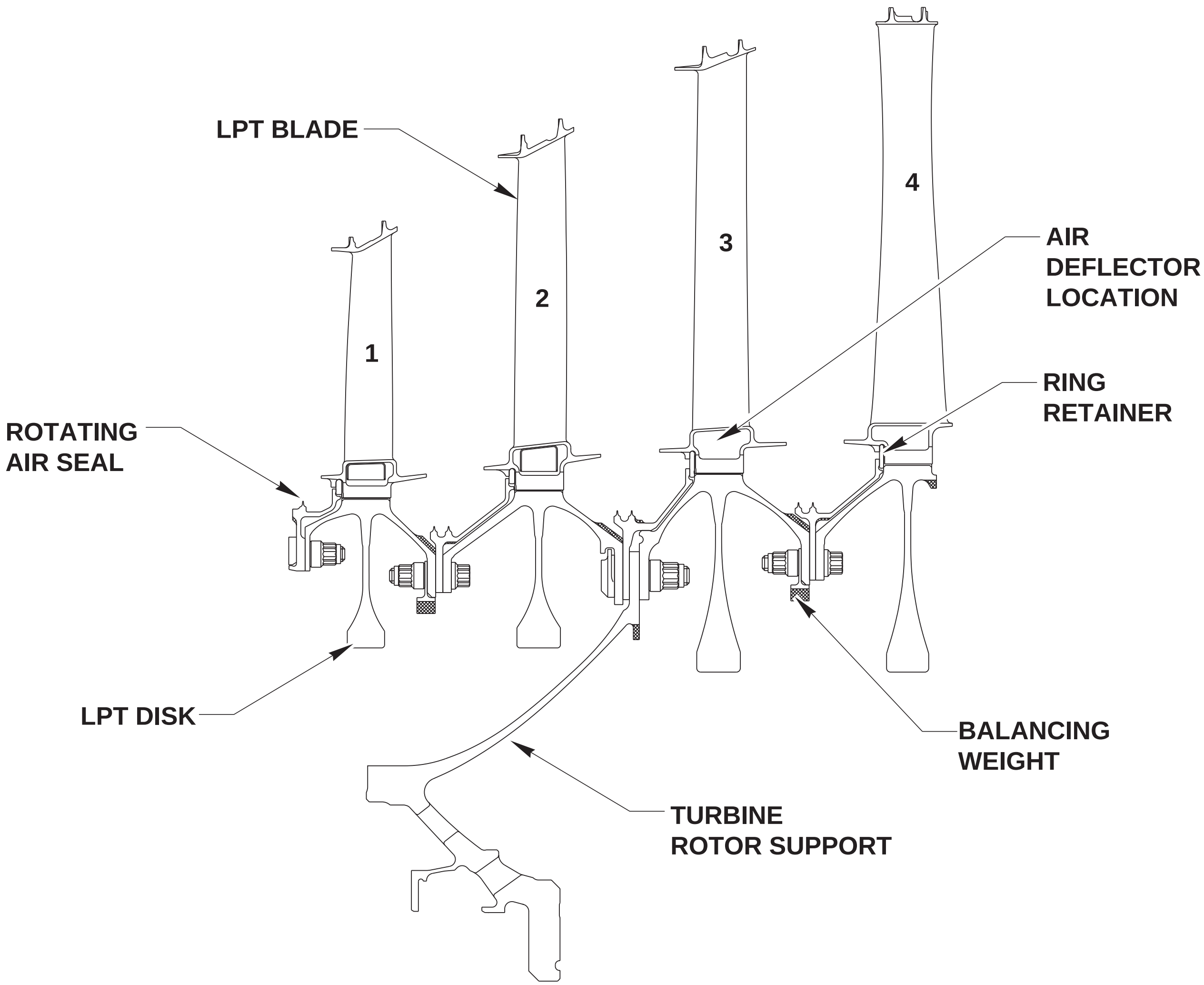
It consists of the following components :

- Stages 1 to 4 disks

- Stages 1 to 4 rotating air seals

- Stages 1 to 4 blades

- A rotor support



LPT ROTOR ASSEMBLY

CTC-044-084-00

ROTOR ASSEMBLY (CONTINUED)

Stage 1 to 4 disks

The disks are made of nickel alloy.

Their outer rims have machined dovetail slots in which the rotor blades are installed. The number of slots varies between stages.

Their front flanges have bolt holes for the installation of rotating air seals.

Except for stage 4, their rear flanges have bolt holes for the installation of the next stage disk together with its rotating air seal.

Stage 1 to 4 rotating air seals

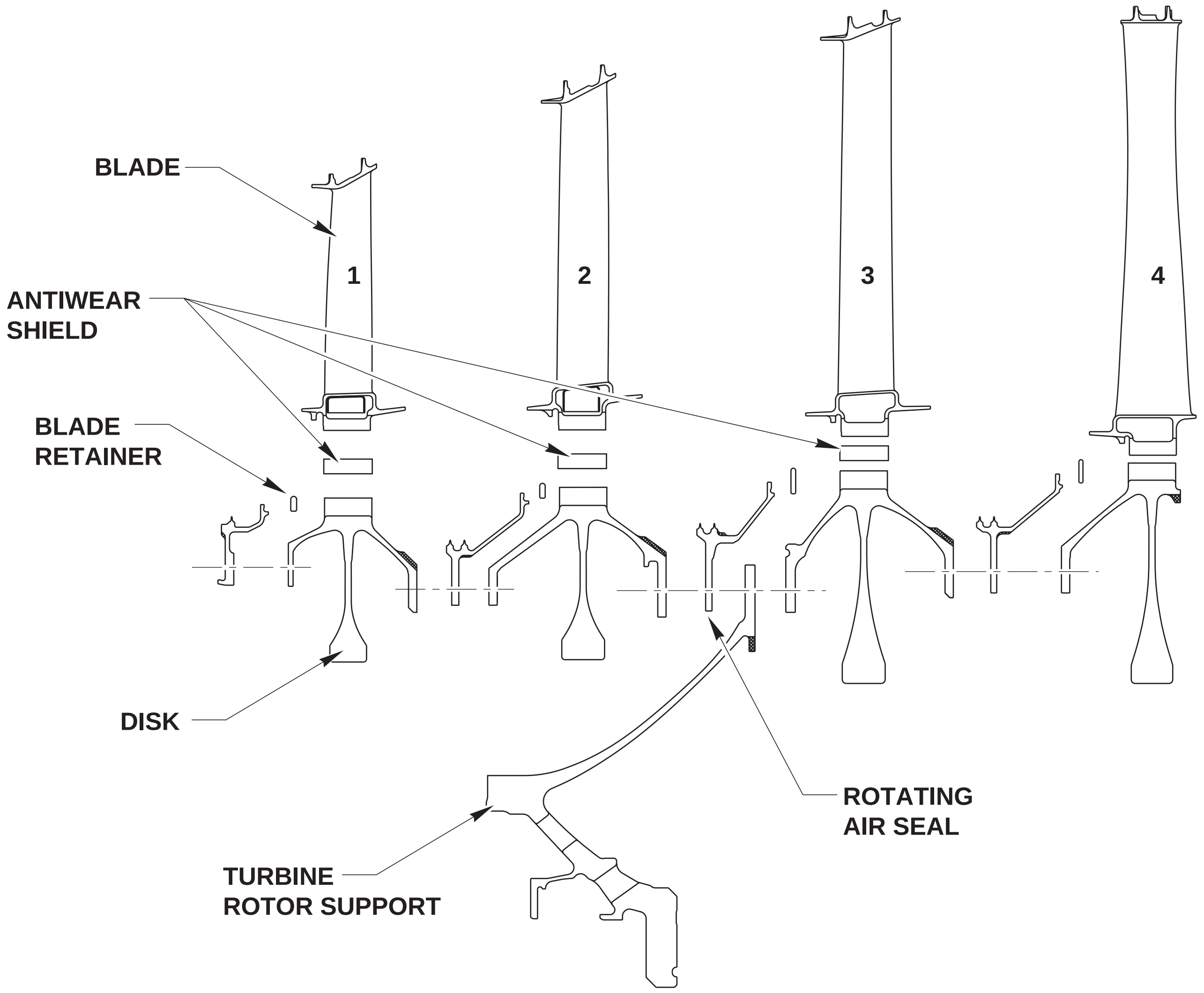
The purpose of the rotating air seals is to control the airflow between the LPT nozzles and the rotor.

They are made of nickel alloy.

The seals are sandwich-mounted between stages 1 to 4 disks, through holes located on their inner front flange, which, except for stage 4, has machined slots to allow the passage of cooling air to the blade roots.

They have seal teeth, one on stage 1, two on stages 2, 3 and 4, that rub against the abradable liner of the inner stationary air seal on the inner platform of the nozzle segments.

The rear face of the seals' outer flange mates with a retainer ring, which holds the blades in their axial position in the disk slots.



CTC-044-085-00

LOW PRESSURE TURBINE ROTOR ASSEMBLY

ROTOR ASSEMBLY (CONTINUED)

Stage 1 to 4 blades

The four stages of the LPT rotor have tip-shrouded blades made of nickel alloy.

On stages 1 and 2 only, the blade airfoil is protected against oxidation by a vapor-phase aluminization treatment.

The number of blades varies between stages :

- Stage 1 has 162 blades
- Stage 2 has 150 blades
- Stage 3 has 150 blades
- Stage 4 has 134 blades

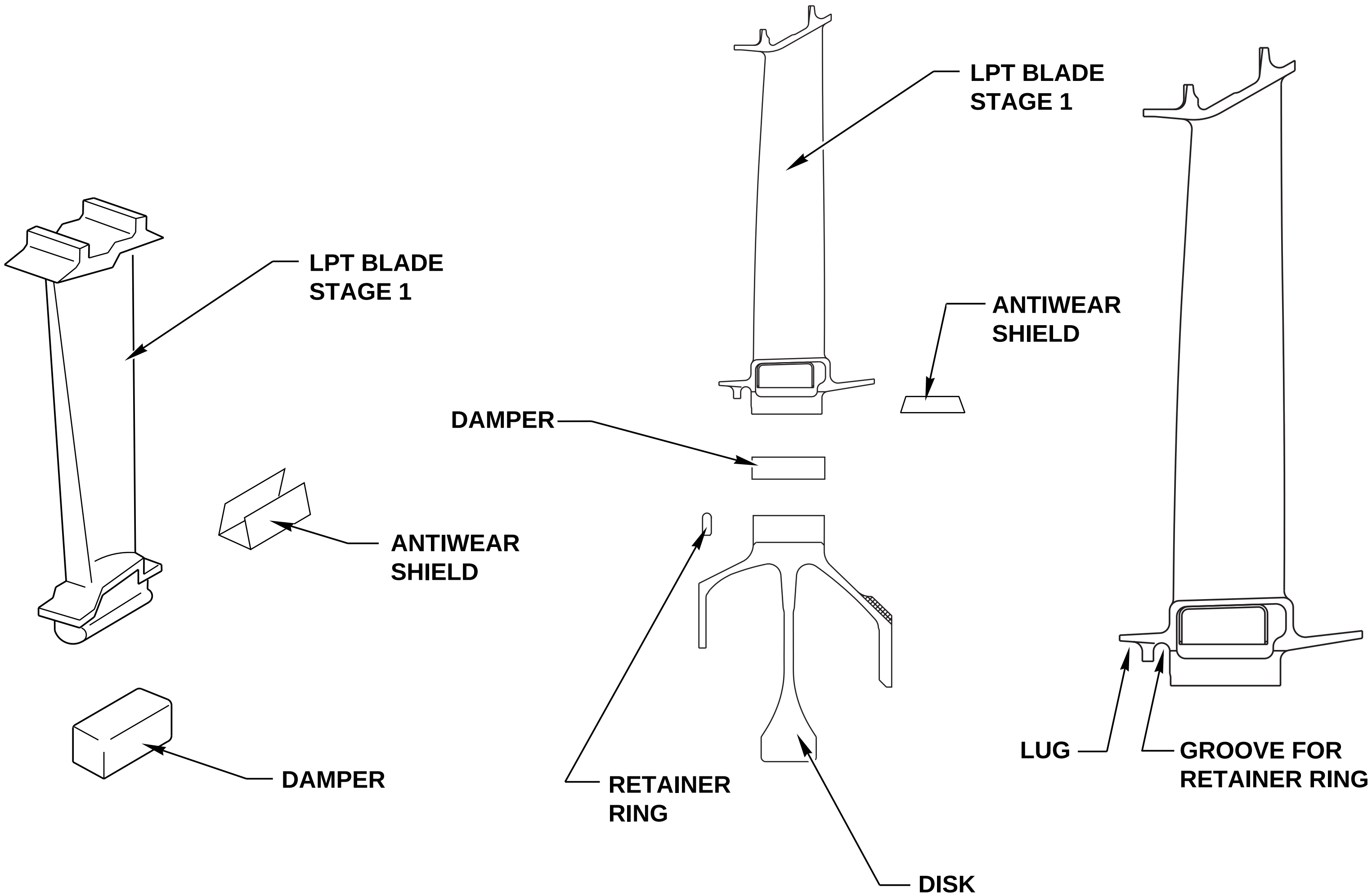
On each stage, 3 of the blades have a hard coating on their tips, to rub against the honeycomb material of the stator seal segments.

Each blade has a dovetail root that slides into dovetail slots on the disk outer rim.

On stages 1, 2 and 3 only, antiwear shields are crimped on the blade roots before installation on the disk, and dampers are installed between each blade, under the blade inner platforms. Stage 4 blades do not have shields or dampers.

A lug is machined on the front of the inner platform of each blade. When all blades are installed side by side on a disk, these lugs form a groove in which a blade retainer ring is inserted, to prevent axial movement of the blades.

The blade retainer ring is held in position by the rotating air seal bolted to the front flange of the disk.



CTC-044-086-00

STAGE 1 TO 4 BLADES

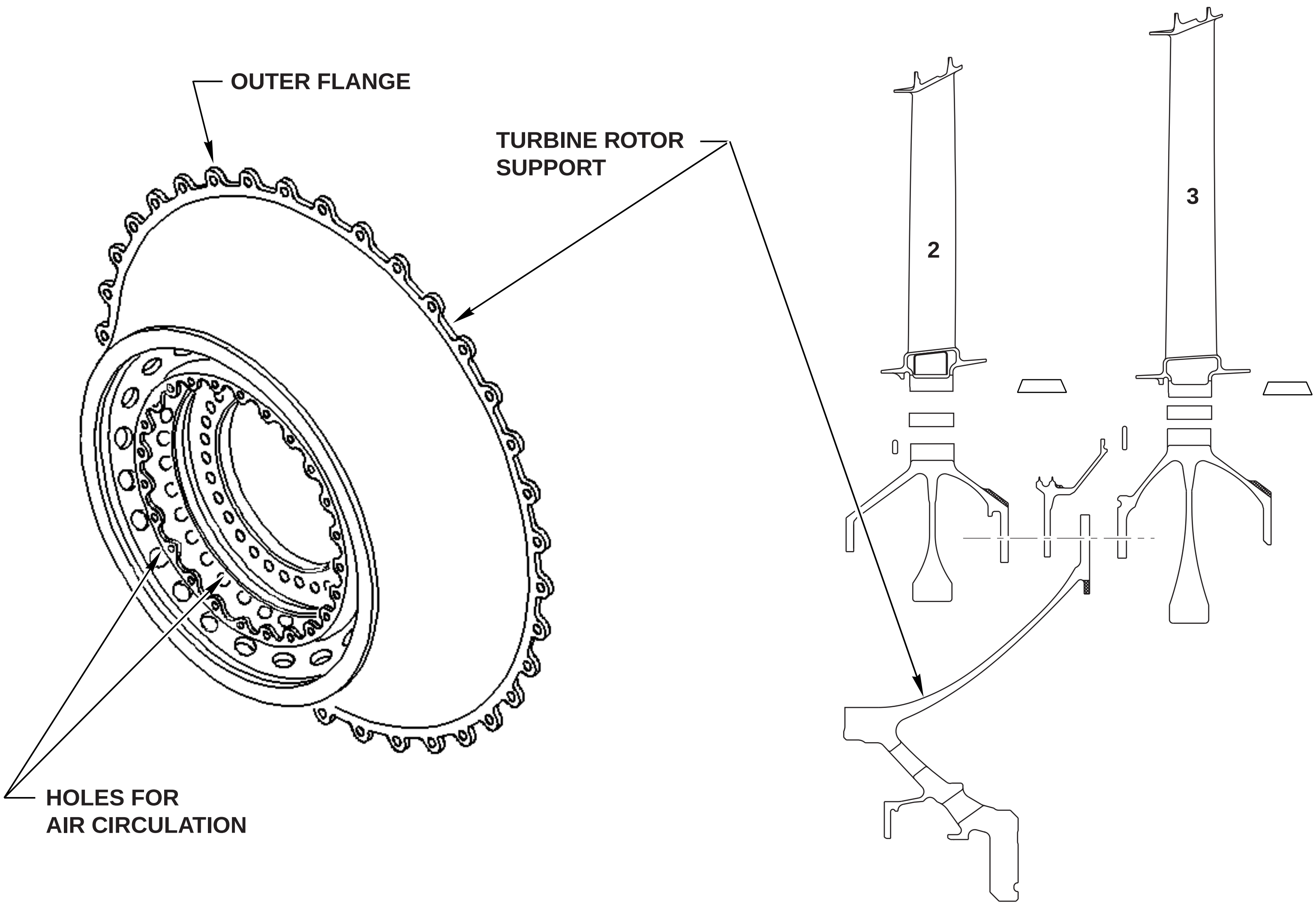
ROTOR ASSEMBLY (CONTINUED)

Rotor support

The rotor support gives structural strength to the rotor assembly, and provides a mechanical connection between the assembled disks and the LPT shaft. It also divides the rotor enclosure into two separate cavities.

