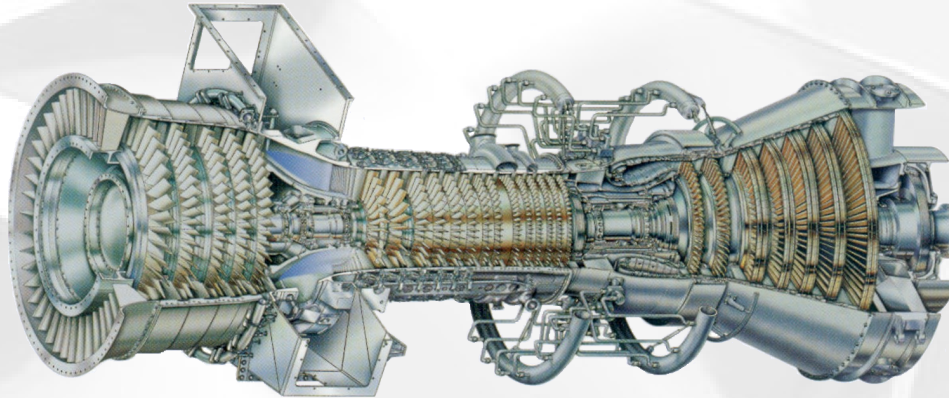


TECHNICAL TRAINING

Basic Training



Industrial Gas Turbine

LM6000

TECHNICAL TRAINING

Table of contents

- 1. Abbreviations and acronyms**
- 2. Gas turbine basics**
- 3. Introduction to the LM6000**
- 4. Major components of the LM6000**
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB, TGB, IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
- 5. Parasitic Air Flow**
- 6. Auxiliary equipment and system**
 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

TECHNICAL TRAINING

Table of contents

- 1. Abbreviations and acronyms**
- 2. Gas turbine basics**
- 3. Introduction to the LM6000**
- 4. Major components of the LM6000**
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
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1. ABBREVIATIONS AND ACRONYMS 1/5

abs	Absolute	CG	Center of Gravity
AC	Alternating Current	cm	Centimeter
AGB	Accessory Gearbox	cm²	Square Centimeter
ALF	Aft Looking Forward	cm³	Cubic Centimeters
amp	Ampere	CRF	Compressor Rear Frame
Assy	Assembly	CRFV	Compressor Rear Frame Flange
		Accelerometer	
b	Bar	CW	Clockwise
B (beta)	Variable Stator Position		
bhp	Brake Horsepower	DC	Direct Current
Blisk	Blade/Disc Combination	Dia	Diameter
Btu	British Thermal Unit	Dim	Dimension
		DLE	Dry Low Emission
°C	Degrees Centigrade (Celsius)	-dPS3/dt	Negative Rate of Change of Discharge
cc	Cubic Centimeter	Compressor Static Pressure	
CCW	Counterclockwise		
CDP	Compressor Discharge Pressure	ECU	Electronic Control Unit
CFF	Compressor Front Frame	ELBO	Lean Blow-Out
		EMU	Engine Maintenance Unit

1. ABBREVIATIONS AND ACRONYMS 2/5

°F	Degrees Fahrenheit	HPCS	High Pressure Compressor Stator
FIR	Full Indicator Reading	HPT	High Pressure Turbine
FMP	Fuel Manifold Pressure	HPTR	High Pressure Turbine Rotor
FOD	Foreign Object Damage	hr	Hour
ft	Foot or Feet	Hz	Hertz
ft²	Square Foot or Feet		
FWD	Forward	ID	Inside Diameter
		IGB	Inlet Gearbox
g	Gram	IGHP	Isentropic Gas Horsepower
gal	Gallon	IGKW	Isentropic Gas Kilowatt
GEK	GEAE Publication Identification Number	IGV	Inlet Guide Vane
GG	Gas Generator	in	Inch
GT	Gas Turbine	in²	Square Inch
Hg	Mercury	in³	Cubic inch
Horiz	Horizontal	IPB	Illustrated Parts Breakdown
hp	Horsepower		
HP	High Pressure	J	Joules
HPC	High Pressure Compressor		
HPCR	High Pressure Compressor Rotor	kg	kilogram

1. ABBREVIATIONS AND ACRONYMS 3/5

kcal	Kilocalorie	mm	Millimeter
kg cm	Kilogram-centimeter	MW	Megawatts
kg m	Kilogram-meter		
kJ	Kilojoules	N	Newton
kPa	Kilopascal	N•m	Newton-meter
kW	Kilowatt	No	Number
		NGG	Gas Generator Speed
l	Liter	NOx	Oxides of Nitrogen
lb	Pound	NPT	Power Turbine Speed
lb/ft²	Pound per Square Foot		
l/min	Liters per Minute	OAT	Outside Air Temperature
l/sec	Liters per Second	OD	Outside Diameter
LVDT	Linear-Variable Differential Transformer	OGV	Outlet Guide Vane
LPC	Low Pressure Compressor	oz	Ounce
LPT	Low Pressure Turbine		
		Pa	Pascal
m	Meter	P_{amb}	Ambient Pressure
m³	Cubic Meter	PCB	Printed Circuit Board
mA	Milliampere	PCR	Publications Change Request
Max	Maximum	PN	Part Number
Min	Minimum		

1. ABBREVIATIONS AND ACRONYMS 4/5

ppm	Parts per Million	Standard	atm
Prcp	High Pressure Recoup Pressure	Atmosphere	
PS3	High Pressure Compressor Discharge Static Pressure	Surf	Surface
PT	Power Turbine	SWP	Subordinate Work Package
PT4.8	LP Turbine Inlet Total Pressure	T_{amb}	Ambient Temperature
P0	Gas Turbine Inlet Pressure	TAN	Total Acid Number
P2	Compressor Inlet Total Pressure	TBP	To Be Provided
qt	Quart	T/C	Thermocouple
rpm	Revolutions per Minute	Temp	Temperature
RTD	Resistance Temperature Detector	TGB	Transfer Gearbox
sec	Second	theta 2	Ratio of Measured Absolute Gas Turbine Inlet Absolute Temperature to Standard Day Absolute Temperature
SG	Specific Gravity	TMF	Turbine Mid Frame
shp	Shaft Horsepower	TRF	Turbine Rear Frame Accelerometer
SI	Metric System	TRFV	Turbine Rear Frame Flange Accelerometer
S/O	Shutoff	T2	Compressor Inlet Total Temperature

1. ABBREVIATIONS AND ACRONYMS 5/5

T3 Compressor Discharge Temperature
T4.8 LP Turbine Inlet Temperature

UV Ultra Violet

v Volt

vac Volts, Alternating Current

VG Variable-Geometry

VSV Variable Stator Vanes

WP Work Package

TECHNICAL TRAINING

Table of contents

1. Abbreviations and acronyms
- 2. Gas turbine basics**
3. Introduction to the LM6000
4. Major components of the LM6000
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB, TGB, IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
5. Parasitic Air Flow
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 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

2. GAS TURBINE BASICS

Direction of view

The following points of reference are used throughout this training and are defined as follows:

- * Forward – the air intake end of the engine
- * Aft – the exhaust end of the engine
- * Right – the right side of the engine, when viewed from the aft end and when the engine is in the normal operating position (gearbox down)
- * Left – the side opposite the right side
- * Top – the side of the engine that is up when the engine is in the normal operating position
- * Bottom – the side of the engine on which the gearboxes are mounted

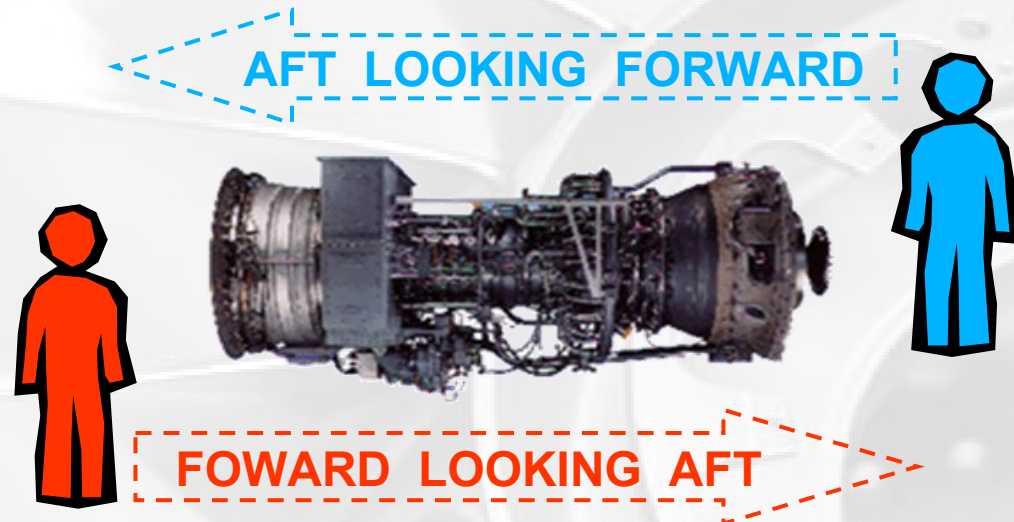
2. GAS TURBINE BASICS

Direction of view

ALF versus FLA

All references to location or position on the LM6000 are based on the assumption that the individual is standing behind the engine and looking forward. This is true in all cases unless stated otherwise.

Unless other wise stated, all views in this training manual are from the left side of the engine, with the intake on the observers left and the exhaust on the right.