It is made of nickel alloy, and has holes for the circulation of cooling and pressurizing air.

The outer flange of the rotor support is sandwich-mounted between the stage 3 rotating air seal and the front flange of the stage 3 disk.



TURBINE ROTOR SUPPORT

CTC-044-087-00

ROTOR ASSEMBLY (CONTINUED)

Rotor support (Continued)

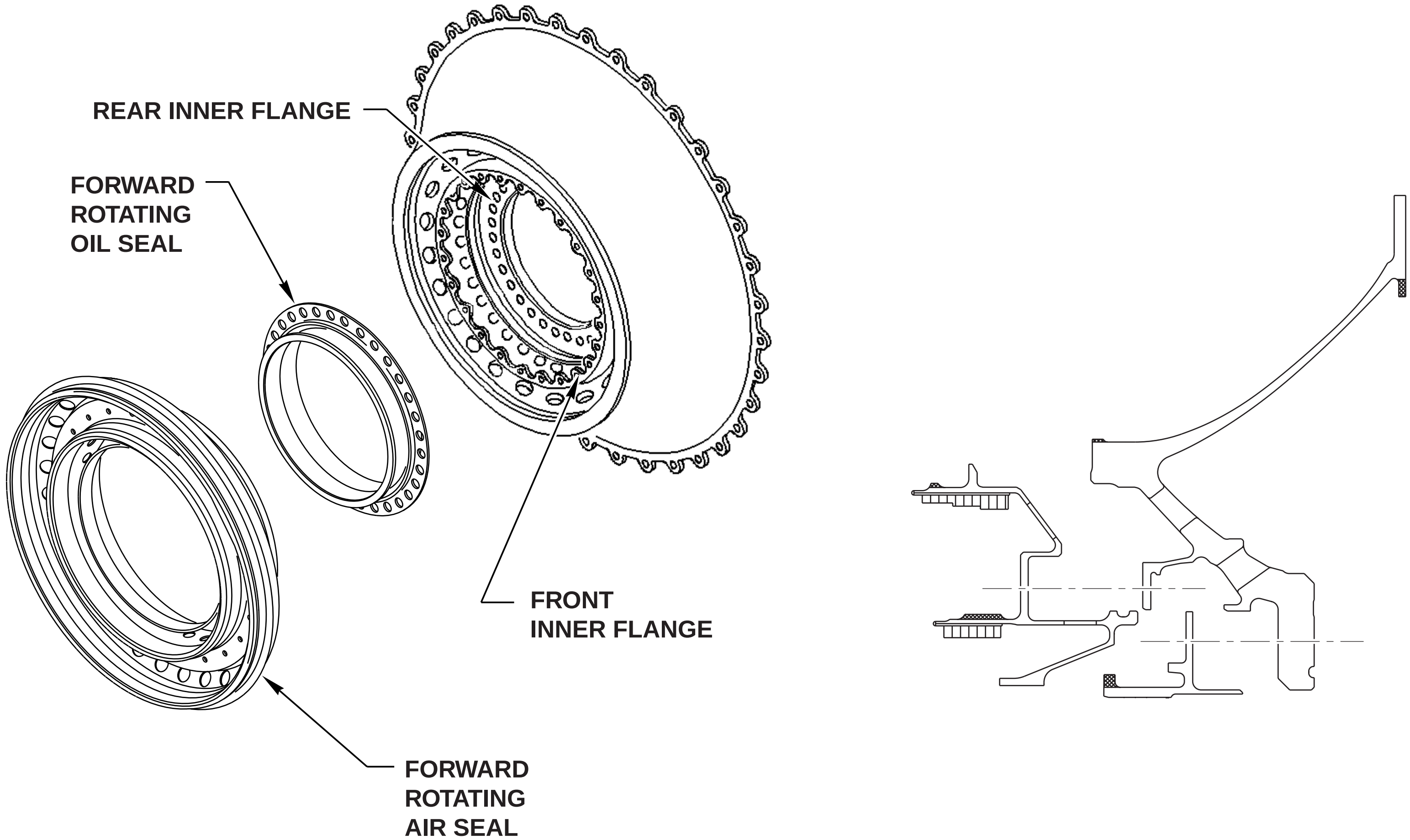
Before it is installed between the stage 3 rotating air seal and the stage 3 disk, the rotor support is equipped with the following components :

- A forward rotating oil seal
- A forward rotating air seal

The forward rotating oil seal is installed on the front face of the support's rear inner flange.

The forward rotating air seal is installed on the front face of the support's front inner flange.

After the rotor support is equipped with these components, its rear inner flange is bolted onto the front face of the LPT shaft hub, making the mechanical connection between the assembled disks and the LPT shaft.



CTC-044-088-00

TURBINE ROTOR SUPPORT

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THE LPT SHAFT MODULE

THE LPT SHAFT MODULE

The LPT shaft module transmits power from the LP turbine to the fan and booster module. Through the No.4 bearing, it also takes up the radial load of the aft of the HP rotor and, through the No.5 bearing, the radial load of the aft of the LP rotor.

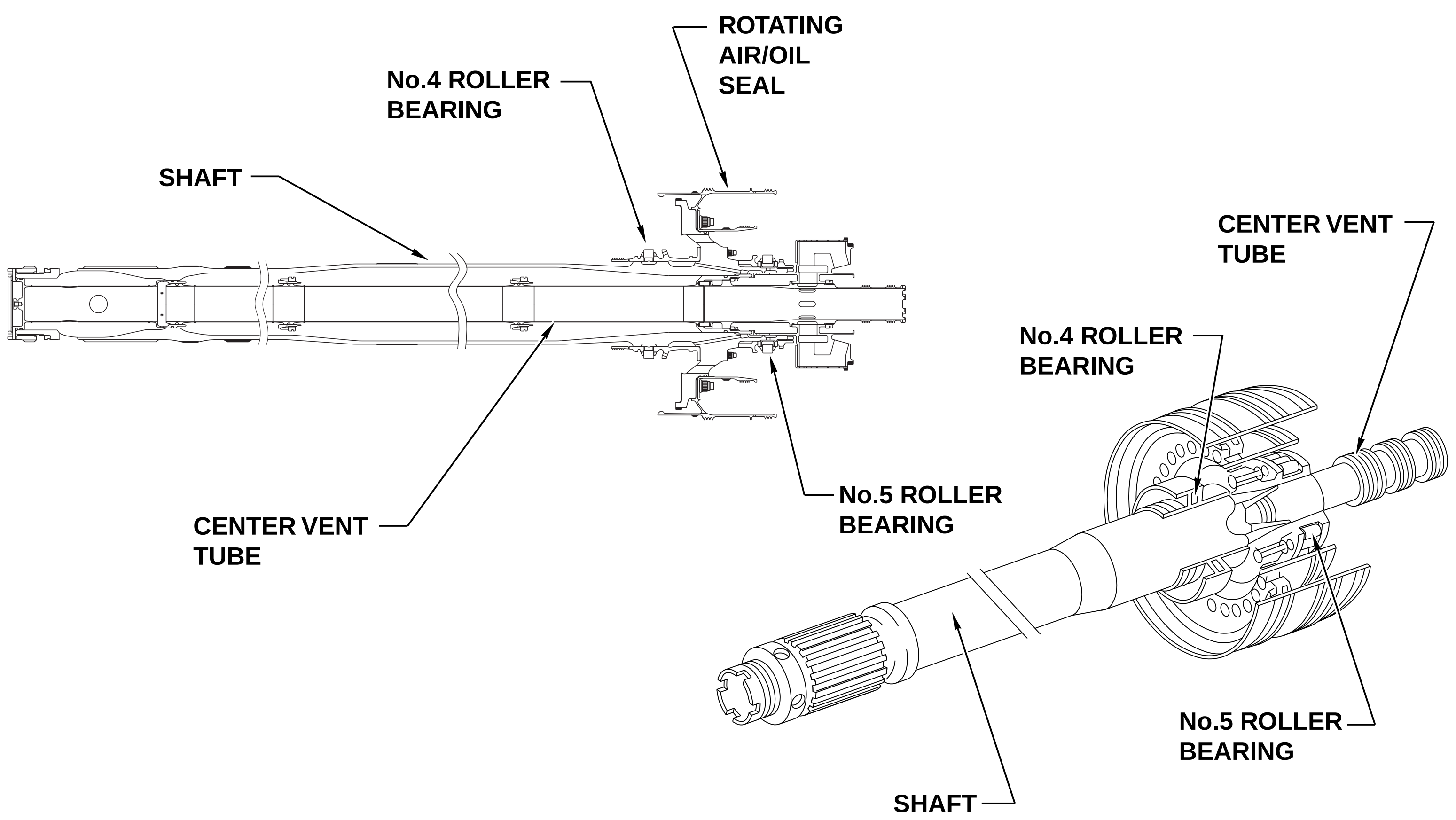
It is located concentrically inside the high pressure rotor system, and connects the fan shaft with the LPT rotor.

It provides support for the rear of the LPT rotor through the No.5 bearing, which holds the LPT rotor inside the turbine frame.

It also vents the engine forward and aft sumps, through the center vent tube.

The LPT shaft module consists of the following components :

- The LPT shaft
- A center vent tube
- The No.4 roller bearing
- The No. 5 roller bearing



CTC-044-089-00

LPT SHAFT ASSEMBLY

THE LPT SHAFT MODULE (CONTINUED)

LPT shaft

The LPT shaft is made of steel alloy, and transmits torque from the LP turbine to the fan and booster module.

It is installed concentrically inside the HP rotor system.

The forward end of the LPT shaft has outer splines that engage into inner splines on the fan shaft. It also has a shoulder that is secured against a mating shoulder in the fan shaft, by the installation of a coupling nut. The shoulder and the coupling nut provide axial retention of the LPT shaft.

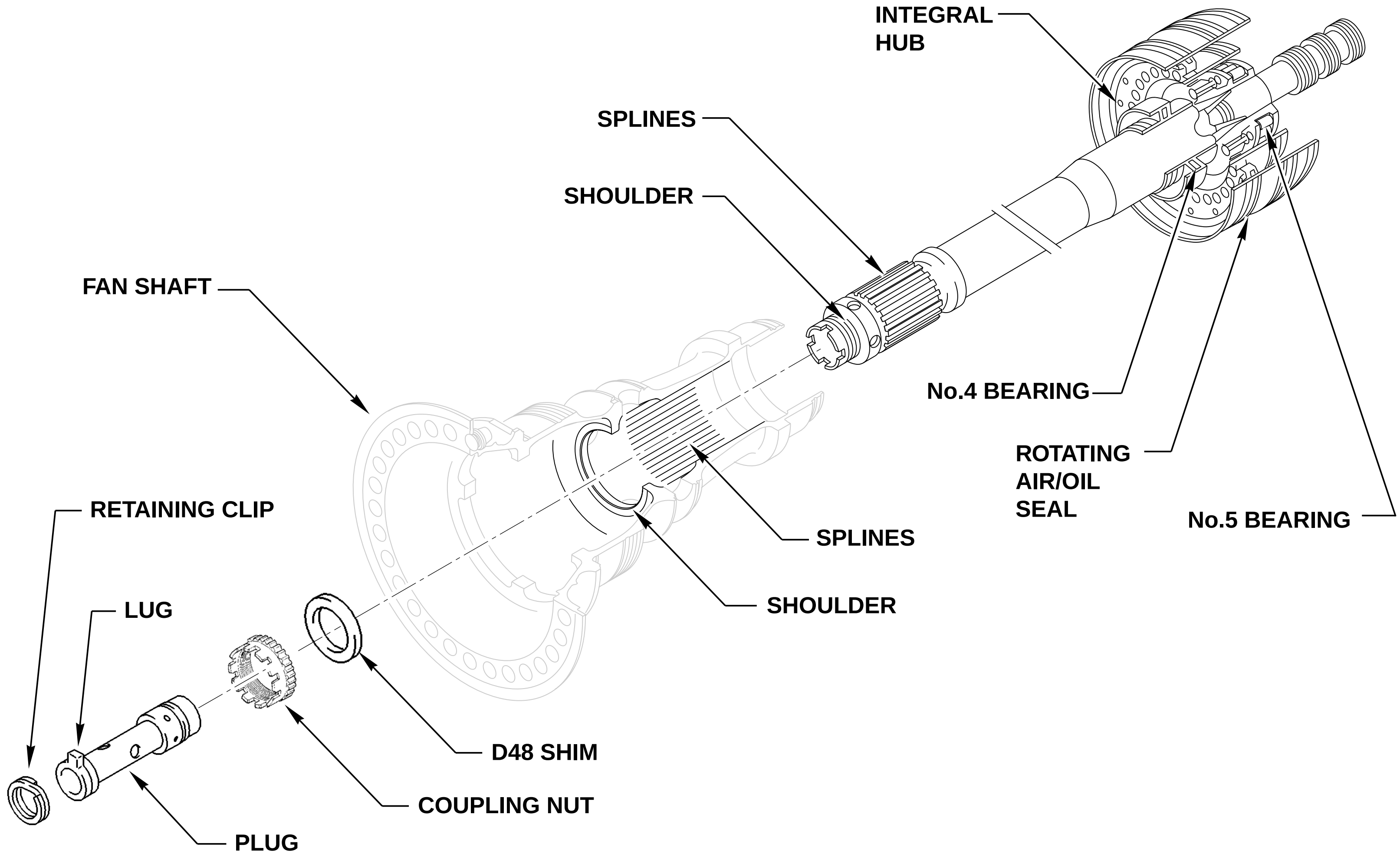
A machined shim, called D48, is installed between the shaft shoulder and the coupling nut, to adjust the position of the LPT.

The forward end of the LPT shaft is closed by a plug, locked in position by a retaining clip. The plug has an anti-rotation lug that engages into a slot on the coupling nut.

The No.4 and No. 5 bearings are installed at the aft end of the shaft, on each side of an integral hub.

The front face of the hub accommodates the turbine rotor support.

The rear face of the hub holds a rotating air/oil seal, which controls air circulation through the LPT rotor and sump pressurization through a set of seal teeth that mate with the oil collector and the No. 5 bearing support located inside the turbine rear frame.



LPT SHAFT

CTC-044-090-00

THE LPT SHAFT MODULE (CONTINUED)

Center vent tube

The center vent tube provides overboard venting for the engine forward and rear sumps.

It is made of titanium alloy, and is installed concentrically inside the LPT shaft. It comes in two parts, the center vent tube and a rear extension duct.

The forward end of the center vent tube is inserted through the rear of the LPT shaft. It is held inside the shaft by means of two expandable-type supports that fit around two locating diameters.

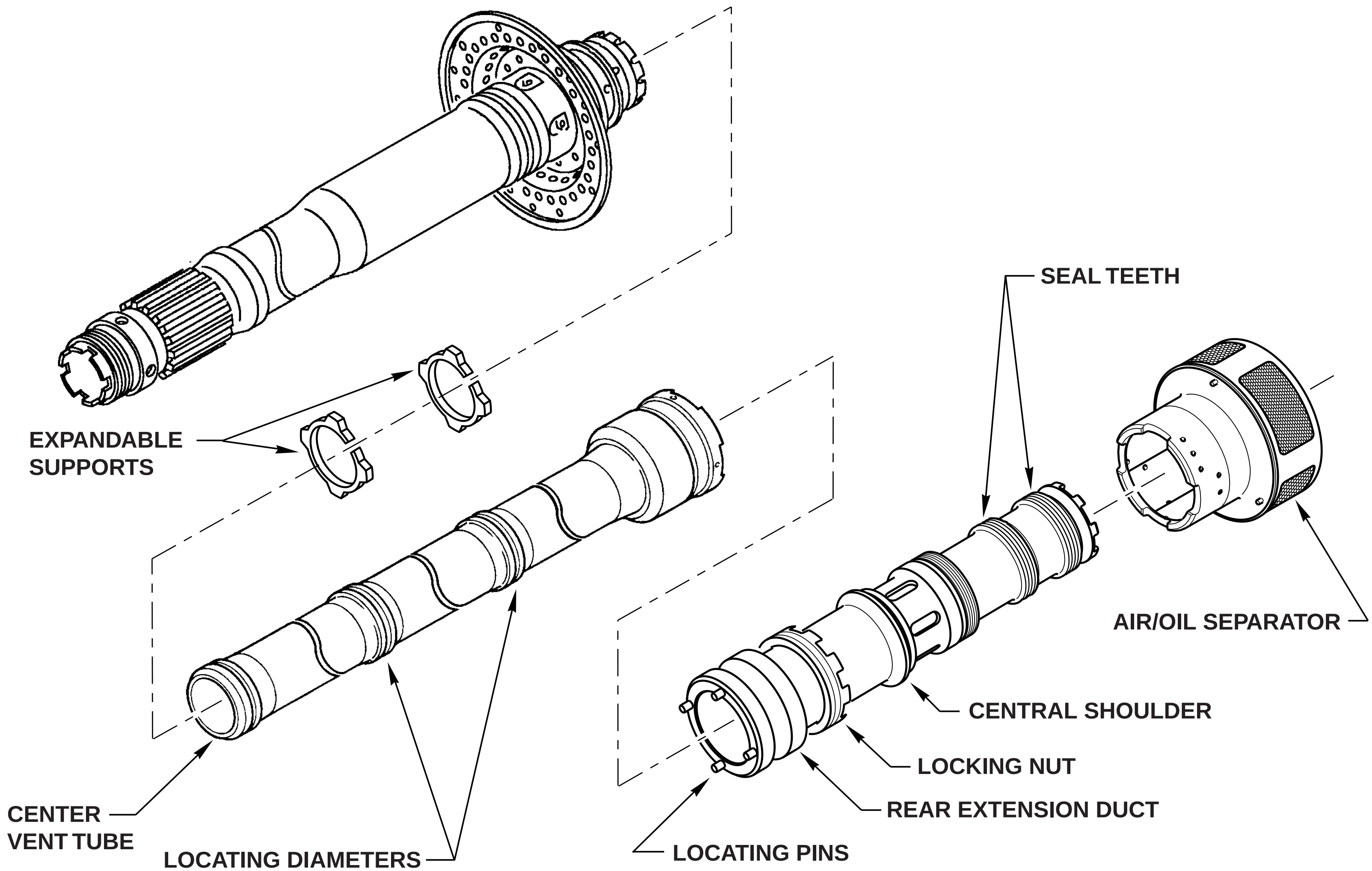
The aft end of the center vent tube is supported by the LPT shaft hub.