2. GAS TURBINE BASICS

The clock positions

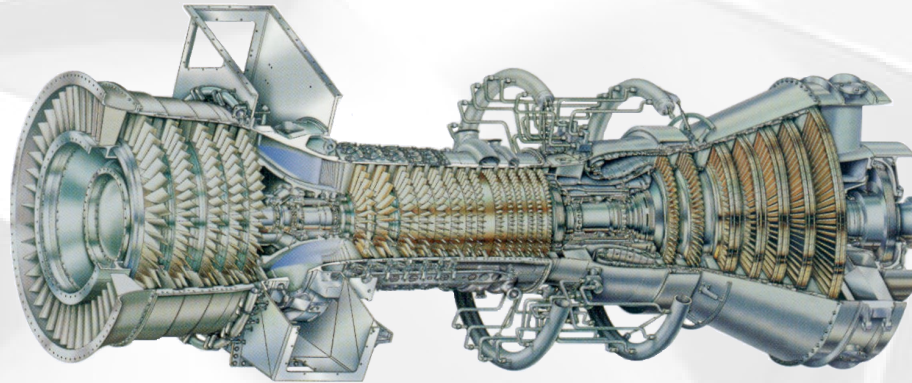
Clock positions are the positions of the numbers of a clock face, as seen from aft looking forward:

- * 12:00 o'clock is at the top
- * 03:00 o'clock is on the right side
- * 06:00 o'clock is at the bottom
- * 09:00 o'clock is on the left side.



2. GAS TURBINE BASICS

History of development



Industrial Gas Turbine

LM6000

2. GAS TURBINE BASICS

History of development



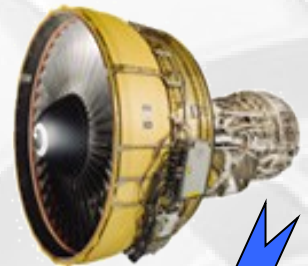
TF39



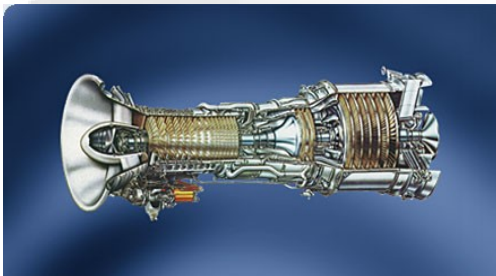
CF6-6



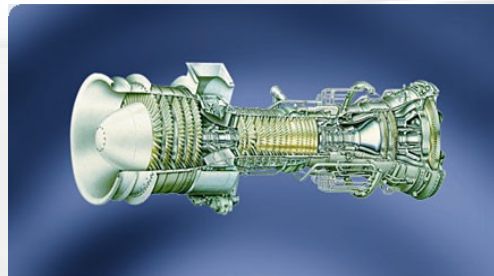
CF6-50



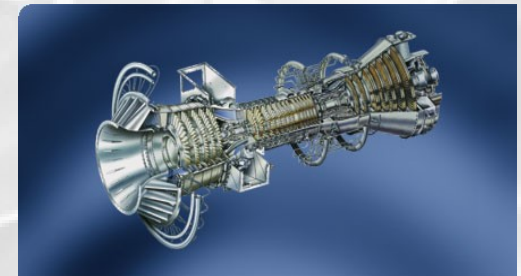
CF6-80



LM2500



LM5000



LM6000

2. GAS TURBINE BASICS

History of development

Heritage: CF6-80C2 Aircraft Engine



**3,575
Engines
In Service**



**131.9 Million
Flight
Hours**



**31.9 Million
Flight
Cycles**



**99.97%
Departure
Reliability**



Data through January, 2007

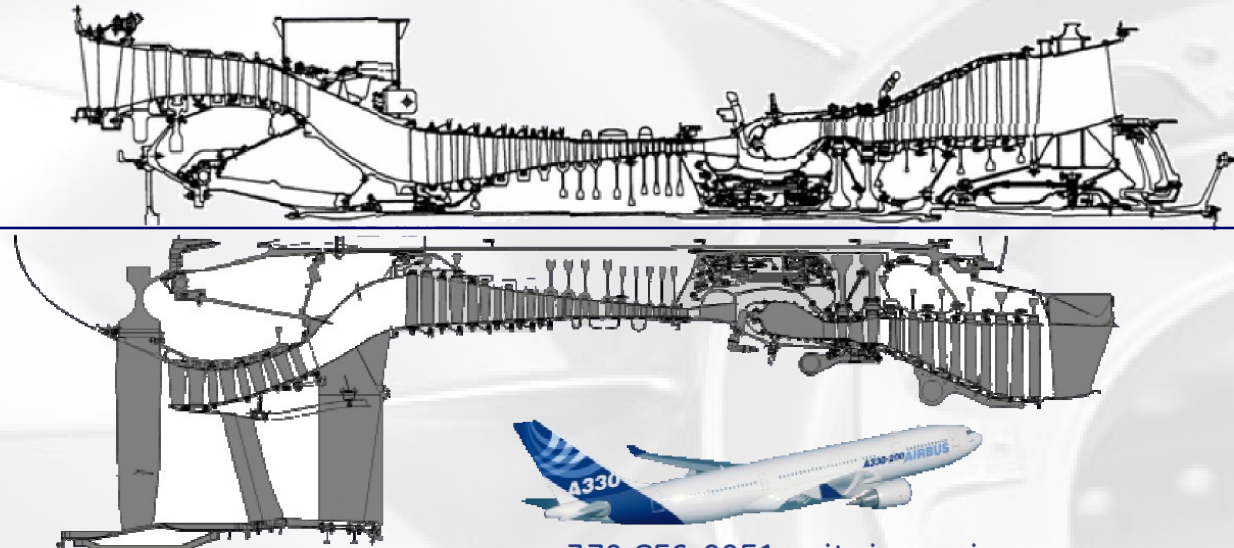
2. GAS TURBINE BASICS

History of development

The LM6000 industrial gas turbine, which derives from General Electric's CF6-80 aircraft engine, is used in variety of power generation applications.

MTU has been providing maintenance services for this type of gas turbine since 1996.

LM6000PA



CF6-80

370 CF6-80E1 units in service on
Airbus A330 with 5M hours

2. GAS TURBINE BASICS

History of development

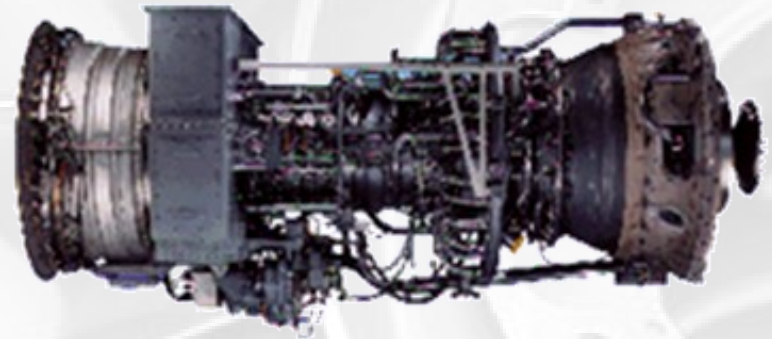


CF6-80C2

Introduced: 1985
Units in service: >3,500
Operating hours: >131,000,000

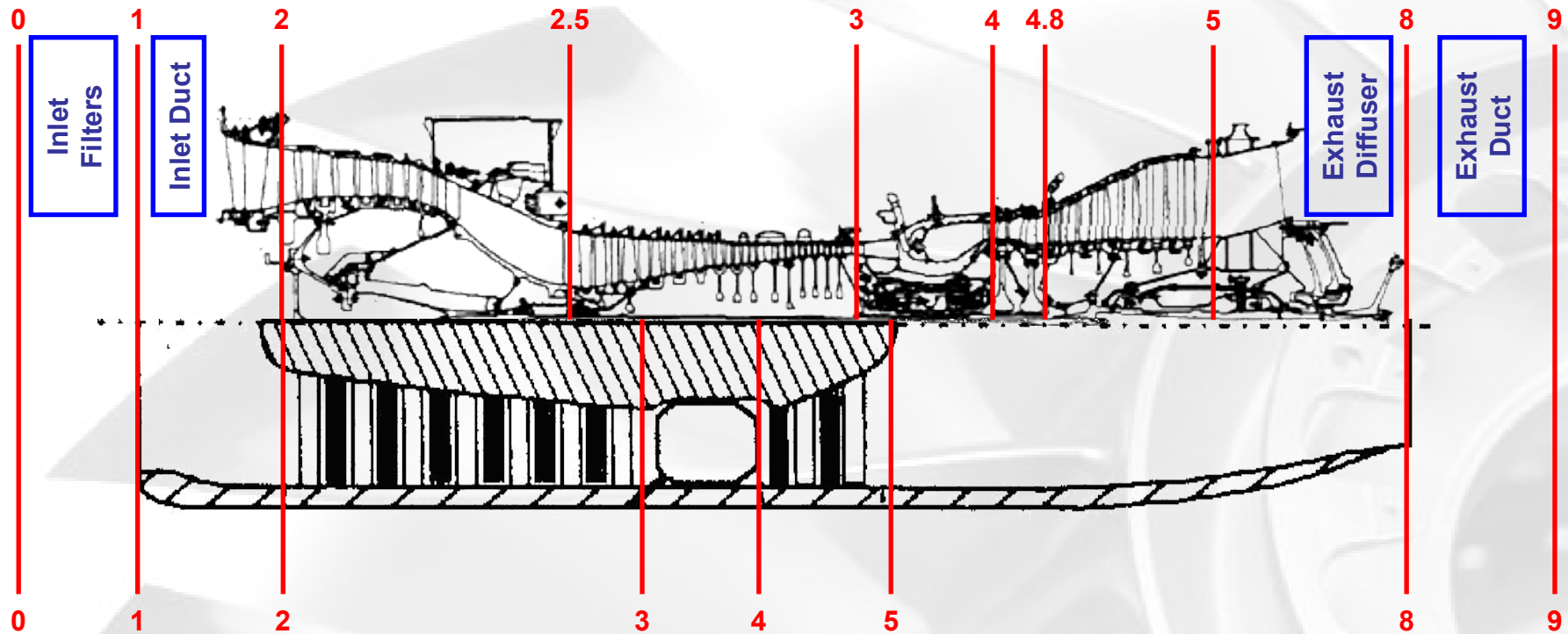
LM6000

Introduced: June 1990
Units in service: >925
Operating hours: >19,560,000
Reliability: 99.2 %
Availability: 97.4 %