The forward end of the rear extension duct fits inside the aft end of the center vent tube. A locking nut with outer threads is installed on it before it is inserted in the center vent tube. The nut is threaded into the center vent tube and gives axial retention of the rear extension duct. Locating pins keep its angular position.

A centrifugal air/oil separator is installed at the rear of the extension duct. It separates the vaporized oil from the aft sump pressurization air, and sends lubrication oil to the No.4 and No. 5 bearings.

The air/oil separator is installed against the central shoulder of the rear extension duct. It has an internal flange that is held against the duct shoulder by a nut. The angular position of the separator is held by slots on its forward end, that engage onto the rear of the center vent tube.

The rear end of the extension duct has two sets of seal teeth that rub against an abradable coating, located inside the oil inlet cover of the turbine frame.



CENTER VENT TUBE

CTC-044-091-00

THE LPT SHAFT MODULE (CONTINUED)

No.4 bearing

The No.4 bearing takes up the radial loads generated by the High Pressure Turbine rotor.

It is a roller bearing, installed between the HPT rear shaft and the LPT shaft, at the front of the LPT shaft hub.

The bearing outer race is housed in the HPT rear shaft bore and its inner race is bolted to the front face of the LPT shaft integral hub.

The No 4 bearing inner race has a shoulder, which acts as an emergency bearing in case of roller failure.

The forward end of the inner race has seal teeth that rub against an abradable coating located on the No.4 bearing forward rotating oil seal, thus acting as one of the sump air/oil seals.

No.5 bearing

The No.5 bearing holds the aft end of the LPT rotor inside the turbine frame, and takes up the radial loads generated by the LPT.

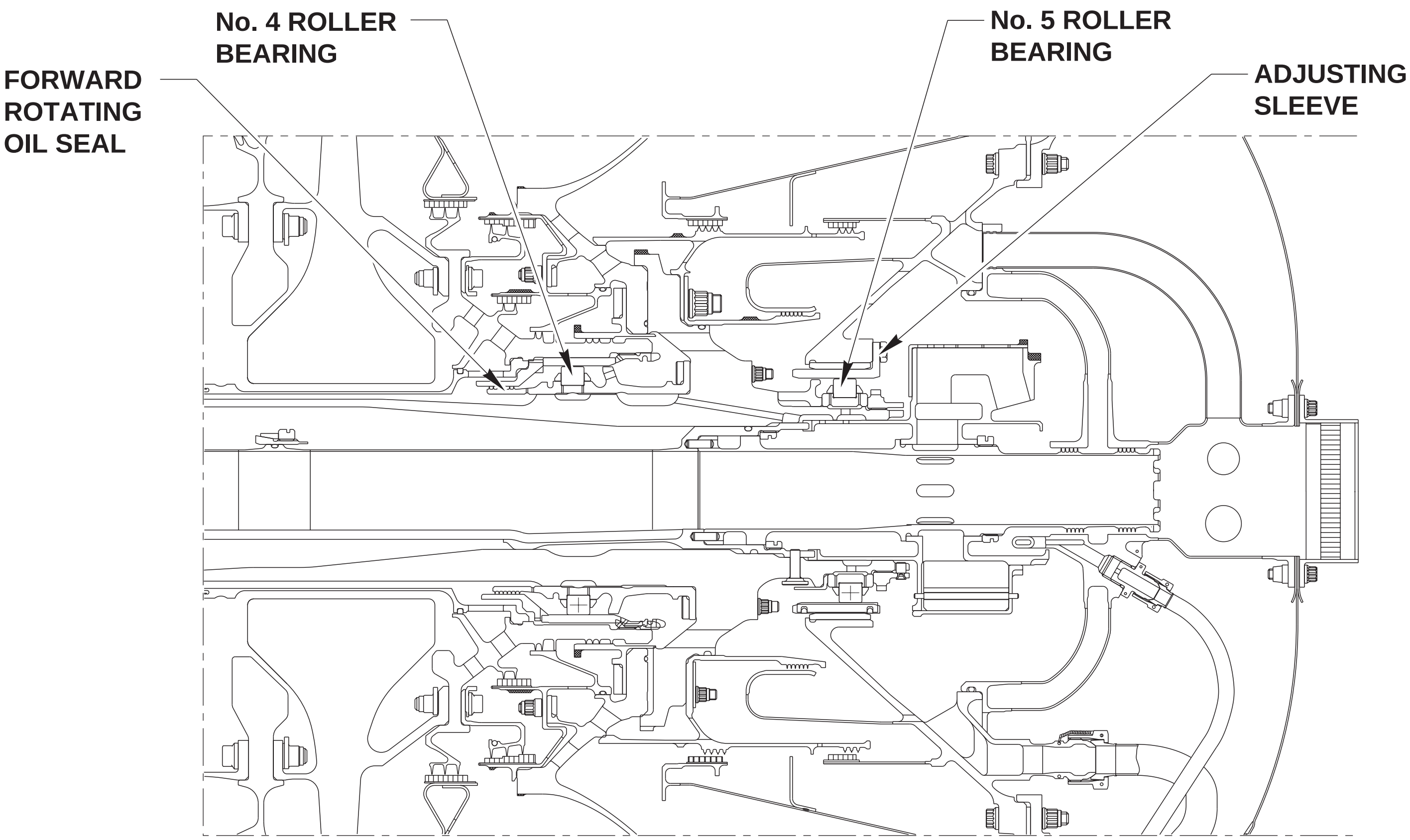
It is an oil-damped roller bearing, mounted at the rear of the LPT shaft hub, which reduces the vibration level of the rotating assembly.

The bearing outer race is installed in an adjusting sleeve inside the turbine frame and its inner race is installed on the aft end of the LPT shaft.

Oil damping is achieved by sending oil pressure between the outer race and the adusting sleeve.

The No.5 bearing is held in position by a retaining ring at the front, and a retaining nut at the rear.

The retaining nut provides axial retention of the bearing, and is locked in position by a rivet pin.



CTC-044-092-00

No. 4 & 5 BEARINGS

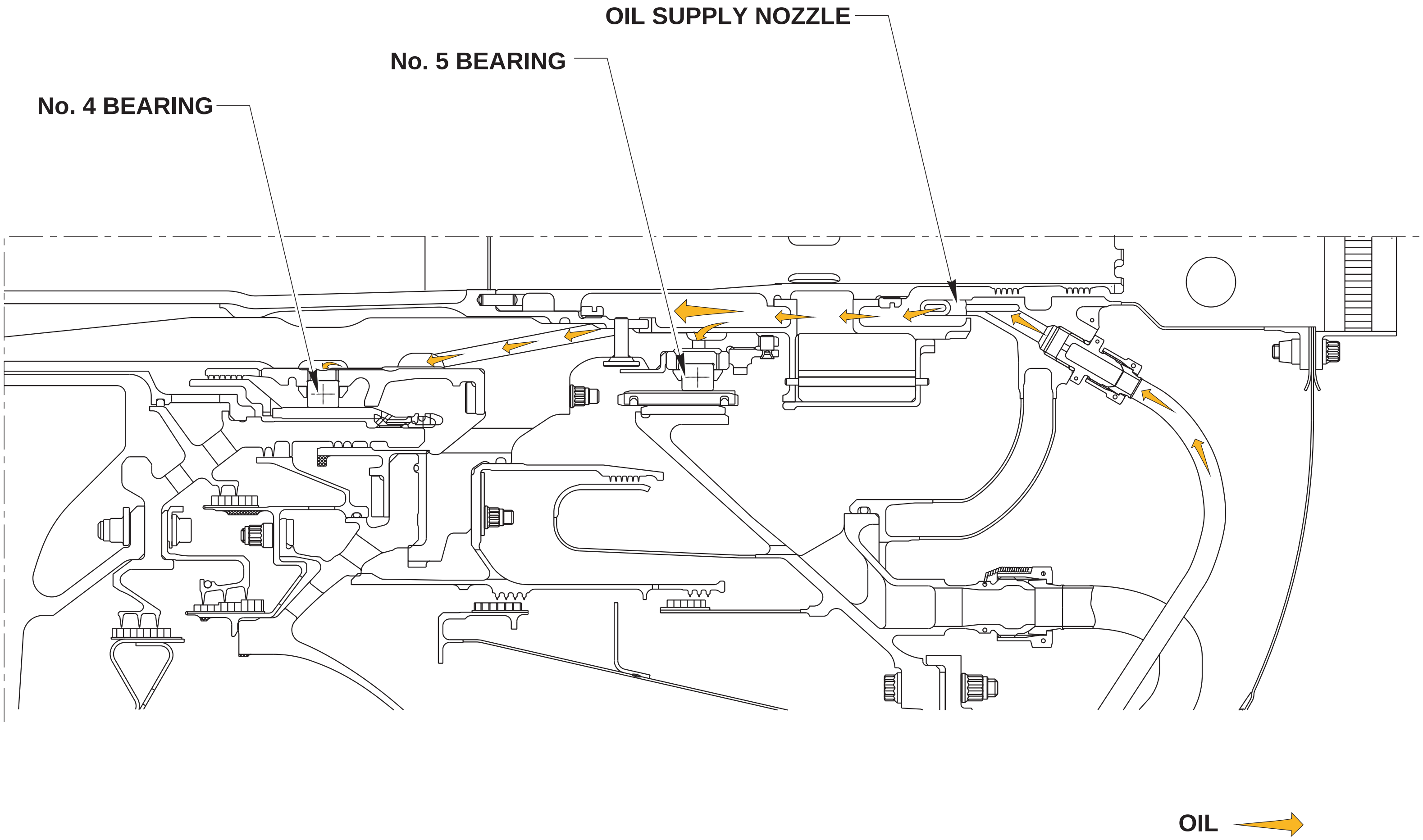
THE LPT SHAFT MODULE (CONTINUED)

Bearings lubrication

A supply tube located in the turbine frame delivers oil to the rotating air/oil separator, which in turn sends this oil forward to the No.5 bearing by centrifugation, through an oil gallery between the separator and the LPT shaft.

Oil finds a passage through holes in the LPT shaft and the No.5 bearing inner race, to lubricate the rollers and outer race of the No 5 bearing.

The remaining oil continues to flow forward, through passageways drilled in the LPT shaft, and lubricates the inner race, the rollers and the outer race of the No.4 bearing.



CTC-044-093-00

BEARINGS LUBRICATION

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THE TURBINE FRAME MODULE

THE TURBINE FRAME MODULE

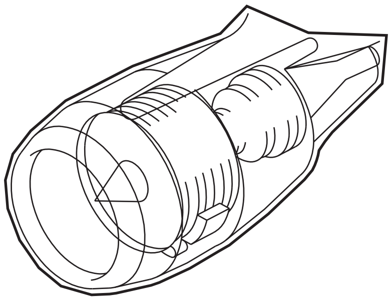
The turbine frame module is one of the engine major structural assemblies, and is located at the rear of the engine.

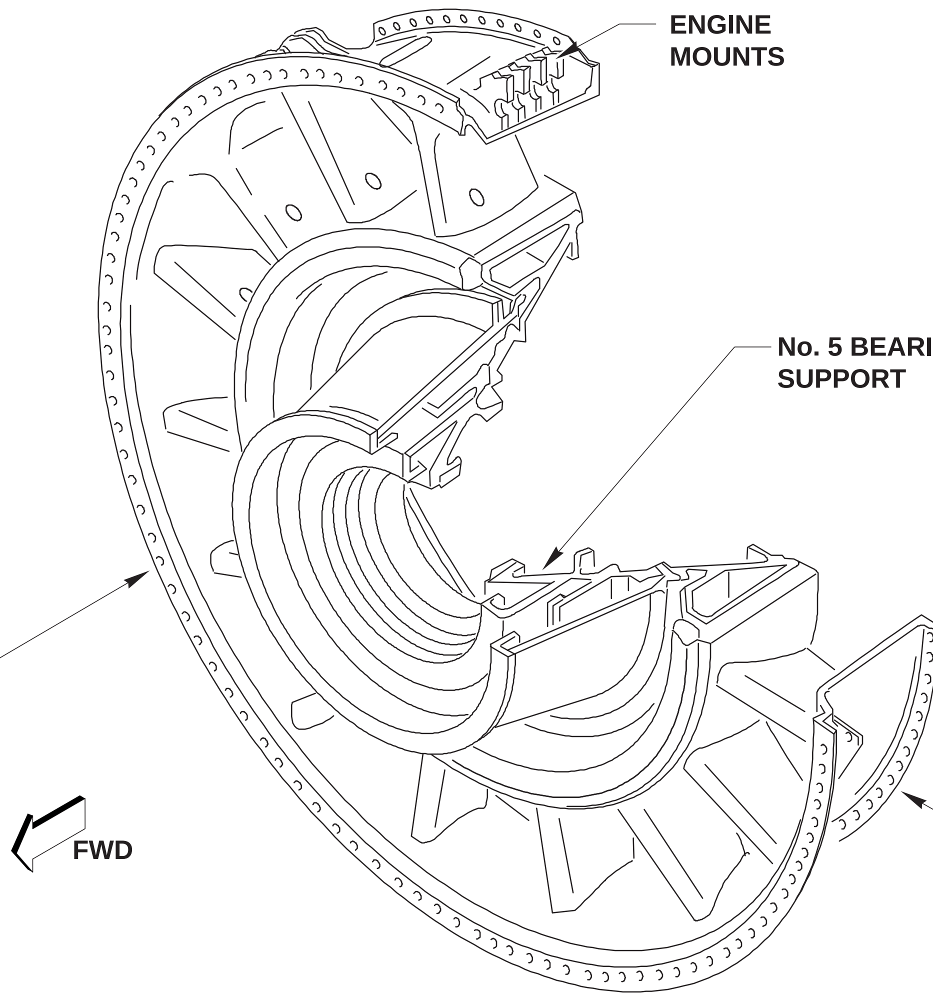
Its front section is bolted to the rear flange of the LPT case, and its rear section provides attachment for the exhaust nozzle and exhaust plug, which are both part of the nacelle.

The main structural component of the module is the turbine frame.

The turbine frame outer casing has engine rear installation mounts.

Its inner hub takes up loads from the rear of the LPT rotor through the No. 5 bearing support, and provides attachment for parts on its front and rear faces.