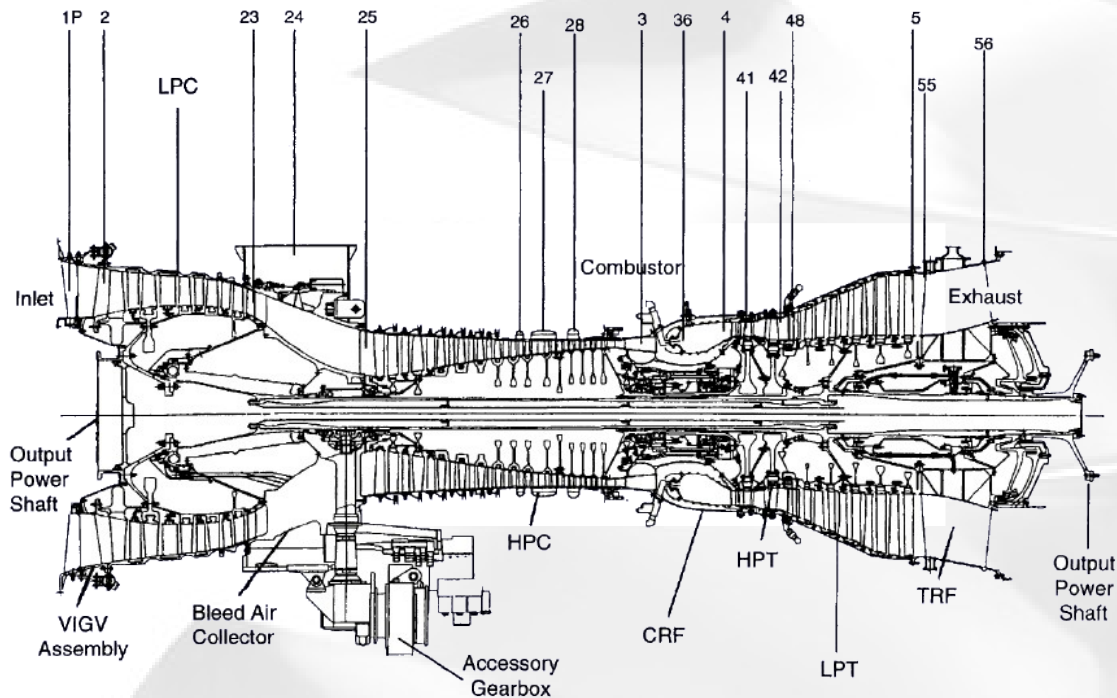
2. GAS TURBINE BASICS

Gas Turbine Stations



2. GAS TURBINE BASICS

Gas Turbine Stations



- 1P VIGV Inlet
- 2 LPC Inlet
- 2.3 LPC Outlet
- 2.4 LPC Bypass Bleed
- 2.5 HPC Inlet
- 2.6 HPC 7th Stage
- 2.7 HPC 8th Stage
- 2.8 HPC 11th Stage
- 3 HP CDP (Compressor Diffuser Exit)
- 3.6 Fuel Nozzle (Fuel Flow and Steam)
- 4 HPT 1st Stage Nozzle Inlet
- 4.1 HPT Rotor Inlet
- 4.2 HPT Rotor Exit
- 4.8 LPT Inlet
- 5 LPT Exit
- 5.5 LPT Rear Frame Strut Inlet
- 5.6 LPT Rear Frame Strut Exit/Diffuser Inlet

2. GAS TURBINE BASICS

Basic Engine and Systems

Power Cycle

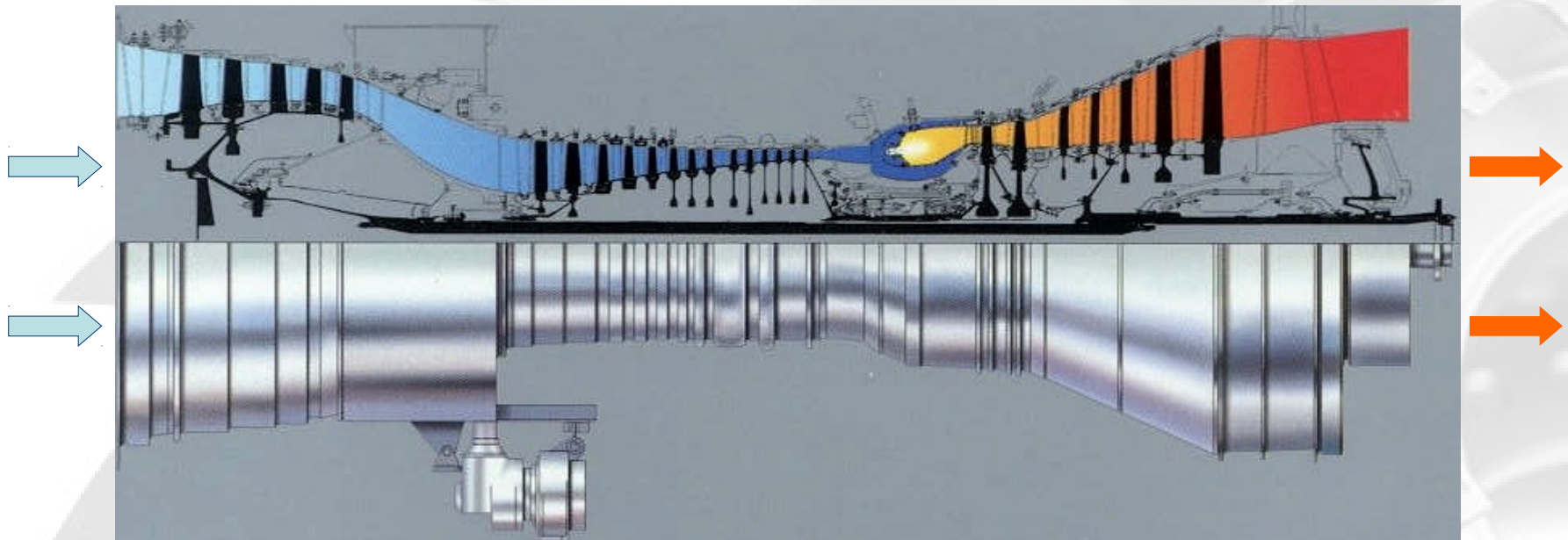
AIR INTAKE

COMPRESSION

COMBUSTION

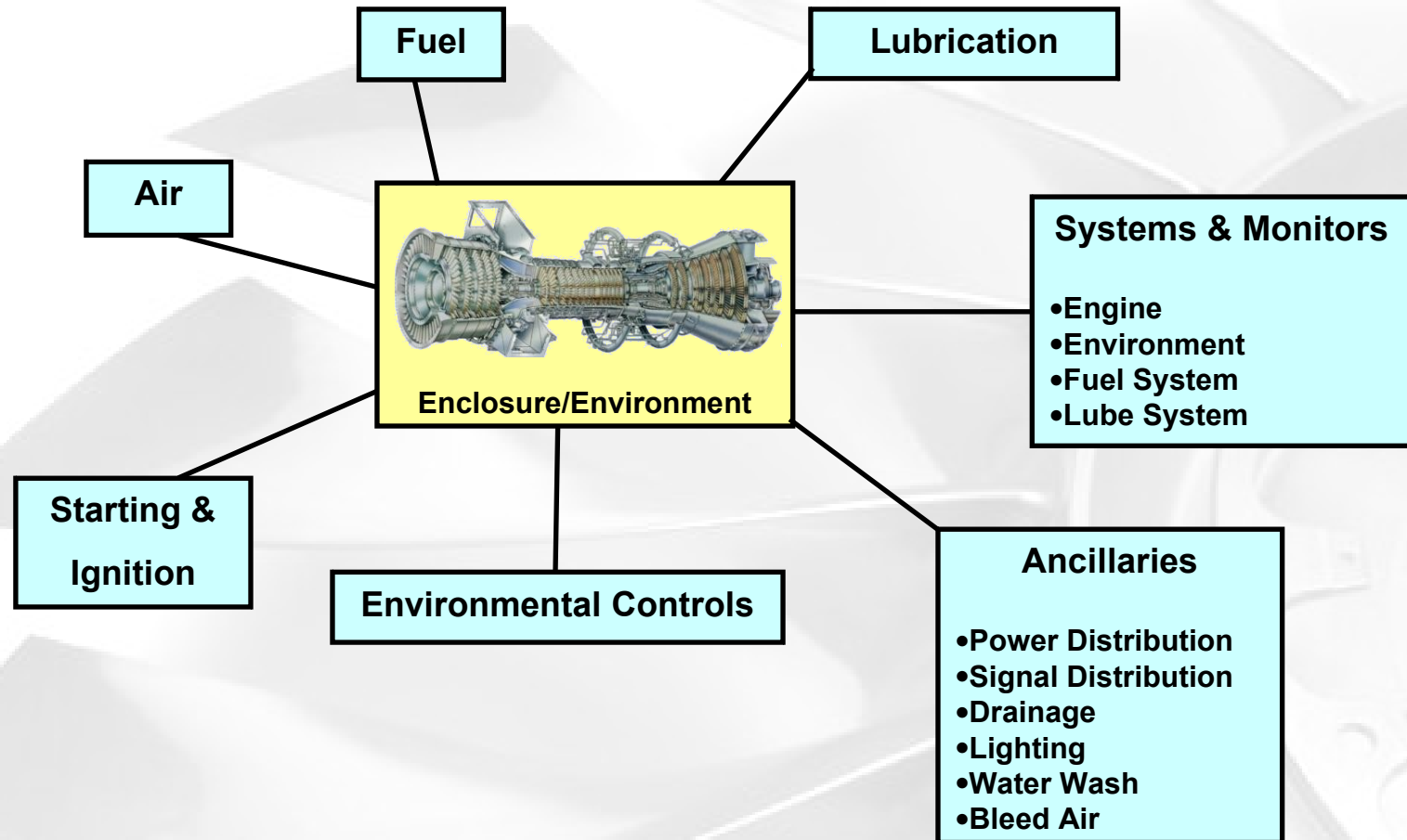
EXPANSION

EXHAUST



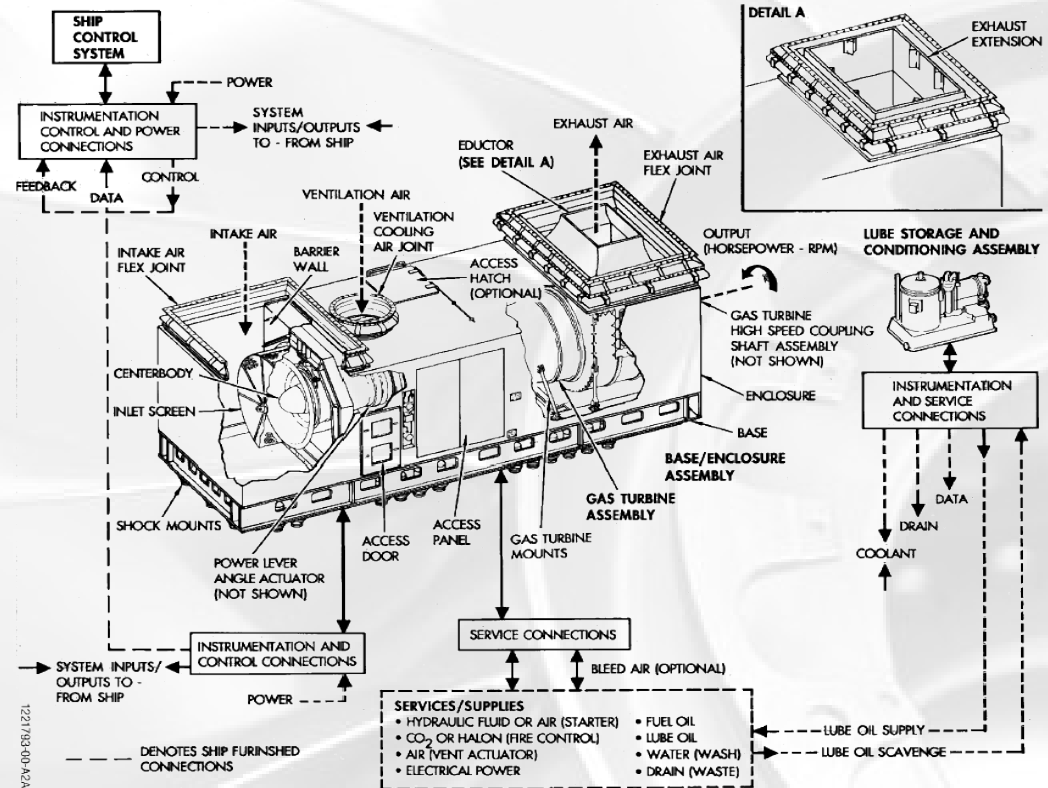
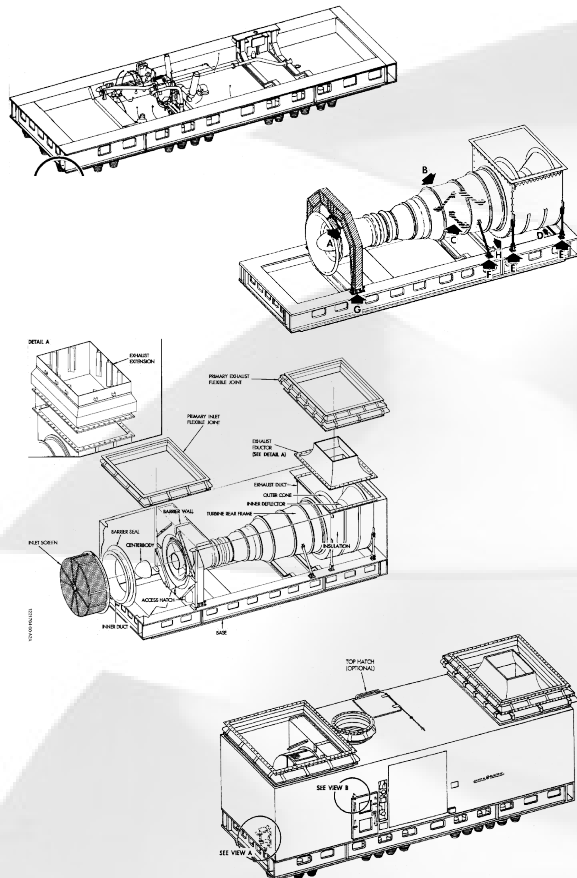
2. GAS TURBINE BASICS

Basic Engine Systems



2. GAS TURBINE BASICS

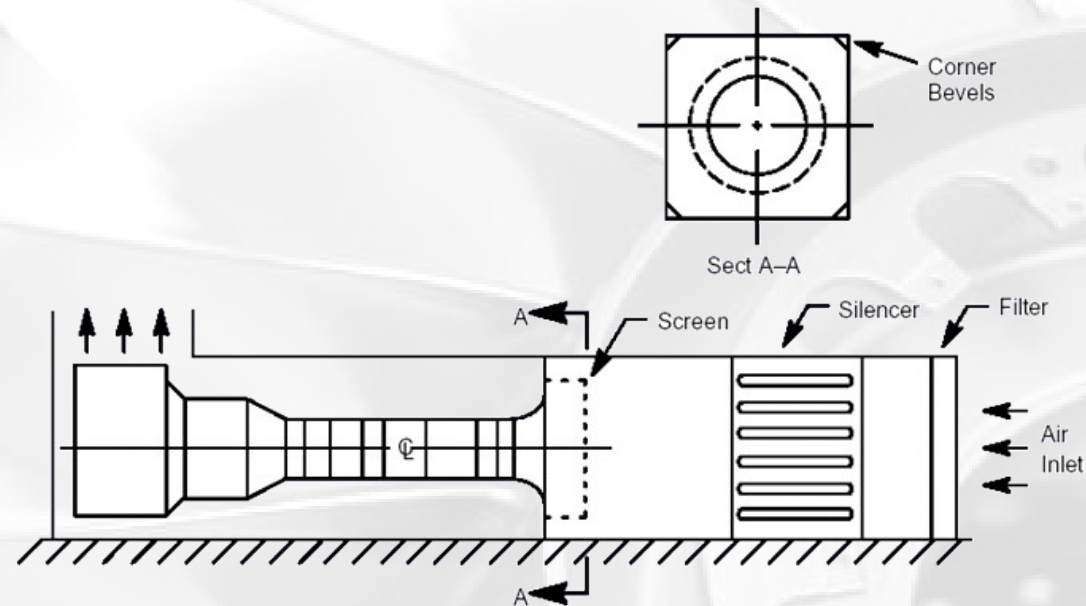
Gas Turbine Package



2. GAS TURBINE BASICS

Gas Turbine Package

- There are two basic inlet system designs for the LM6000. A radial scroll inlet is required for a front drive application and may be used with a rear drive configuration. An axial inlet with a bellmouth and centerbody can only be used for a rear drive application.

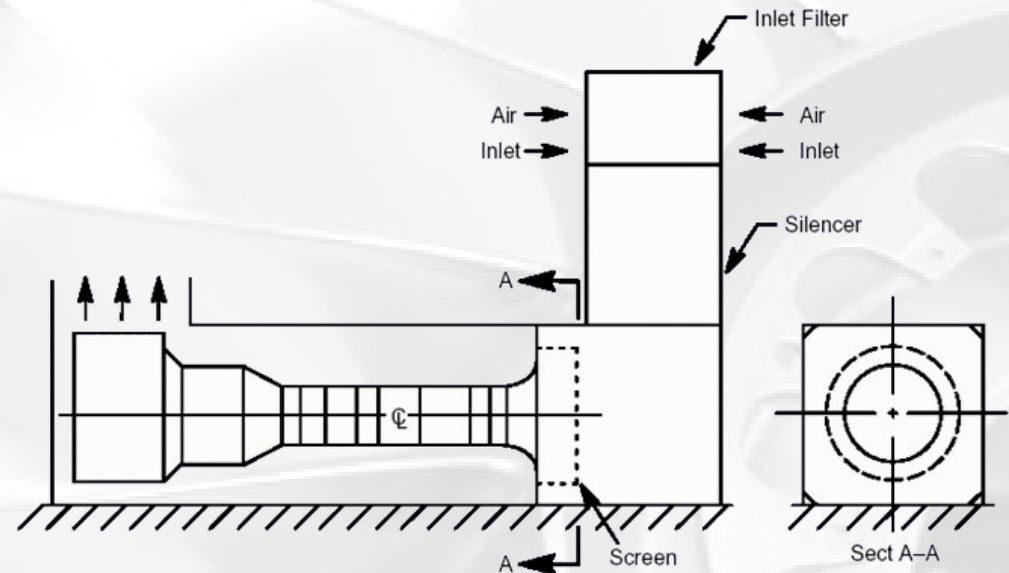


Axial Flow Inlet - Configuration 1

2. GAS TURBINE BASICS

Gas Turbine Package

- The air inlet system should be designed with a minimum number of bends and obstructions. The inlet plenum in front of the gas turbine should be designed so that the inlet air enters as parallel to the gas turbine centerline as possible.