TURBINE FRAME MODULE

CTC-044-094-00

THE TURBINE FRAME MODULE (CONTINUED)

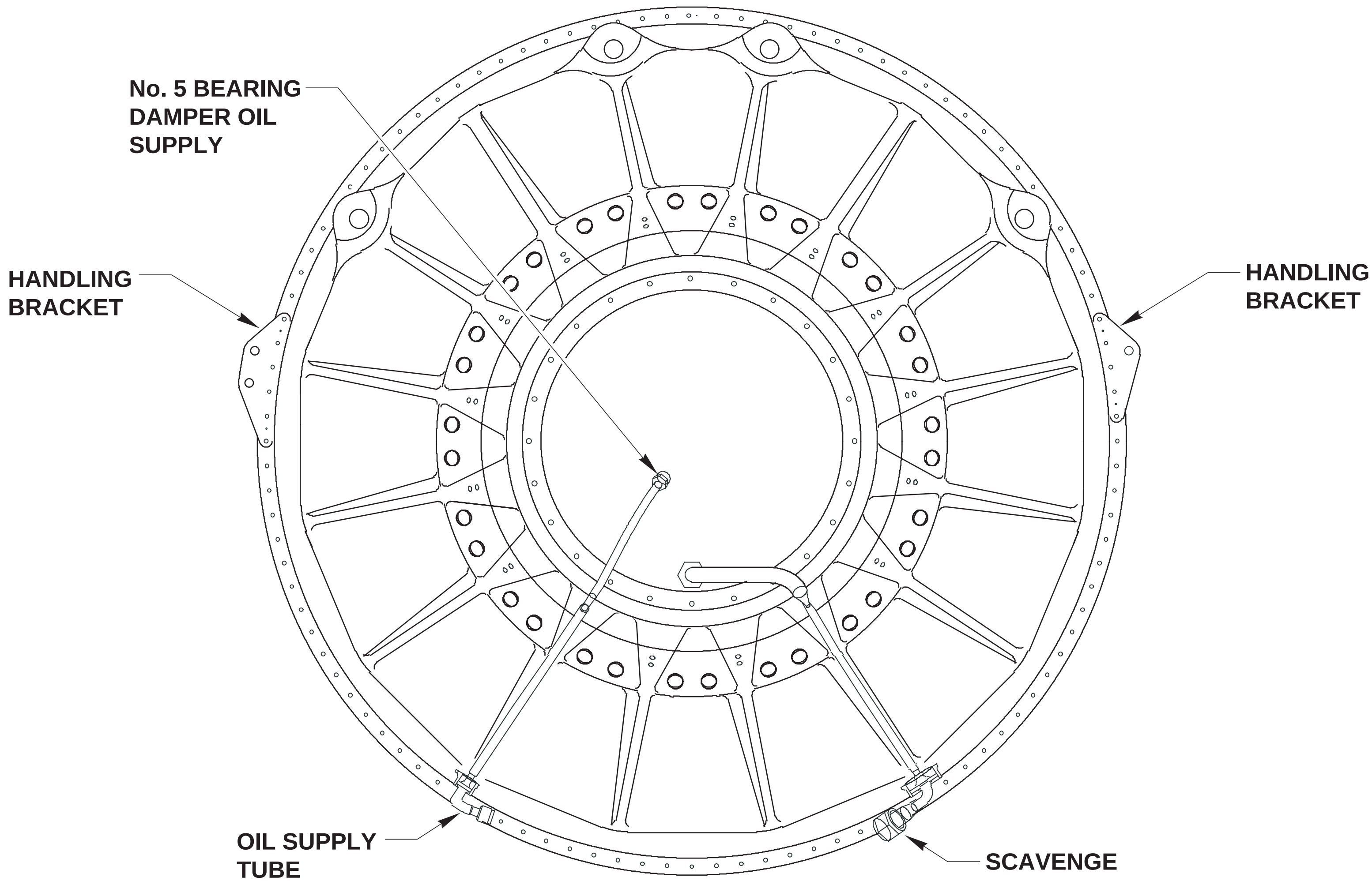
Turbine Frame - General

The turbine frame is made of nickel alloy.

It consists of a polygonal outer casing connected to an inner hub with 16 airfoil-shaped radial struts.

Some of the struts have internal passages for oil tubes :
- Strut No. 10 accommodates the oil supply tube for the No. 4 and No. 5 bearings.
- Strut No. 7 accommodates the aft oil sump scavenge tube.
- The outer case drain tube is routed between struts No. 8 and No. 9.

The turbine frame has brackets used for handling and installation on engine storage stands and the outer casing has clevis mounts for engine installation on the airframe.



CTC-044-095-00

TURBINE FRAME STRUTS

THE TURBINE FRAME MODULE (CONTINUED)

Turbine Frame Hub - Front

The front of the turbine frame hub has three flanges that provide attachment for various components.

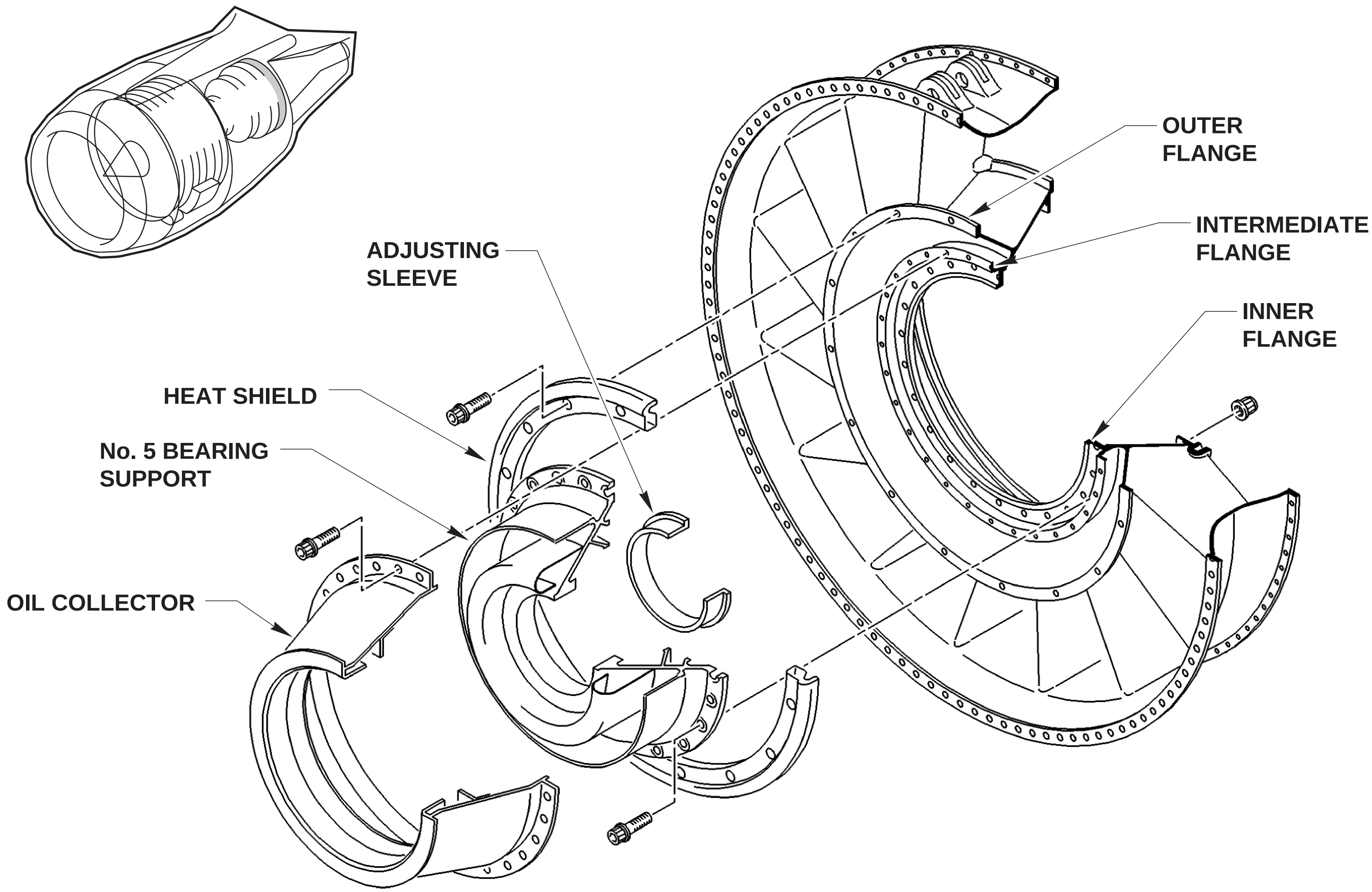
- The hub inner flange provides attachment for the outer flange of the No. 5 bearing support, which has an adjusting sleeve to secure the No. 5 bearing outer race in position and allow bearing oil damping.

  The support's forward section has an outer and an inner wall, which mate with the rear seal teeth of the rotating air/oil seal located at the rear of the LPT shaft, thus providing sealing and pressurization of the aft oil sump.

  The support has machined passages for the circulation of pressurizing air to the oil inlet cover, sump air to the center vent tube, oil to the scavenge tube and oil to the outer race damper.

- The hub intermediate flange accommodates the rear flange of the oil collector which provides containment for the aft oil sump. Its inner front flange is lined with abradable material which mates with the front seal teeth of the rotating air/oil seal, for oil sump sealing and pressurization purposes.

- The hub outer flange accommodates a steel alloy heat shield, which holds the front of the fairing in position, and provides protection against heat from the rear of the LPT rotor.



CTC-044-096-00

TURBINE FRAME HUB-FRONT

THE TURBINE FRAME MODULE (CONTINUED)

Turbine Frame Hub - Rear

The rear of the turbine frame hub provides attachment for various components; some on the center section of the No. 5 bearing support, and some on two flanges.

- The rear center section of the No. 5 bearing support provides attachment for the front flange of the oil inlet cover.

  The oil inlet cover is made of steel alloy and forms the end boundary of the aft sump. It supports the oil supply tube for the No. 4 and No. 5 bearings, and has a port for a nipple to connect the damping oil tube. It has external tubes that carry booster discharge air to pressurize the sump rear seals.

  The rear flange of the oil inlet cover provides attachment for a nickel alloy flame arrestor.

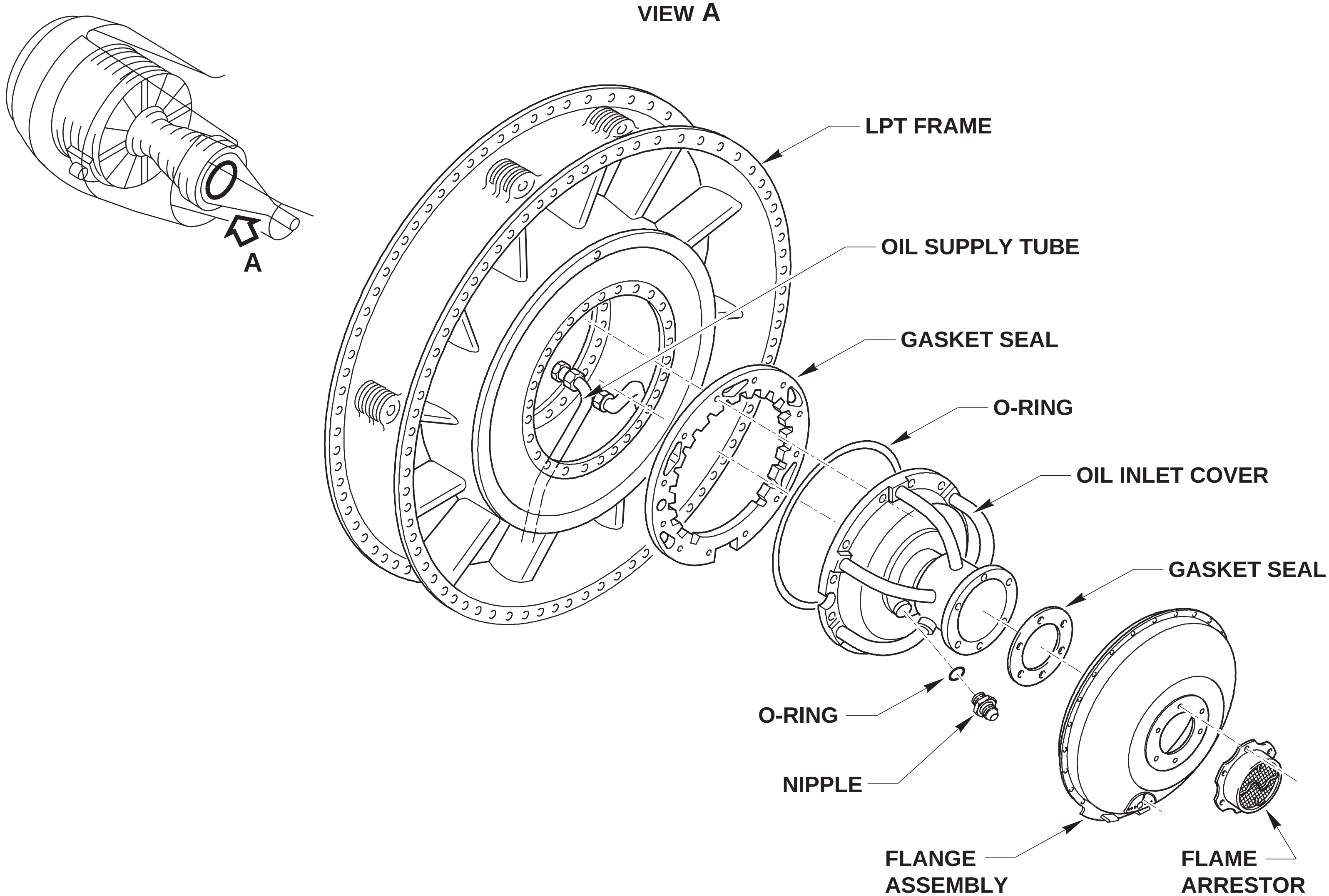
- The flame arrestor is the exit point of sump pressurization airflow, and is designed to prevent flame propagation into the engine exhaust system.

- The hub outer flange provides attachment for the back of the fairing, and is fitted with mounting studs for the exhaust plug, which is part of the nacelle.

- The hub inner flange provides attachment for the flange assembly which closes the rear of the engine.

  Its central section receives the flame arrestor and its lower section provides a passage for the seal overboard drain tube.

VIEW A



TURBINE FRAME HUB-REAR

CTC-044-097-00

LPT MAJOR MODULE – BORESCOPE PORTS

The rotor/stator assembly of the Low Pressure Turbine needs regular line maintenance inspection to identify defects, mainly on the rotor blades.

The nozzle segments can also be inspected, but with limited visibility.

Five borescope inspection ports are available.
Their location corresponds to the nozzle segments stages 1 to 4 that are equipped with borescope holes.

- Ports S17 and S18 go through the stage 1 nozzle shroud. Located at the rear of the combustion case at the 5 :30 and 8:30 clock positions, they are used to inspect the leading edge of stage 1 blades.

- Port S20 goes through the stage 2 nozzle shroud. It is located on the LPT case at 5 o'clock, and is used to inspect the trailing edge of stage 1 blades and the leading edge of stage 2 blades.

- Port S21 goes through the stage 3 nozzle shroud. It is located on the LPT case at 5 o'clock, and is used to inspect the trailing edge of stage 2 blades and the leading edge of stage 3 blades.

- Port S22 goes through the stage 4 nozzle shroud. It is located on the LPT case at 5 o'clock, and is used to inspect the trailing edge of stage 3 blades and the leading edge of stage 4 blades.

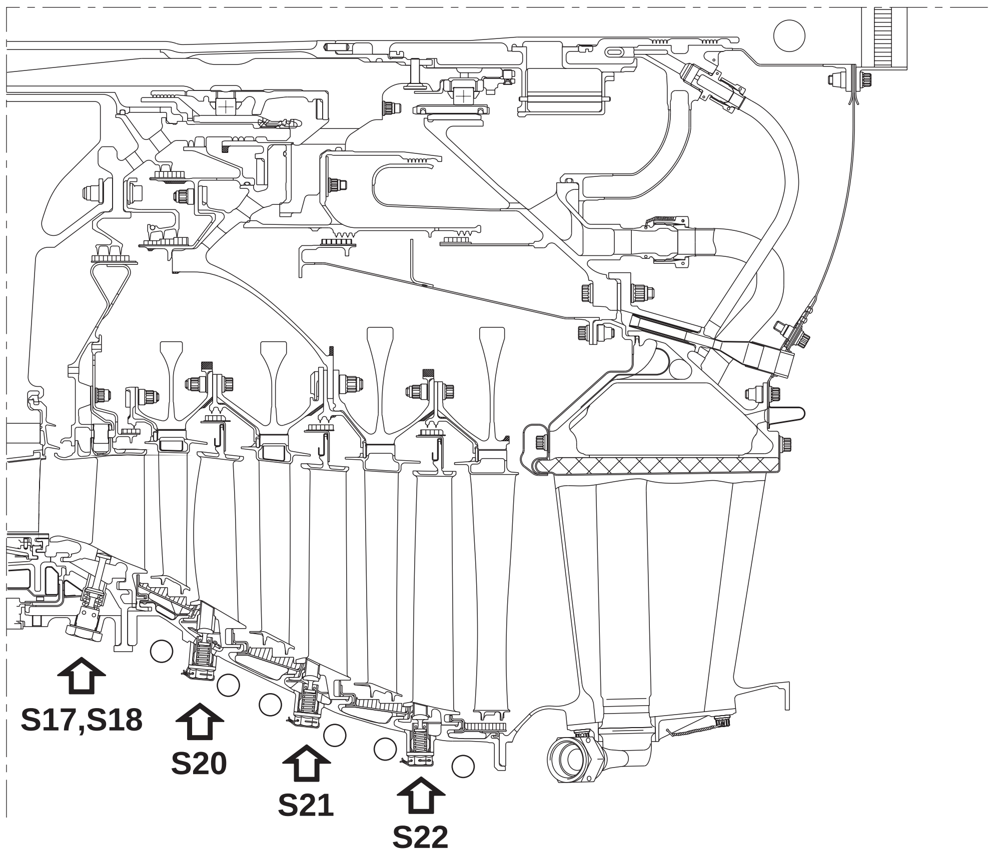
NOTE : There is no port S19 on -5A engines.

The trailing edge of stage 4 blades can be inspected through an instrumentation boss located at the 8.30 clock position on the turbine frame.

When not in use, all borescope ports are closed by plugs.

Ports S17 and S18 are fitted with long spring-loaded plugs with hexagonal head caps.

Ports S20, S21 and S22 are fitted with short spring-loaded plugs with hexagonal head caps.



CTC-044-098-00

LPT BORESCOPE INSPECTION

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ACCESSORY DRIVE MODULE

ACCESSORY DRIVE SYSTEM

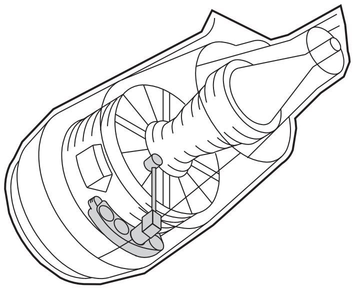
At engine start, the accessory drive system transmits external power from the engine air starter to drive the core engine.

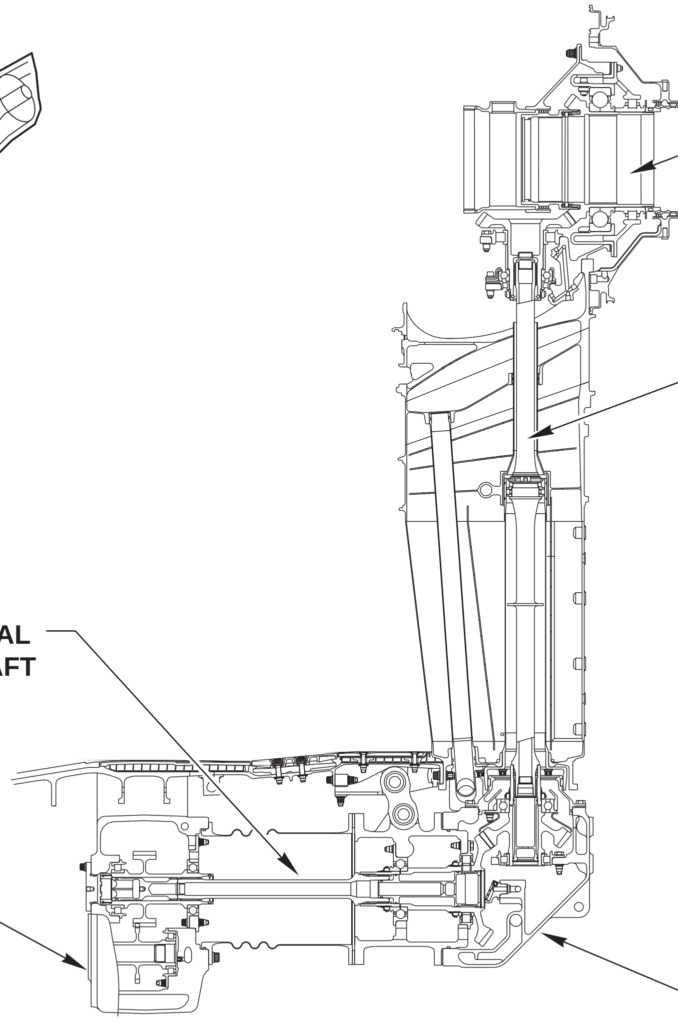
When the engine is running, the accessory drive system extracts part of the core engine power and transmits it through a series of gearboxes and shafts in order to drive the engine and aircraft accessories.

For maintenance tasks, the core can be cranked manually through the Accessory Gearbox.

The accessory drive system is located at the 6 o'clock position and consists of the following components :

- Inlet Gearbox (IGB), that takes power from the HPC front shaft.
- Radial Drive Shaft (RDS), that transmits the power to the Transfer Gearbox.
- Transfer Gearbox (TGB), which redirects the torque.
- Horizontal Drive Shaft (HDS), that transmits power from the Transfer Gearbox to the Accessory Gearbox.
- Accessory Gearbox (AGB), that supports and drives both engine and aircraft accessories.





ACCESSORY DRIVE SECTION DESIGN

CTC-044-099-00

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INLET GEARBOX

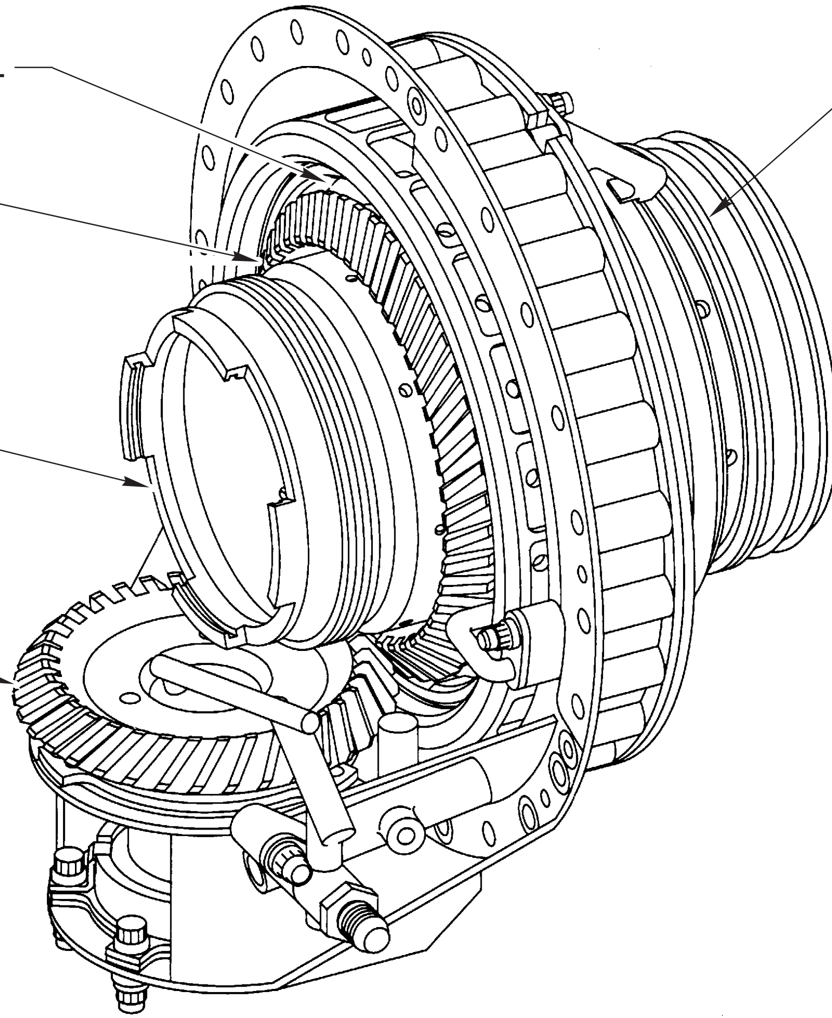
THE INLET GEARBOX (IGB)

The IGB transfers torque between the HPC front shaft and the radial drive shaft. It also supports the front end of the core engine.

It is located in the fan frame sump and is bolted to the forward side of the fan frame aft flange. It is only accessible after different engine module removals.

The IGB contains the following parts :

- Horizontal bevel gear (with coupling/locking nut)
- Radial bevel gear
- No 3 bearing (ball and roller)
- Rotating air/oil seal



CTC-044-100-00

INLET GEARBOX ASSEMBLY

THE INLET GEARBOX (CONTINUED)

The horizontal bevel gear

The horizontal bevel gear mates with the radial bevel gear to provide rotational torque to the TGB assembly.

It is secured onto the HPC forward shaft and carries the No 3 bearing inner race.

The horizontal bevel gear has 47 teeth.

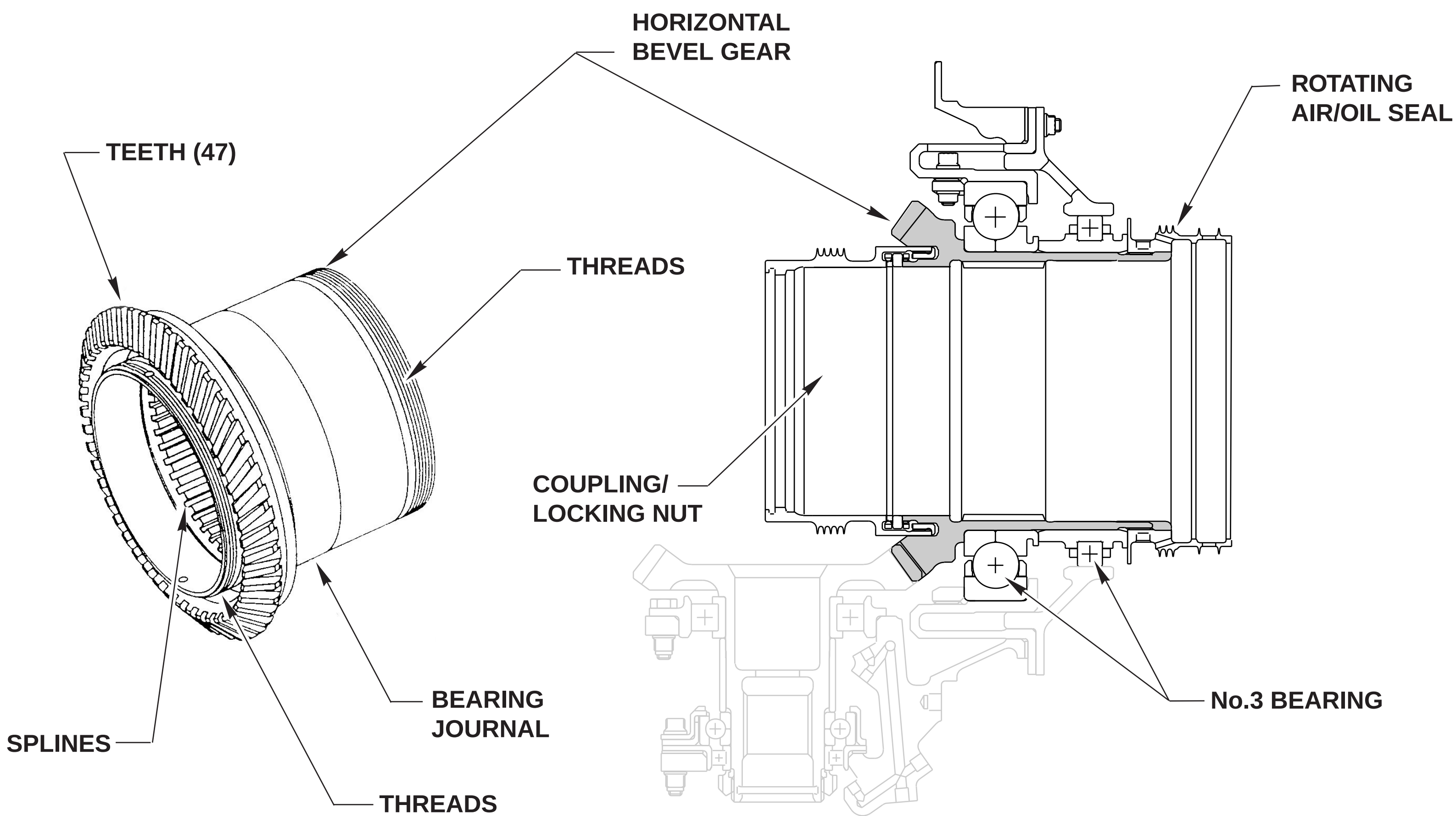
It is splined to the compressor rotor front shaft and secured to it by a coupling/locking nut.

The coupling/locking nut is installed in such a way that it rotates independently, but its internal thread secures the HPC front shaft to the horizontal bevel gear.

The nut is also used to pull out the core engine rotor during engine disassembly.

The nut has teeth on its outer surface to provide sealing with the forward stationary oil seal.

The bevel gear's outer shaft provides for the inner races of the bearing. The rear end has threads for the installation of a rotating air/oil seal, which also acts as a locking nut for the No 3 ball and roller bearing.



CTC-044-101-00

HORIZONTAL BEVEL GEAR

THE INLET GEARBOX (CONTINUED)

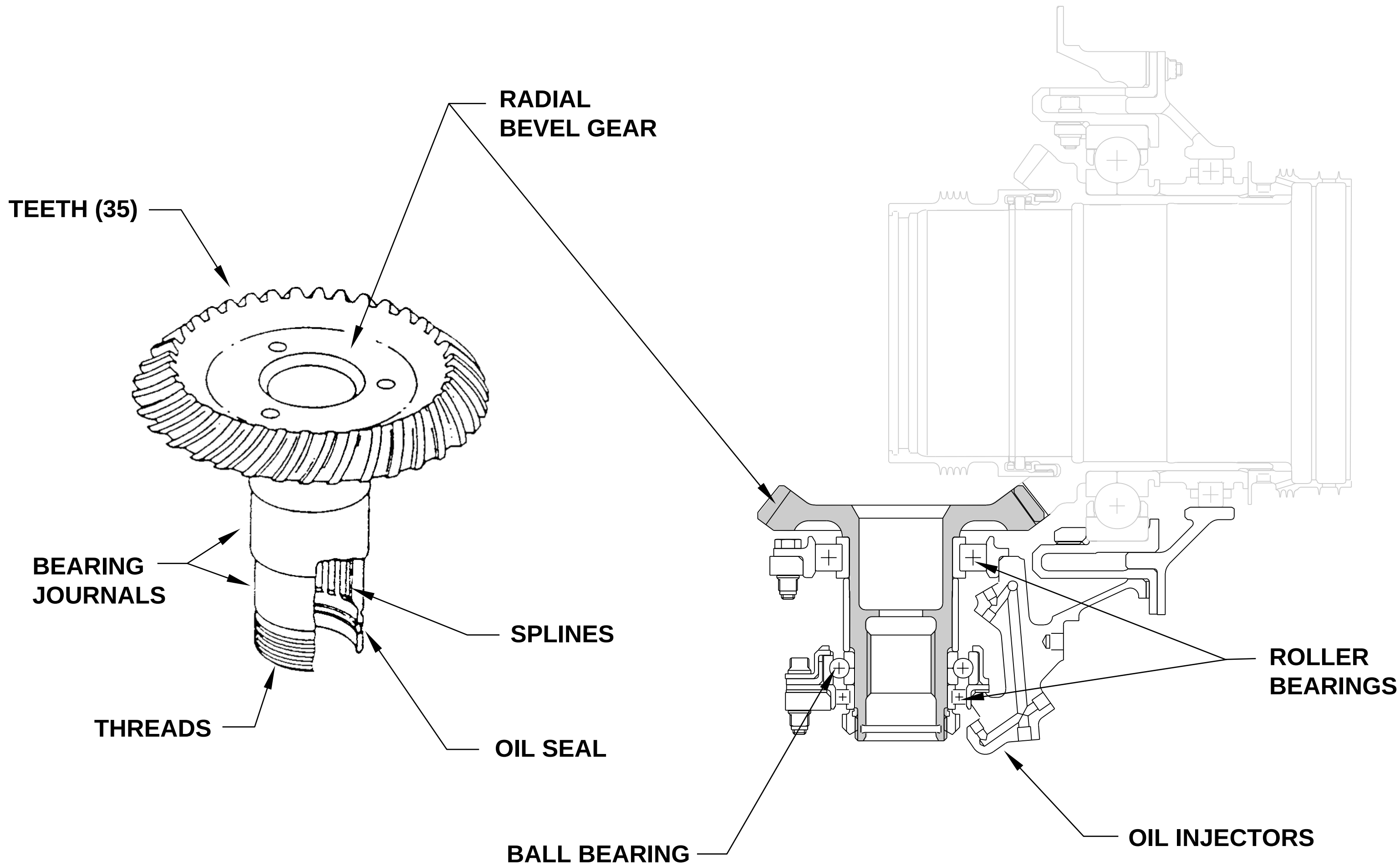
The radial bevel gear

The radial bevel gear has 35 teeth.

It is mounted on 1 ball bearing and 2 roller bearings, one at each end of the bevel gear hub.

The gear is internally splined to drive the radial drive shaft, which is removable from the exterior of the engine to allow individual replacement of the IGB.

The bearings and gear are lubricated and cooled by oil, supplied through the forward sump oil manifold assembly.



CTC-044-102-00

RADIAL BEVEL GEAR

THE INLET GEARBOX (CONTINUED)

The No 3 bearing

The No 3 bearing assembly consists of a ball bearing and a roller bearing.

The assembly is installed between the IGB housing and the horizontal bevel gear.

The No 3 ball bearing acts as the core engine thrust bearing and provides axial positioning of the forward end of the HPC rotor.

The roller bearing is located directly after the ball bearing and radially positions the core engine rotor.

The bearings and gear are lubricated and cooled by oil, supplied through the forward sump oil manifold assembly.

Forward stationary air/oil seal.