Note: Inlet duct may be oriented to right, left or down as well as up as shown

Axial Flow Inlet - Configuration 2

2. GAS TURBINE BASICS

Gas Turbine Package

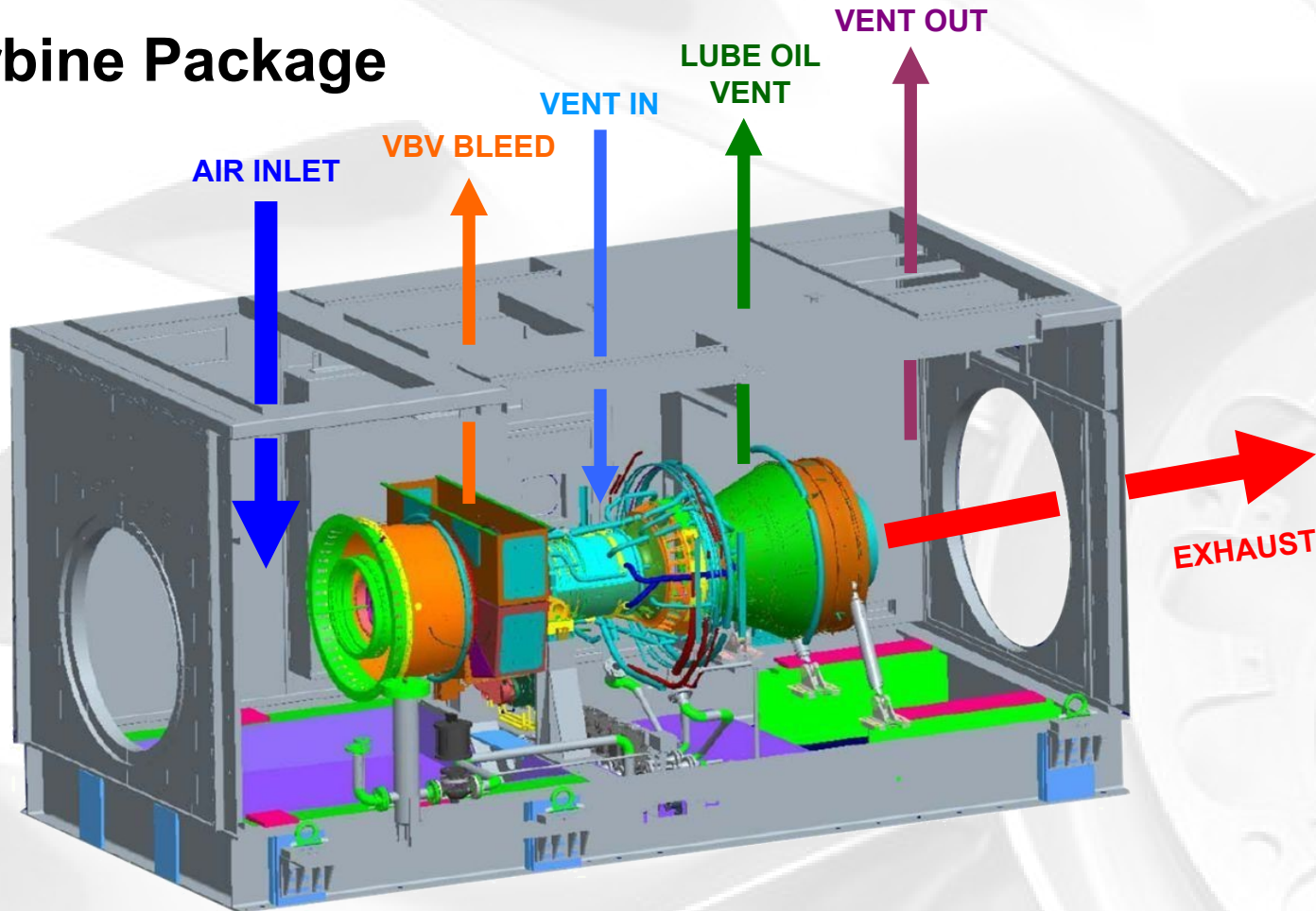
Several items must be considered in the design of an air inlet system for the LM6000 gas turbine.

A successful design will:

- Minimize inlet pressure loss because of the effect on gas turbine performance.
- Minimize pressure gradients and swirl at the face of the variable inlet guide vane (VIGV) and low pressure compressor (LPC) to reduce distortion and the risk of aero-mechanical excitation of compressor flowpath components.
- Incorporate an inlet screen ahead of the VIGV and LPC to protect the compressor flowpath components from foreign object ingestion. The design of the inlet screen is critical and must consider airflow pressure loss, screen mechanical integrity, and aero-mechanical excitation of compressor flowpath components due to air flow distortion from screen structure.
- Utilize quality inlet components so as not to generate foreign objects which may be ingested by the compressor and result in severe damage to flowpath components.

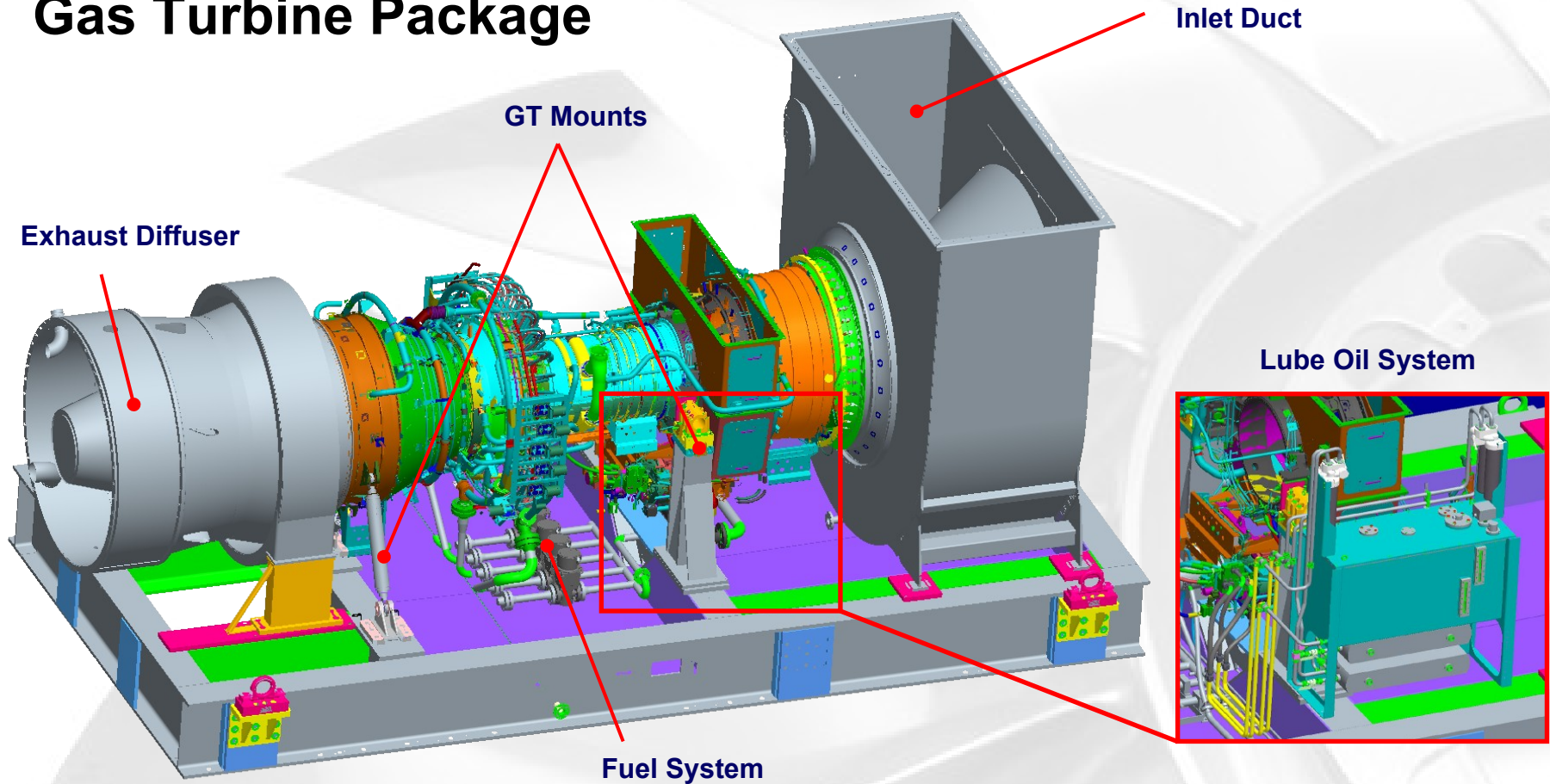
2. GAS TURBINE BASICS

Gas Turbine Package



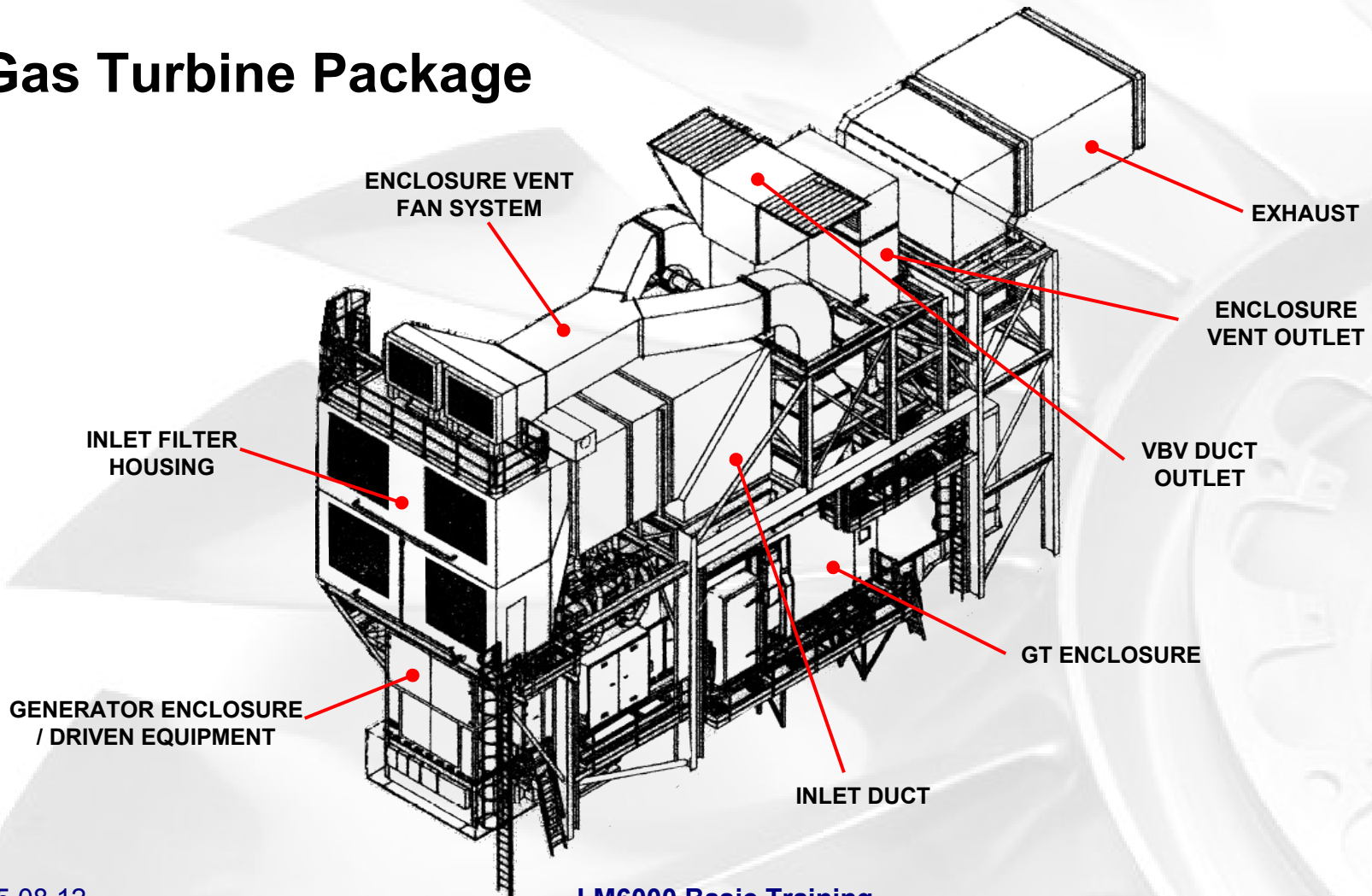
2. GAS TURBINE BASICS

Gas Turbine Package



2. GAS TURBINE BASICS

Gas Turbine Package



TECHNICAL TRAINING

Table of contents

1. Abbreviations and acronyms
2. Gas turbine basics
- 3. Introduction to the LM6000**
4. Major components of the LM6000
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB, TGB, IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
5. Parasitic Air Flow
6. Auxiliary equipment and system
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 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

3. INTRODUCTION TO THE LM6000

General Description

- LM6000 Gas Turbines consists of two types of machines, one to put air in motion and one to convert this airflow into rotational torque to do work.
- The air mover normally called “core engine” and the flow converter (to rational torque) is named low pressure turbine (LPT).
- In the LM6000 the turbine that rotates the LPC rotates both the LPC and the load. Consequently, it retains the title “LPT” even though this LPT also drives the load. In other words, there is technically no power turbine in the LM6000.
- This is just one of the factors that make the LM6000 40% efficient versus the 25% efficiency of most other gas turbines. But taking more kinetic energy out of the gas path means lower temperature exhaust flow.

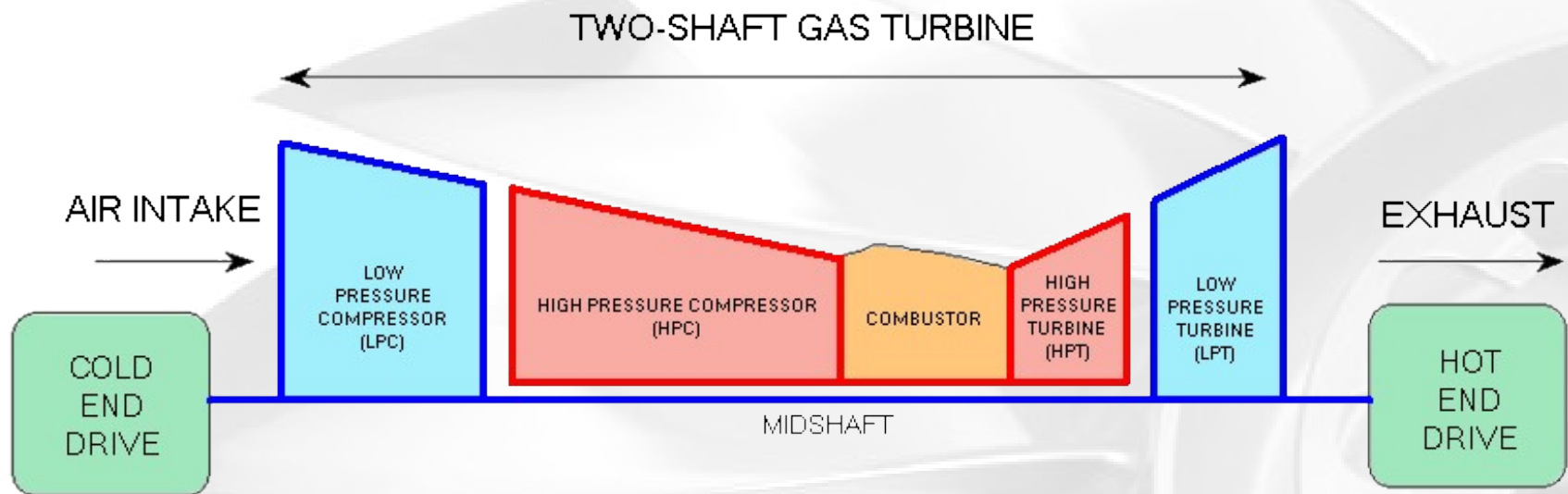
3. INTRODUCTION TO THE LM6000

General Description

- There are two sections, core engine or high pressure (HP) system and low pressure (LP) system. The LP system compresses to a lower pressure so it will operate at a lower rpm than the HP system.
- On some applications the specific rpm will be dictated by the load (e.g. 3,600 for 60Hz cogeneration and 3,300 for natural gas compression). It is important that the operator knows the correct load rpm has been achieved. A redundant speed sensor system indicates LP RPM as XN2.
- Because a gas turbine is a high speed machine, it is sensitive to conditions causing imbalance within the two rotors for each system. The engine is equipped with two accelerometers, one on the compressor rear frame (CRF) and one on the turbine rear frame (TRF). These accelerometers provide protection against self-induced synchronous vibration. Each sensor is capable of monitoring both high-speed and low-speed rotor vibration levels.

3. INTRODUCTION TO THE LM6000

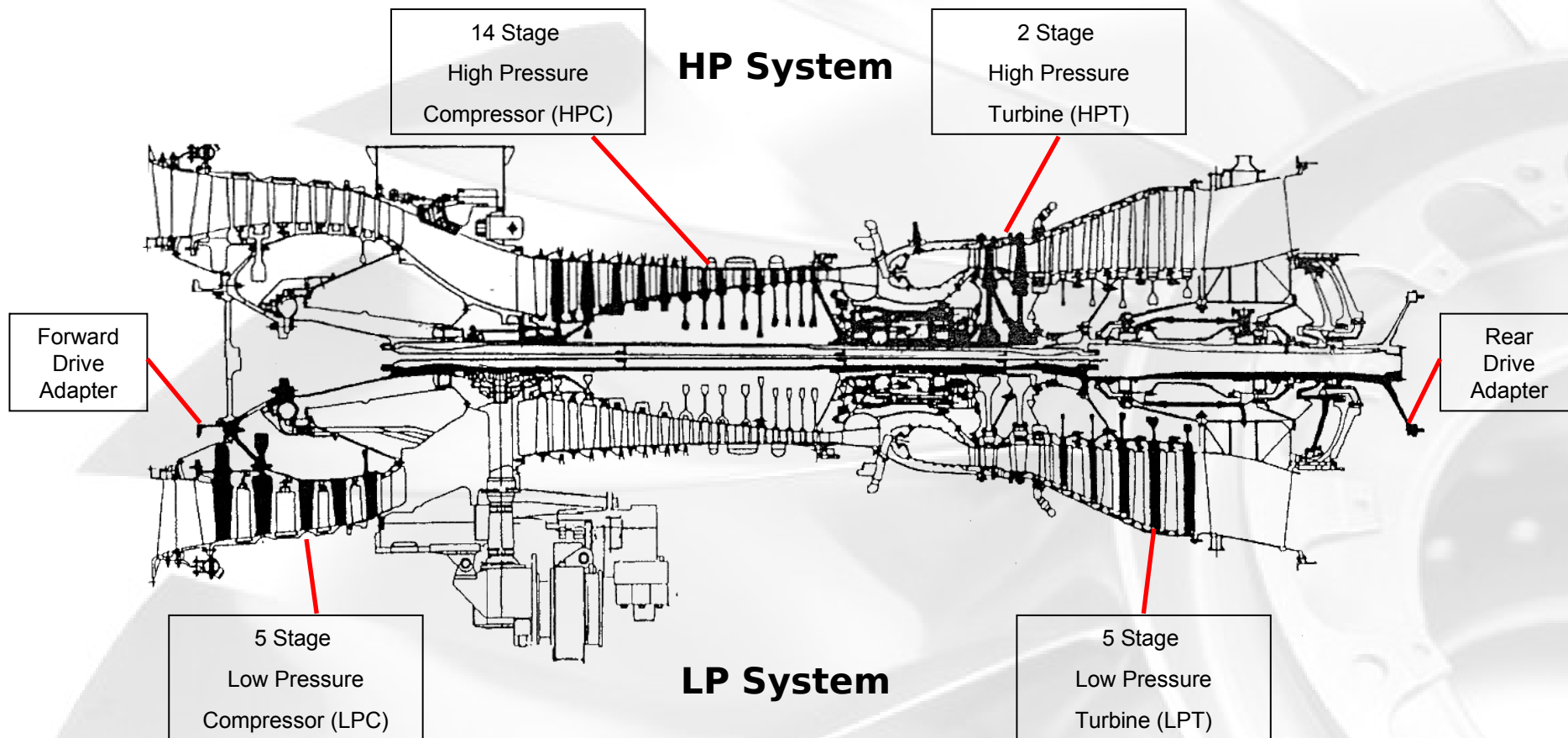
General Description



- Two Shaft Rotor System
- HPT drives HPC
- LPT drives LPC and load (cold or hot end drive)
- No separate Power Turbine necessary