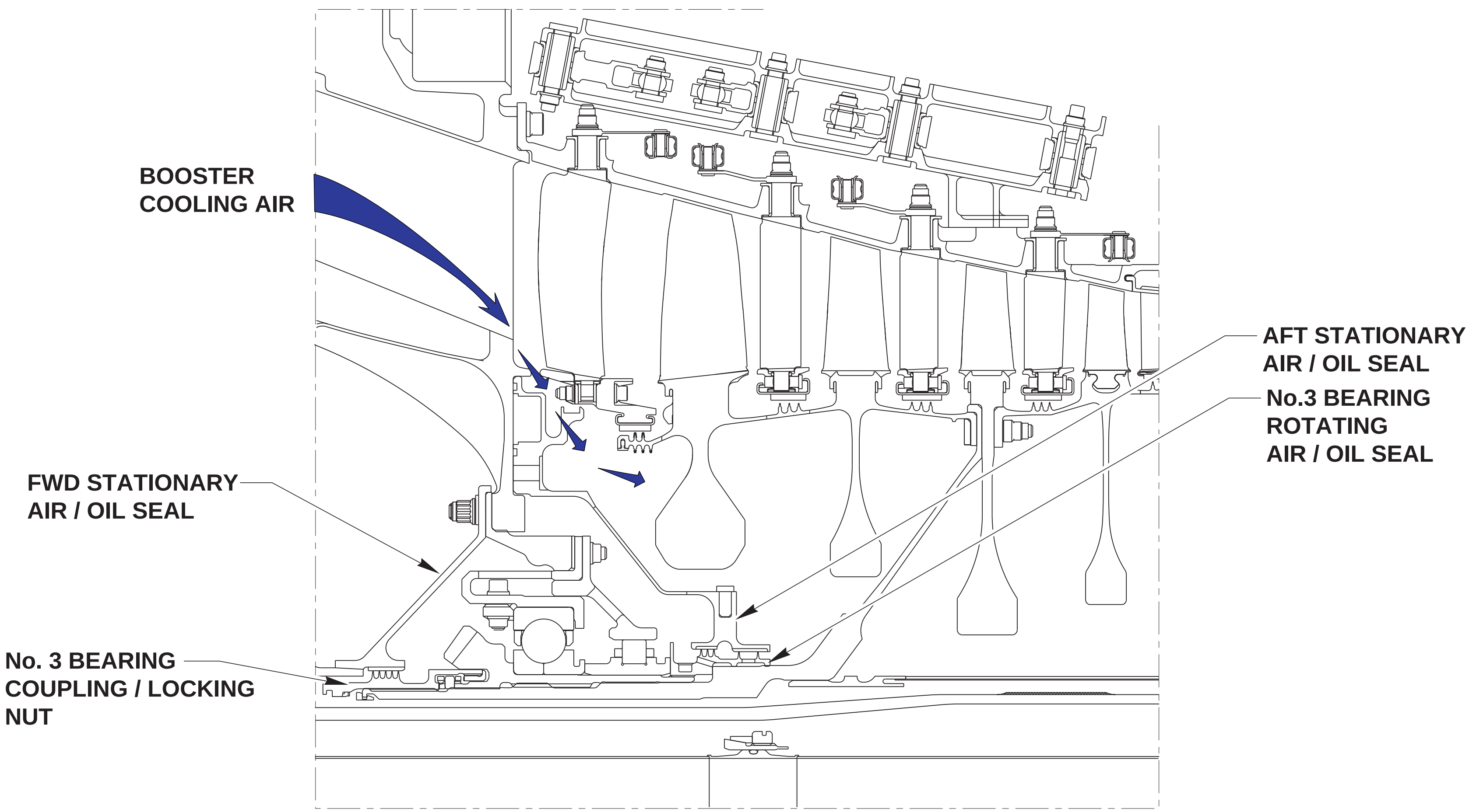
The No.3 bearing forward stationary oil seal is bolted on the forward face of the fan frame center hub aft flange.

The forward seal contacts the seal teeth on the No.3 bearing coupling/locking nut.

Aft stationary air/oil seal.

The aft stationary air/oil seal is bolted to the aft face of the fan frame center hub aft flange.

The aft end of the stationary seal contains two abradable coated seal lands which contact the seal teeth of the No.3 bearing aft rotating seal.



CTC-044-103-00

No. 3 BEARING

THE INLET GEARBOX (CONTINUED)

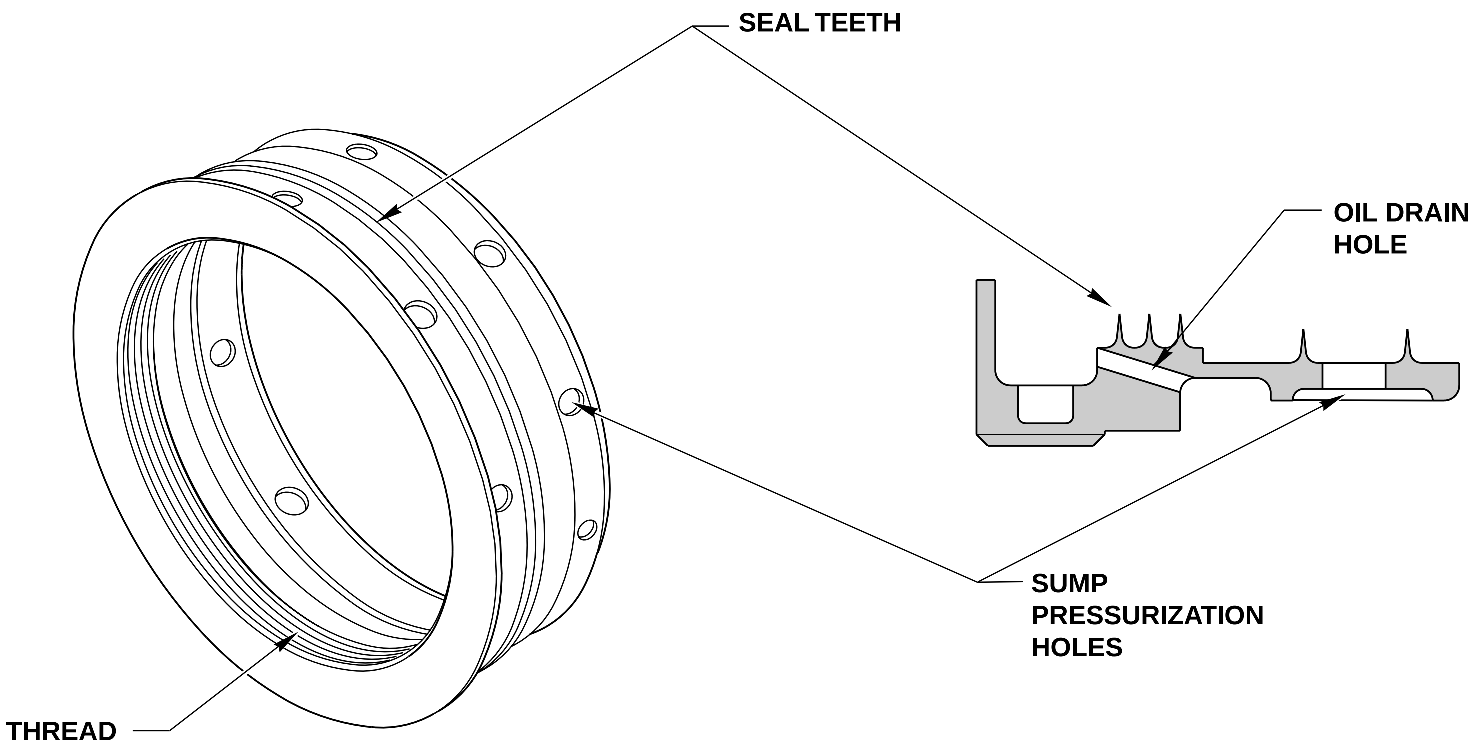
The No.3 bearing aft rotating seal

The No.3 bearing aft rotating seal provides the sealing of the aft end of the forward sump and also acts as a locknut for the No 3 bearing.

Holes between the two aft seal teeth allow passage of sump pressurizing air.

Holes passing underneath the forward seal teeth allow oil to be drained into the No 3 bearing cavity.

The rotating air/oil seal has internal threads for installation onto the horizontal bevel gear and its front face locks the No 3 bearing inner races in position.



CTC-044-104-00

ROTATING AIR/OIL SEAL

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TRANSFER GEARBOX

THE RADIAL DRIVE SHAFT (RDS)

The Radial Drive Shaft transmits power from the IGB to the TGB and the assembly is installed inside the fan frame No 7 strut at the 6 o'clock position.

It consists of the radial drive shaft and a mid-length bearing.

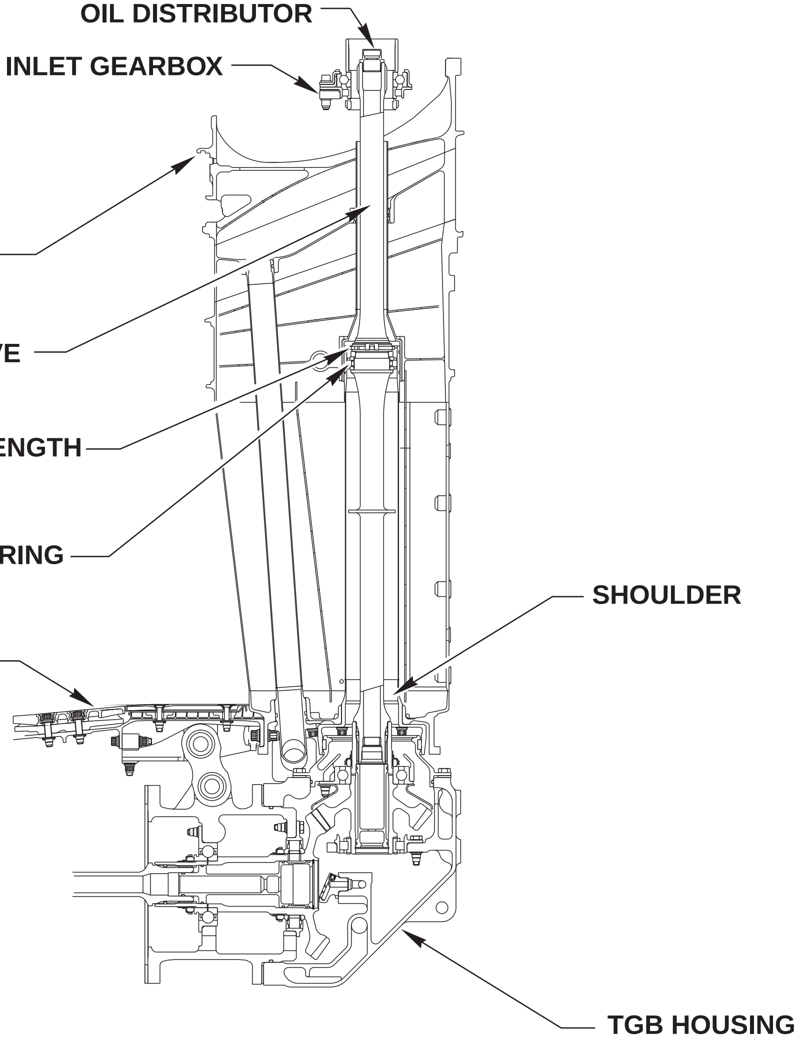
The RDS is hollow and made of steel alloy and measures approximately 29.52 ins (0.75 m).

Both ends are externally splined and connect the IGB bevel gear with the TGB input bevel gear.

A foolproof slot is machined on the shaft to avoid inversion of the RDS during installation.

The lower end of the shaft has a shoulder, which prevents disengagement and ensures correct seating into the gear.

The shaft mid-length bearing provides proper centering of the RDS in its housing. Its inner race is mounted halfway up on the RDS and the outer race is part of the RDS housing.



THE RADIAL DRIVE SHAFT

CTC-044-105-00

THE TRANSFER GEARBOX (TGB)

The transfer gearbox.

Driven by the RDS, the Transfer Gearbox reduces rotational speed and redirects the torque from the IGB to the AGB, through the horizontal drive shaft.

It is secured under the fan frame module at the 6 o'clock position and consists of :

- The gearbox housing
- The input bevel gear
- The horizontal bevel gear

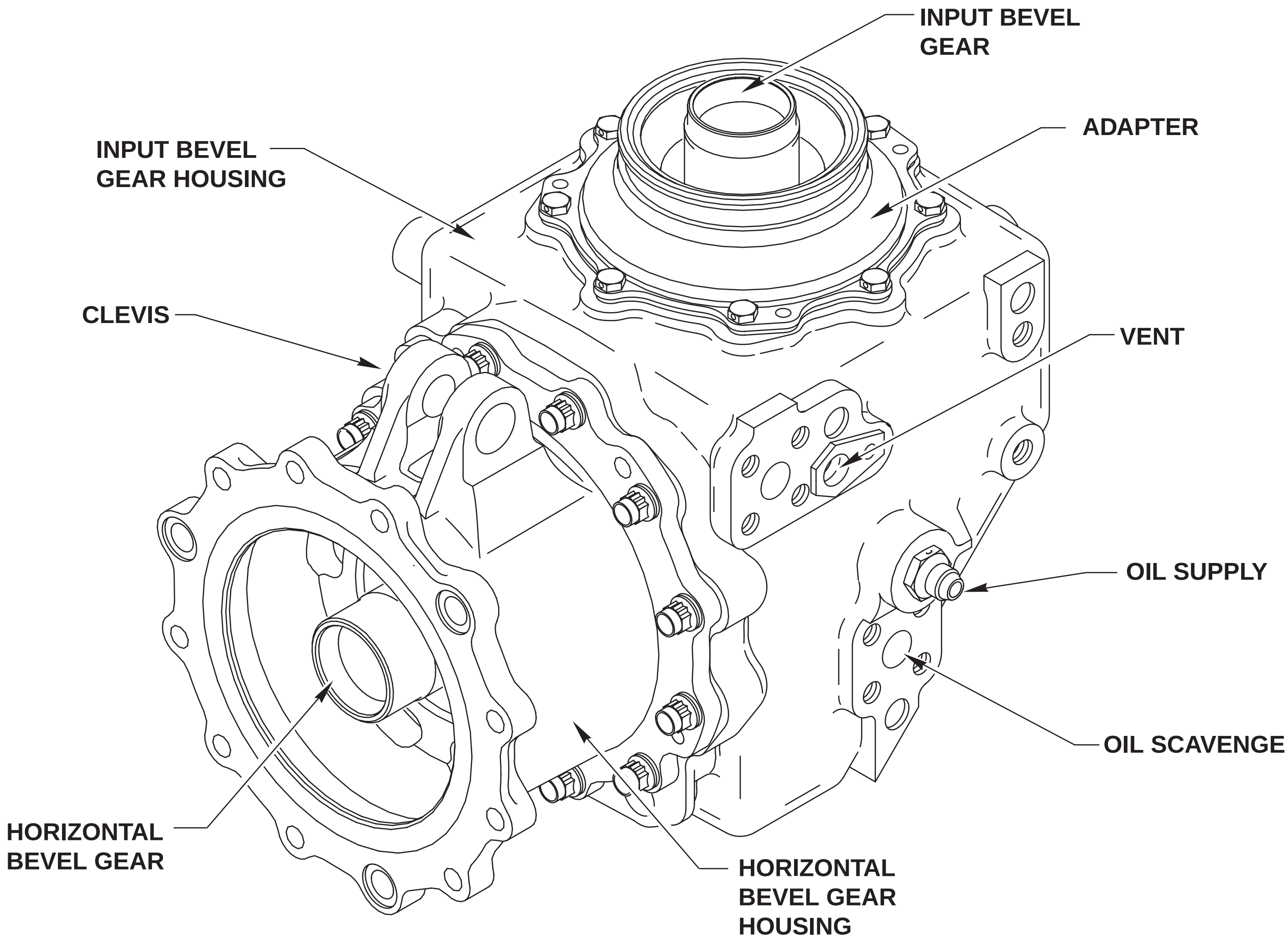
The gearbox housing

The TGB housing is made of aluminium alloy and consists of two parts bolted together to form one assembly.

The upper part of the TGB contains an adapter, which fits in the bell-shaped outer end of the RDS housing.

The horizontal part provides the attachment to the fan inlet case through a single clevis/link rod mounting arrangement located at the top of the housing.

The TGB housing contains 2 oil nozzles for lubrication of the bevel gears and bearings.



CTC-044-106-00

TRANSFER GEARBOX ASSEMBLY

THE TRANSFER GEARBOX (CONTINUED)

The input bevel gear

The upper part of the TGB houses the input bevel gear, its bearing housing, ball bearing and roller bearing.

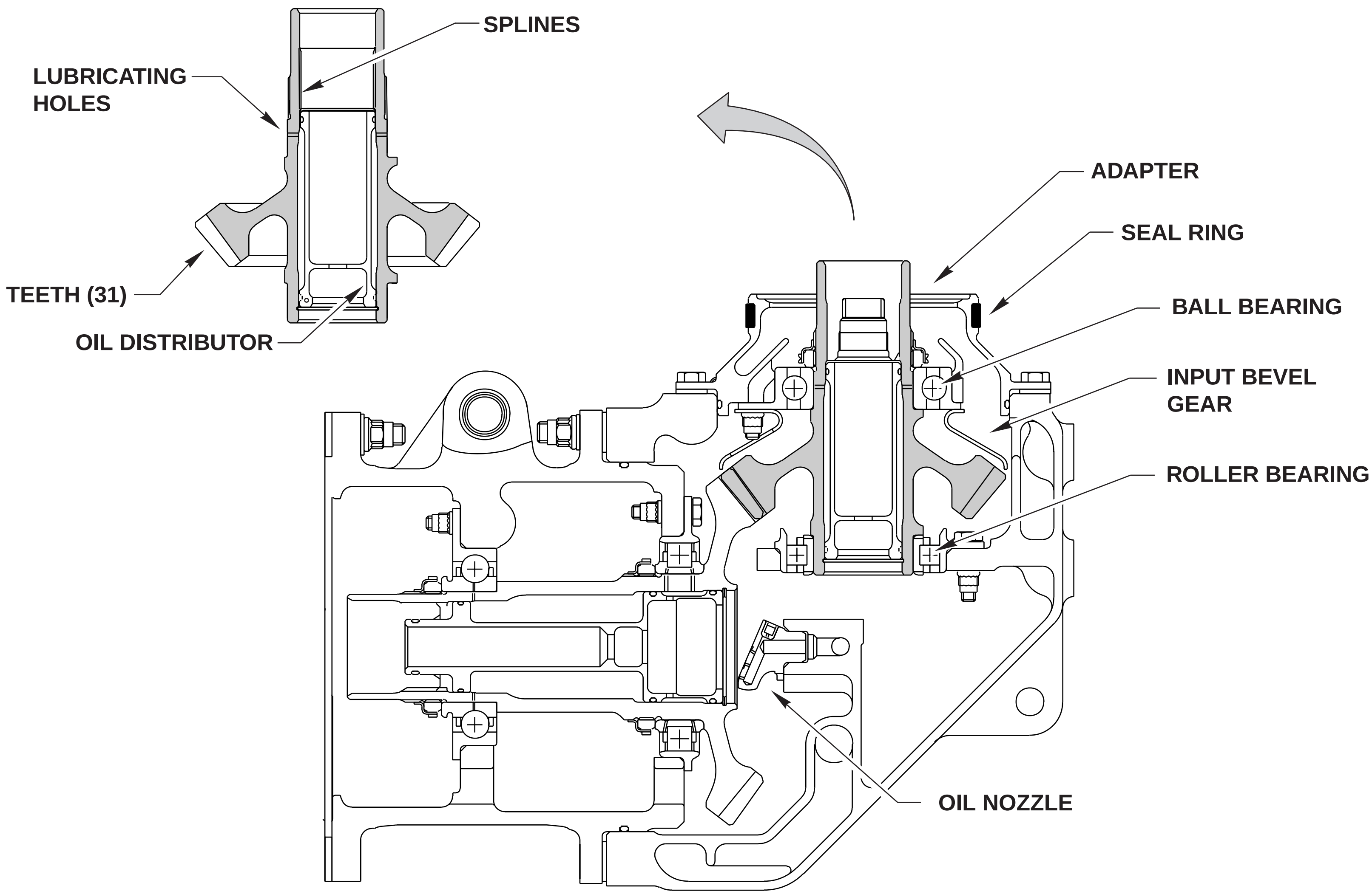
The input bevel gear has 31 teeth.

The bore of the bevel gear is splined at its upper end and engages with the radial drive shaft.

Sealing is provided by a seal ring installed externally on the adapter.

An oil nozzle (not shown on diagram) supplies a jet of oil directly onto the bevel gear. Another oil nozzle supplies a jet of oil onto the roller bearing.

An oil distributor, installed inside the bevel gear and secured by an anti-rotation system, ensures oil distribution to the ball bearing and axial retention of the RDS.



INPUT BEVEL GEAR

CTC-044-107-00

THE TRANSFER GEARBOX (CONTINUED)

The horizontal bevel gear

The horizontal part of the TGB includes the housing, the horizontal bevel gear, a ball bearing and a roller bearing.

The horizontal bevel gear has 40 teeth.

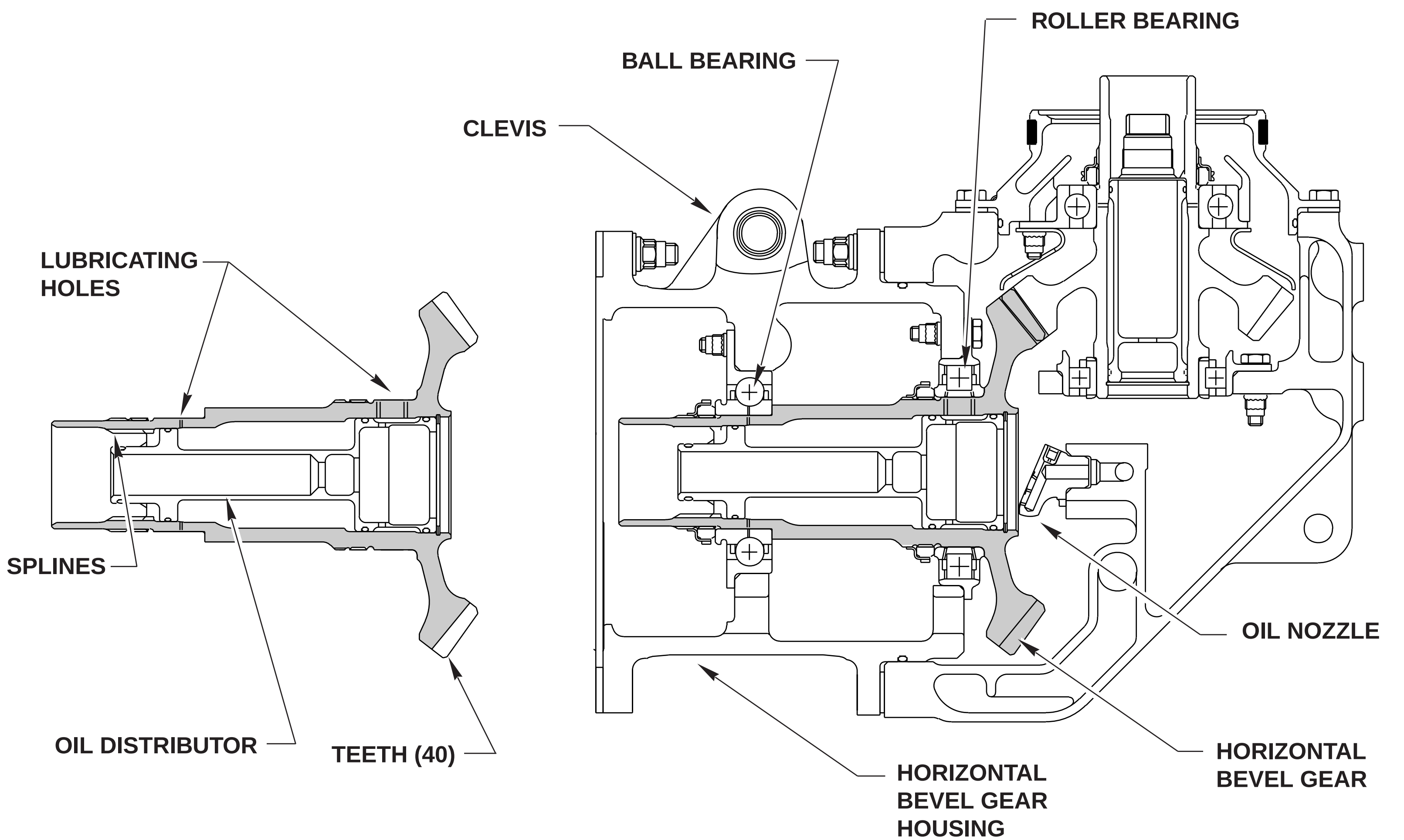
The gear housing is a cast part.

The suspension clevis, which attaches to the fan inlet case through a link, is a cast part and integral with the housing.

An oil nozzle directs 3 jets of oil into various parts of the horizontal bevel gear.

An oil distributor, installed in the bevel gear and attached by an anti-rotation system, permits oil distribution to the bearings.

The bore of the bevel gear is splined at its forward end and connects with the Horizontal Drive Shaft (HDS).



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HORIZONTAL BEVEL GEAR

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ACCESSORY GEARBOX

THE ACCESSORY GEARBOX (AGB)

The Horizontal Drive Shaft (HDS)

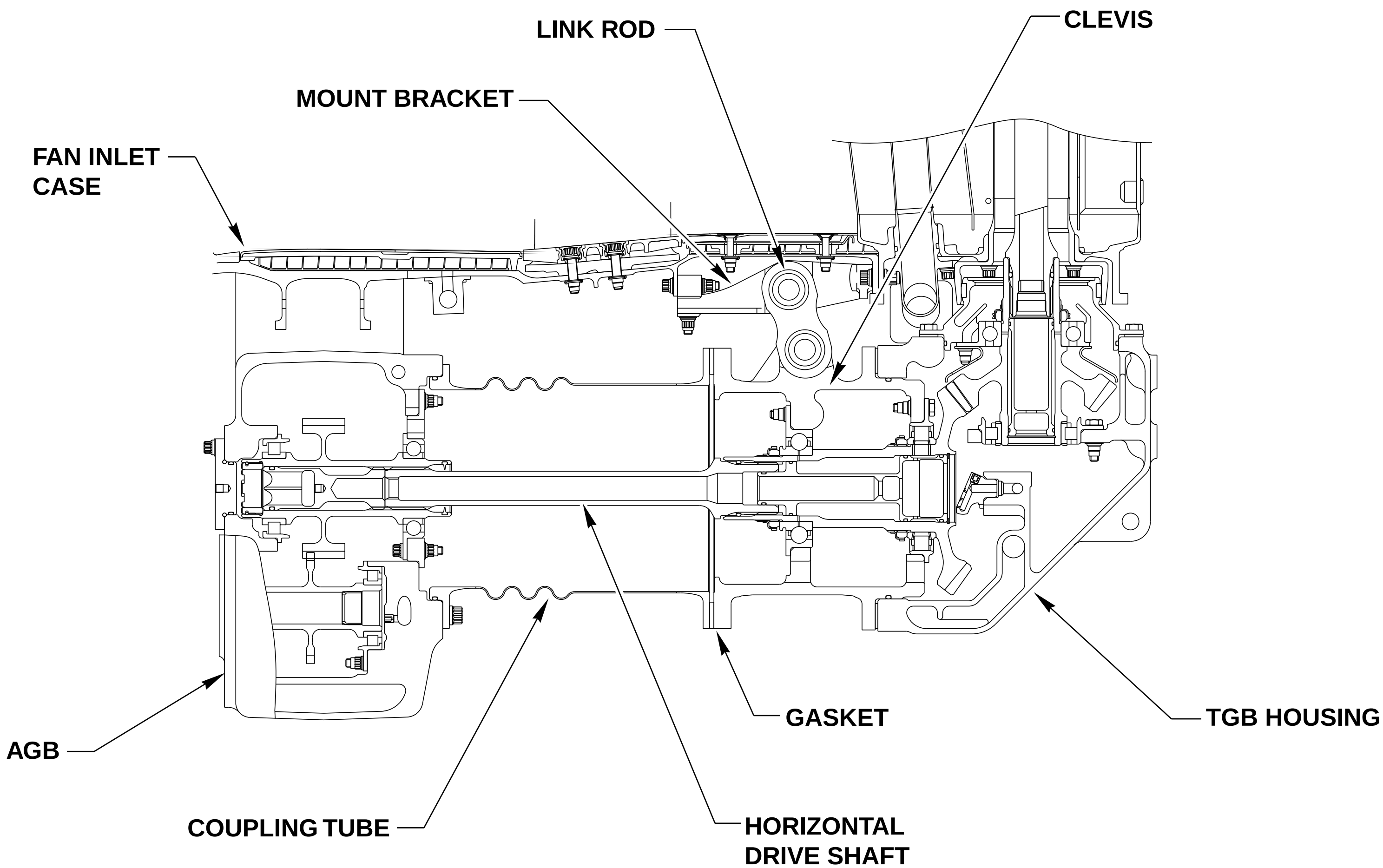
The steel alloy Horizontal Drive Shaft provides power transmission between the TGB and the AGB.

The coupling tube, bolted between the TGB and AGB housings, is made of aluminium alloy. It protects the HDS and ensures connection with the AGB.

A gasket between the tube and the TGB front flange and an O-ring between the tube and the AGB rear flange, provide the necessary sealing of the assembly.

The HDS is splined at both ends and drives the AGB gears through the hand-cranking drive gear.

The shaft is secured in the drive gear by a castellated nut.



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HORIZONTAL DRIVE SHAFT LOCATION

THE ACCESSORY GEARBOX (CONTINUED)

The accessory gearbox supports and drives both aircraft and engine accessories.

The AGB assembly is mounted under the fan inlet case at the 6 o'clock position and is secured by 2 clevis mounts with shouldered bushings.

The housing is an aluminium alloy casting.

The AGB consists of a gear train that reduces and increases the rotational speed to meet the specific drive requirements of each accessory.

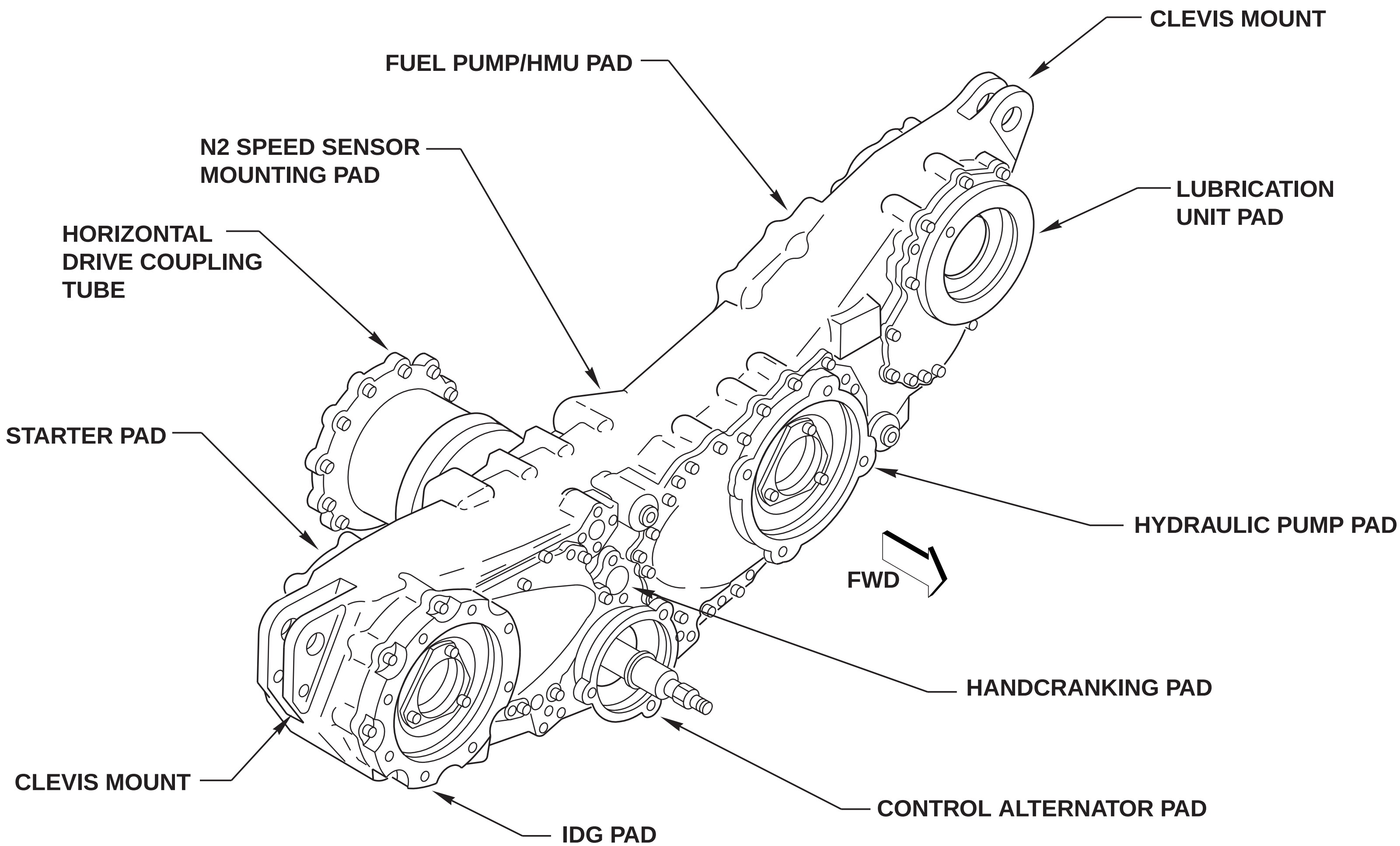
The AGB's front face has mounting pads for the following equipment :

- Lube unit
- Hydraulic pump
- Hand-cranking drive
- Control alternator
- Integrated Drive Generator (IDG)

Its rear face connects with the HDS coupling tube and provides mounting pads for :

- The fuel pump
- The N2 speed sensor
- The starter

Some of the accessories are installed on the AGB through Quick Attach/Detach (QAD) rings.



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ACCESSORY GEARBOX HOUSING

THE ACCESSORY GEARBOX (CONTINUED)

The gear train

The gear train is contained in the AGB housing and consists of an arrangement of gear shafts, which drive the accessories.