3. INTRODUCTION TO THE LM6000

General Description



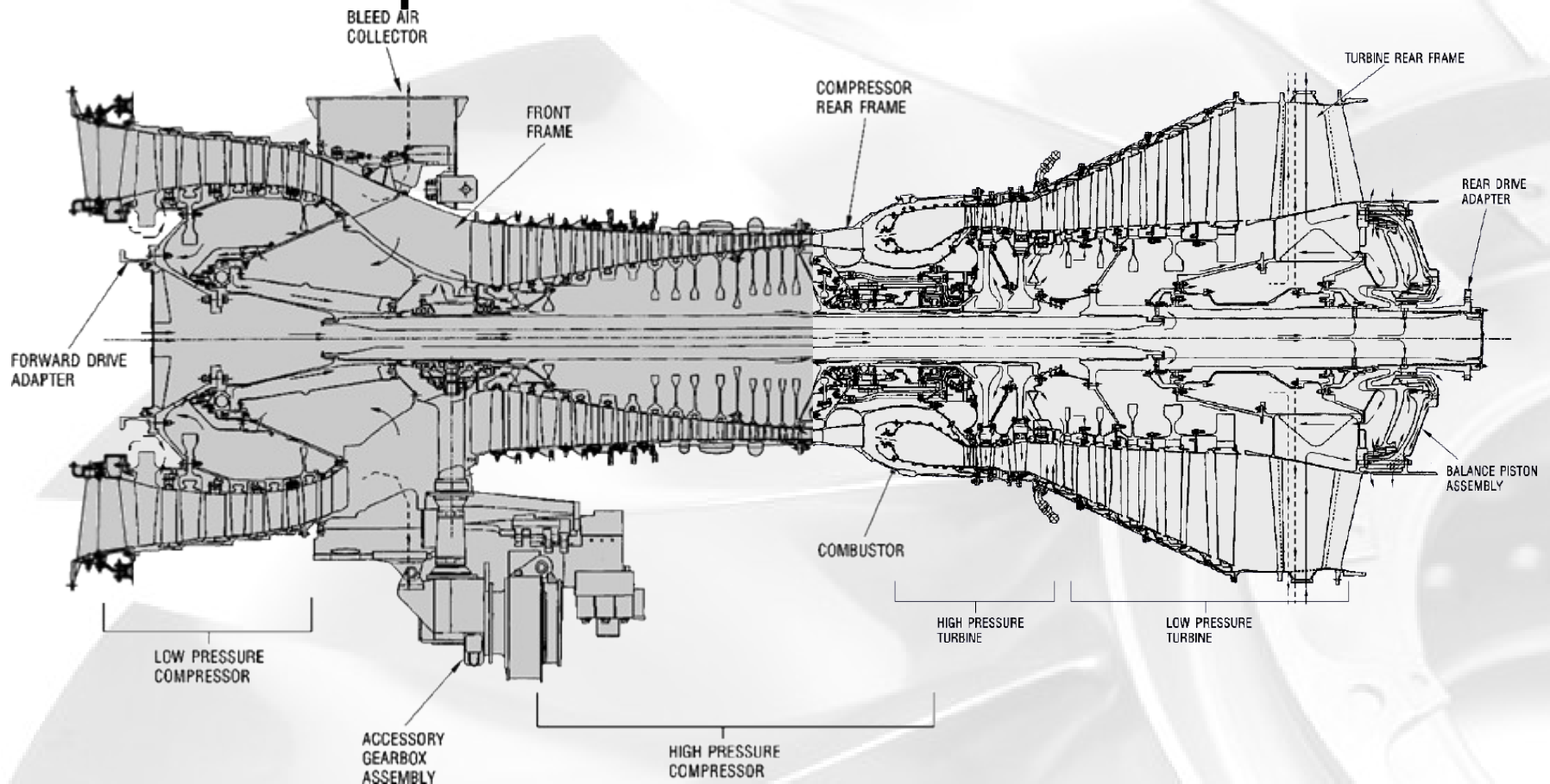
3. INTRODUCTION TO THE LM6000

General Description

- The LM6000 Gas Turbine is a two shaft machine capable of driving a load from either the front or rear of the low pressure rotor (LPR).
- The dual-rotor gas turbine consists of a variable inlet guide vane (VIGV) or inlet frame assembly, a 5-stage low pressure compressor (LPC), a 14-stage high pressure compressor (HPC), either a single annular combustor (SAC) or a dry low emission combustor (DLE), a 2-stage high pressure turbine (HPT), a 5-stage low pressure turbine (LPT), a transfer gearbox (TGB)/ accessory gearbox assembly (AGB), and accessories, such as oil pumps, starter motor etc.
- The engine compresses the air to a ratio of approximately 30:1 relative to ambient.