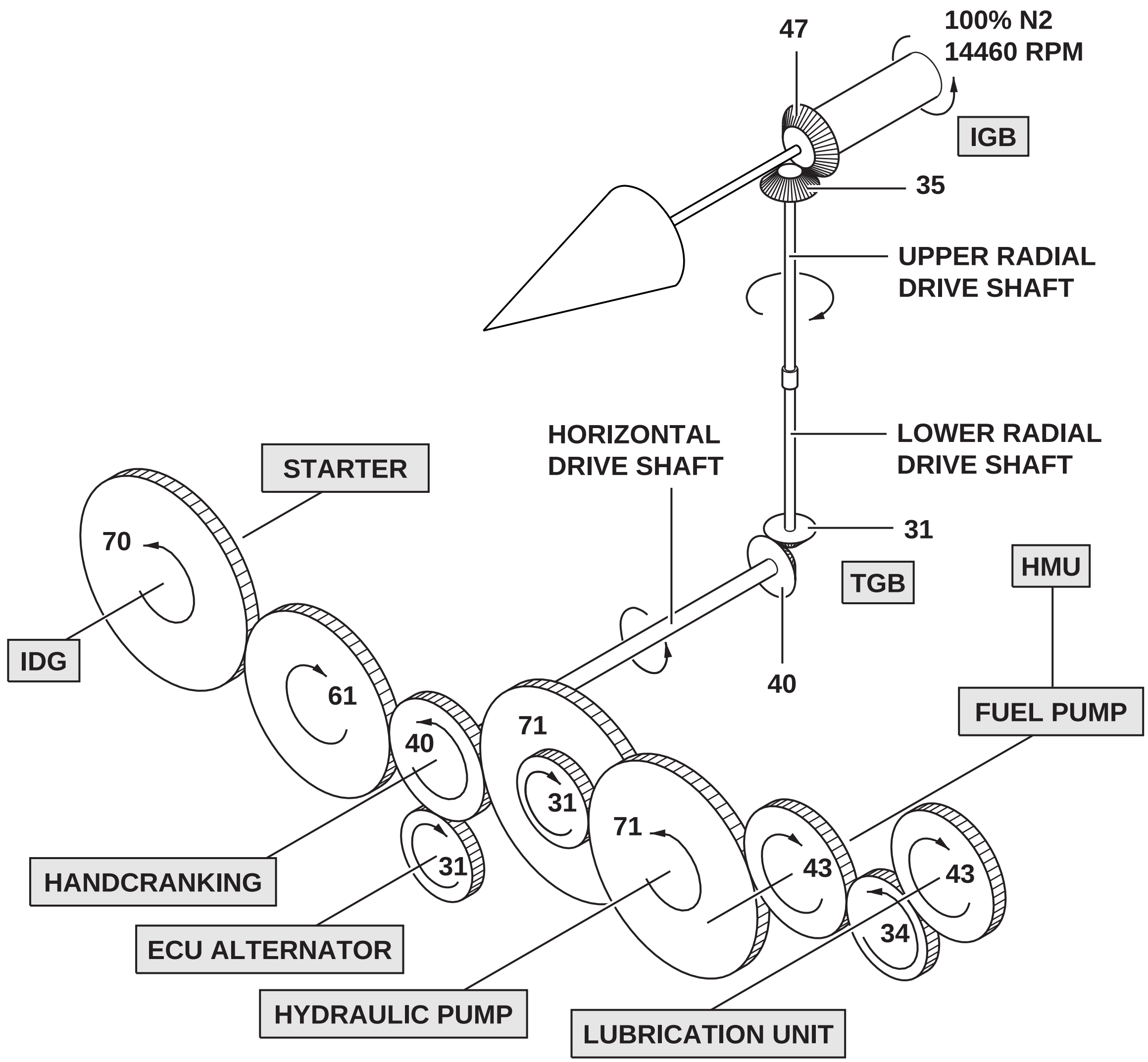
Each gear shaft assembly consists of a spur gear supported by a ball and roller bearing.

The gears, their bearings and bearing supports are plug-in type systems.

They are lubricated by oil distributors, which supply oil jets onto specific areas (bearings and splines).

Accessory ratios :

- The IDG	0.5947 N2
- The hydraulic pump	0.256 N2
- The HMU and fuel pump	0.423 N2
- The lubrication unit	0.423 N2
- The ECU alternator	1.342 N2
- The starter	0.5947 N2
- Hand cranking	1.04 N2



ACCESSORY DRIVE SYSTEM GEAR TRAIN

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THE ACCESSORY GEARBOX (CONTINUED)

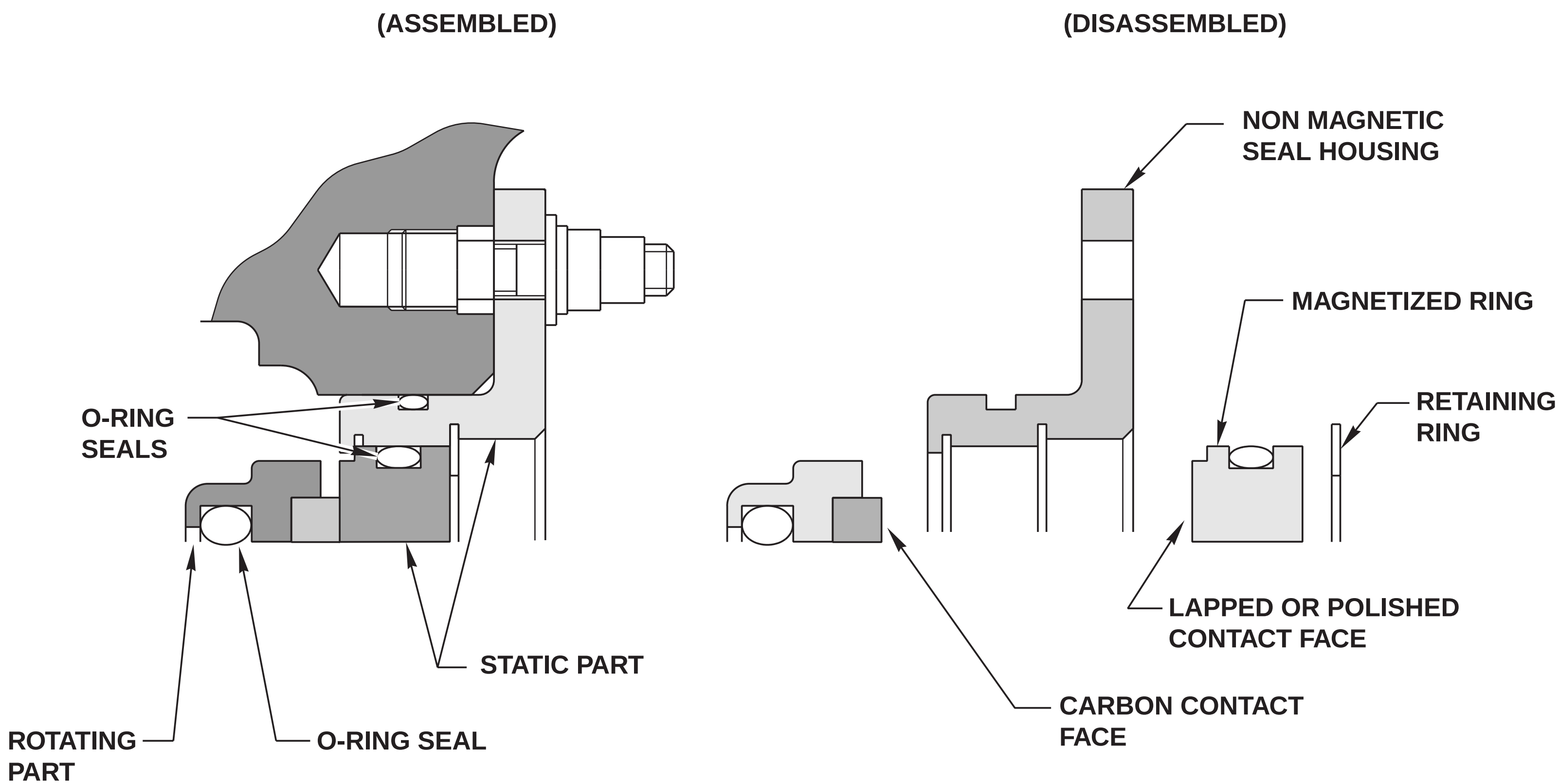
Sealing

Sealing of the AGB is provided by 2 configurations of carbon-contact seals :
- Magnetic type
- Spring-loaded type

Magnetic seals

The magnetic-type seal consists of :
- A non-magnetic housing, which contains a magnetized mating ring with a polished face and a retaining ring
- A rotating seal with carbon material held in a rotating ring

This seal type can be used on the following pads :
- Integrated Drive Generator (IDG)
- Hydraulic pump
- Fuel pump



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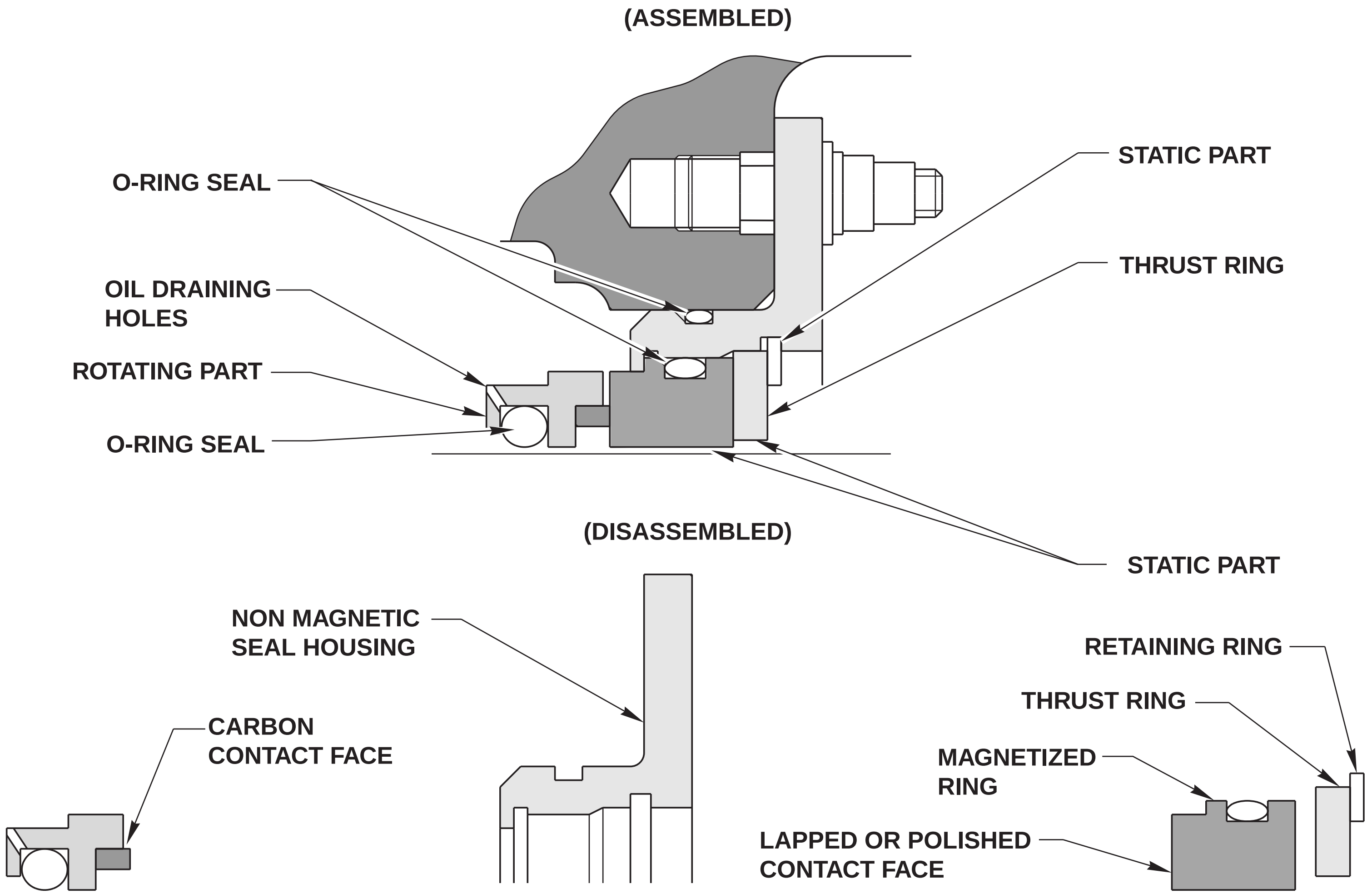
MAGNETIC SEAL

THE ACCESSORY GEARBOX (CONTINUED)

Starter drive pad seal

On the starter drive pad only, a different configuration of magnetic seal is used.

It has a thrust ring, which also acts as a heat sink, installed in between the mating ring and retaining ring.



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MAGNETIC SEAL (STARTER DRIVE ONLY)

THE ACCESSORY GEARBOX (CONTINUED)

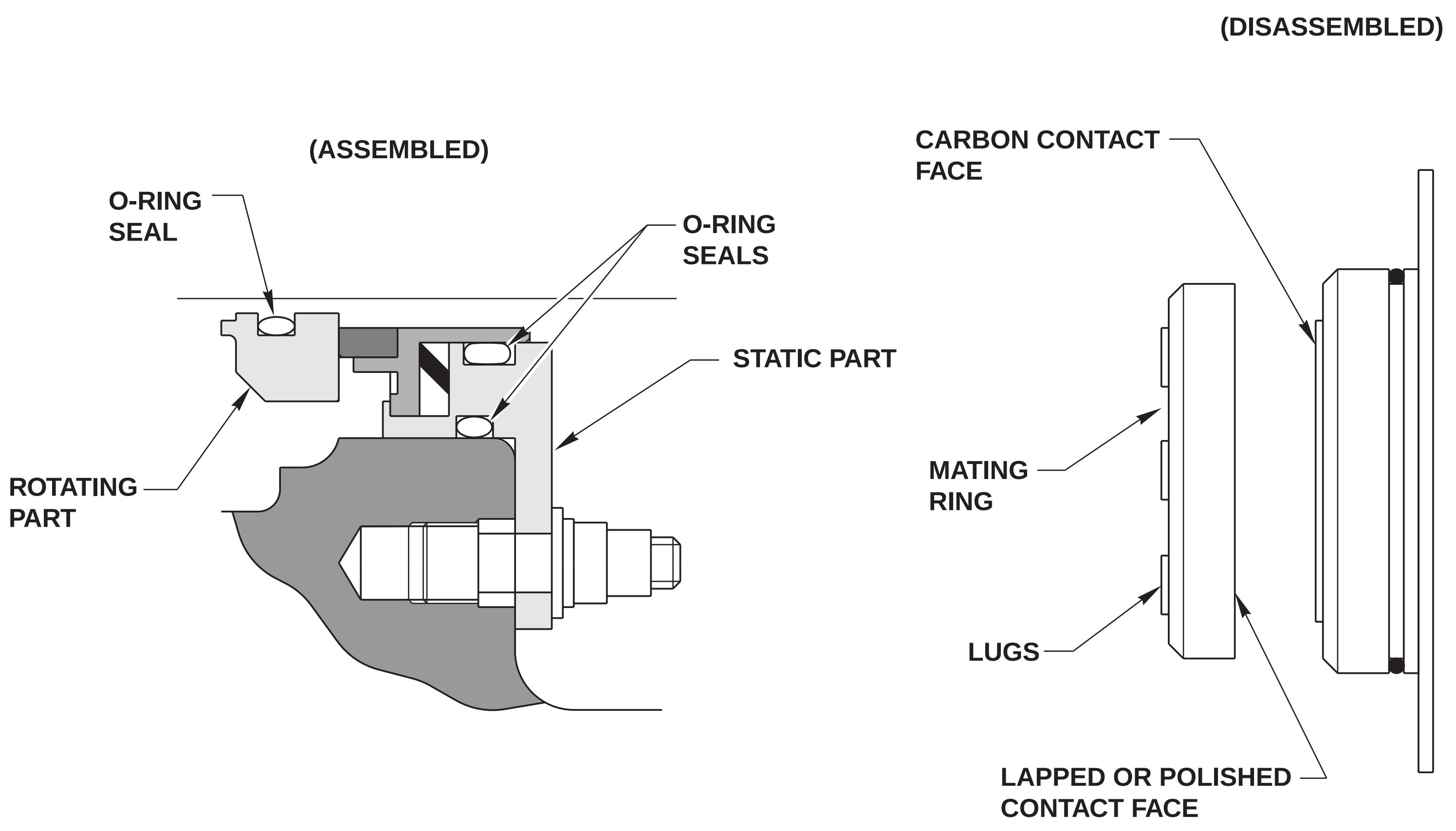
Spring-loaded seals

The spring-loaded seal is made up of carbon packing and a rotating mating ring with a polished face.

The rotating mating ring has 4 lugs that engage in corresponding slots machined in the gear shaft bearing.

A housing, which contains the spring-loaded seal, ensures constant contact between the polished face and the carbon seal element.

This seal type can be used on the following drive pads :
- Integrated Drive Generator (IDG)
- Hydraulic pump
- Starter
- Fuel pump



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SPRING LOADED SEAL

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