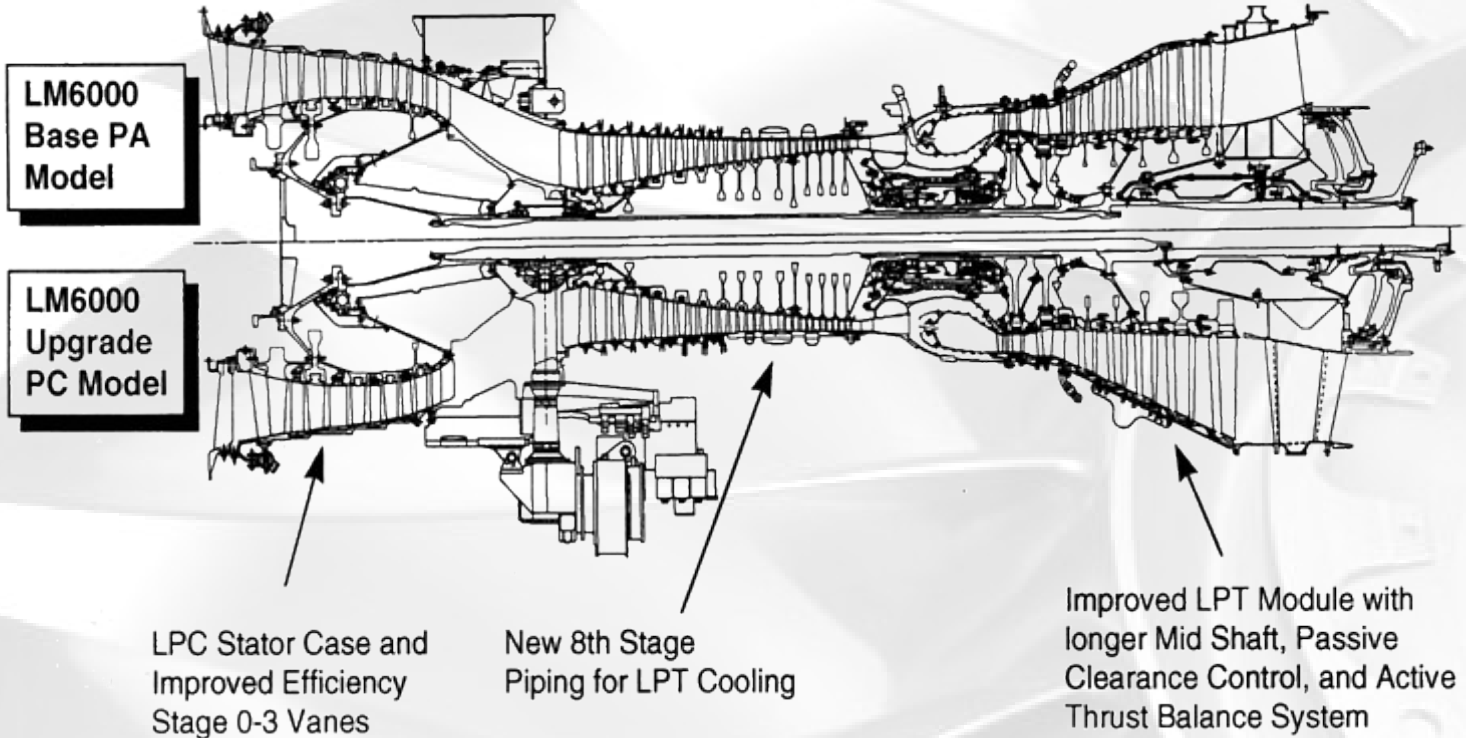
3. INTRODUCTION TO THE LM6000

General Description



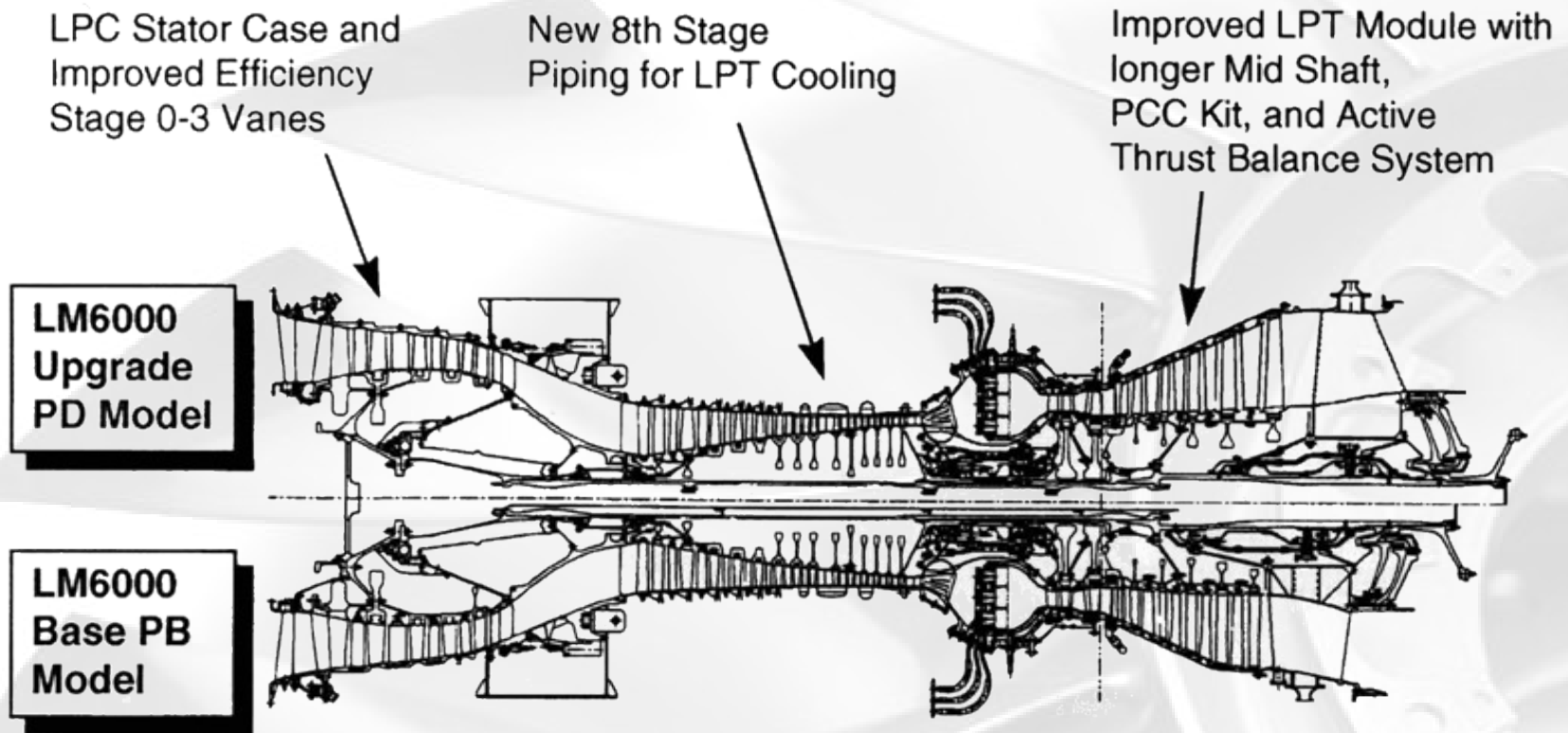
3. INTRODUCTION TO THE LM6000

General Description



3. INTRODUCTION TO THE LM6000

General Description



3. INTRODUCTION TO THE LM6000

General Description

Combustion System	ALL	SAC	DLE
Total Engines	939	718	220
Total Operating Hours	19,562,931	14,674,589	4,888,342
High Time Engine	113,725	113,725	107,735
Engines In Service	925	705	220
Total Operating Engines	702	560	142

Combustion System	Model	FUEL System	No. of Units Operating	Cumulative Hours	High Time Engine Hrs
DLE	LM6000 PB	Gas	13	817,544	107,735
	LM6000 PD	Dual	5	121,246	34,906
		Gas	118	3,044,291	79,149
	LM6000 PF	Gas	6	33,198	21,110
SAC	LM6000 PA	Dual	43	2,157,048	101,335
		Gas	36	2,284,544	102,829
		Liquid	15	395,319	78,877
	LM6000 PC	Dual	135	1,941,097	70,078
		Gas	309	4,772,313	86,303
		Liquid	20	260,245	49,719

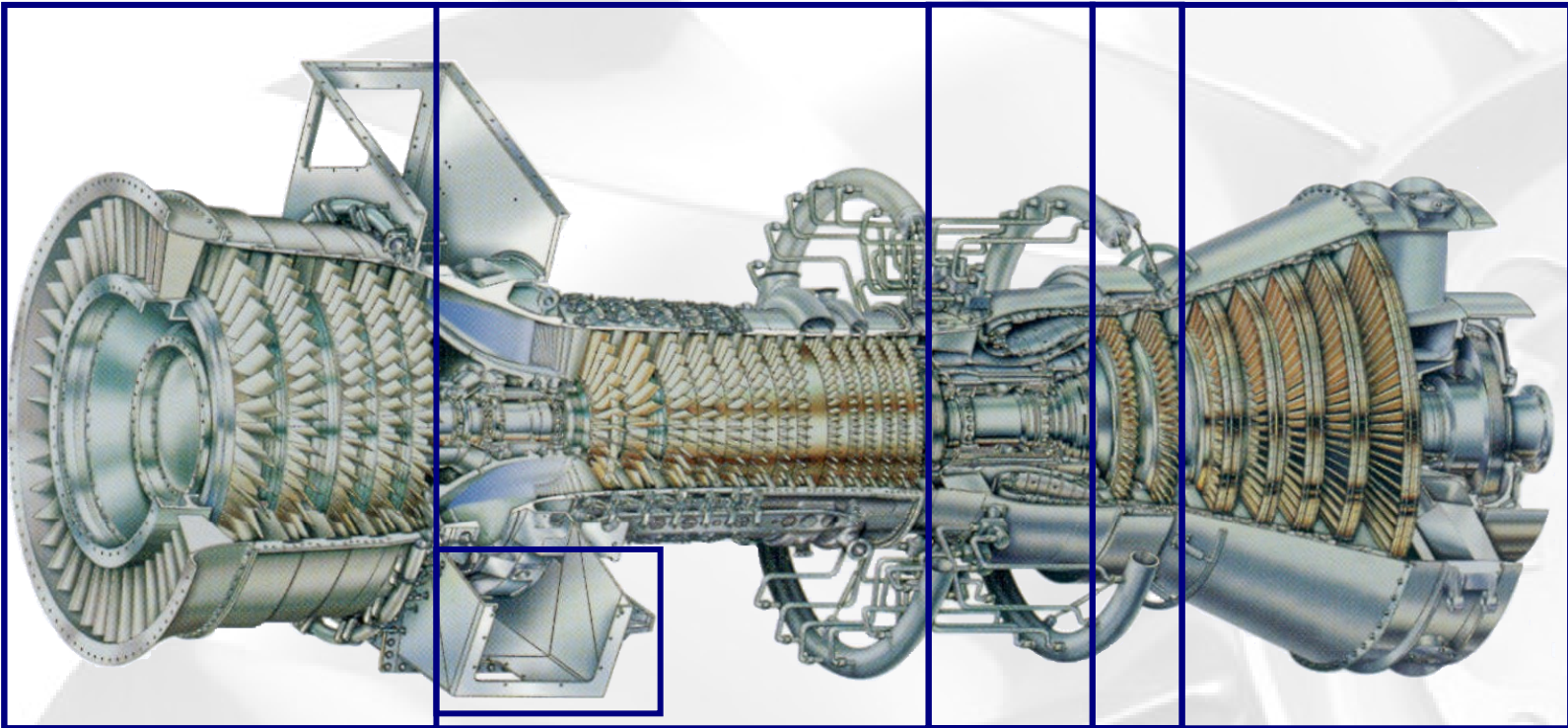
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TECHNICAL TRAINING

Table of contents

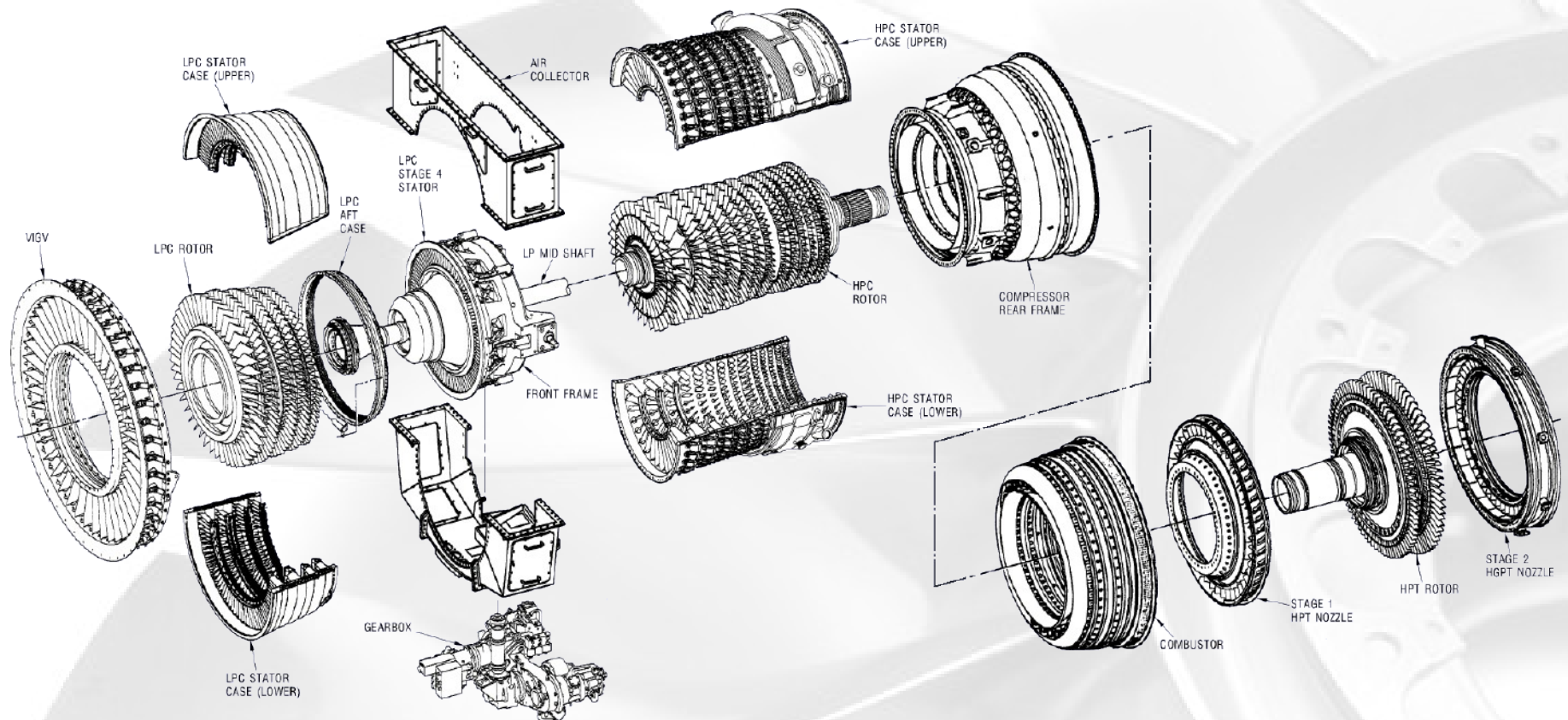
1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
- 4. Major components of the LM6000**
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
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 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
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 - c. Fuel, Water and Steam Systems
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 - e. Instrumentation

4. Major components of the LM6000



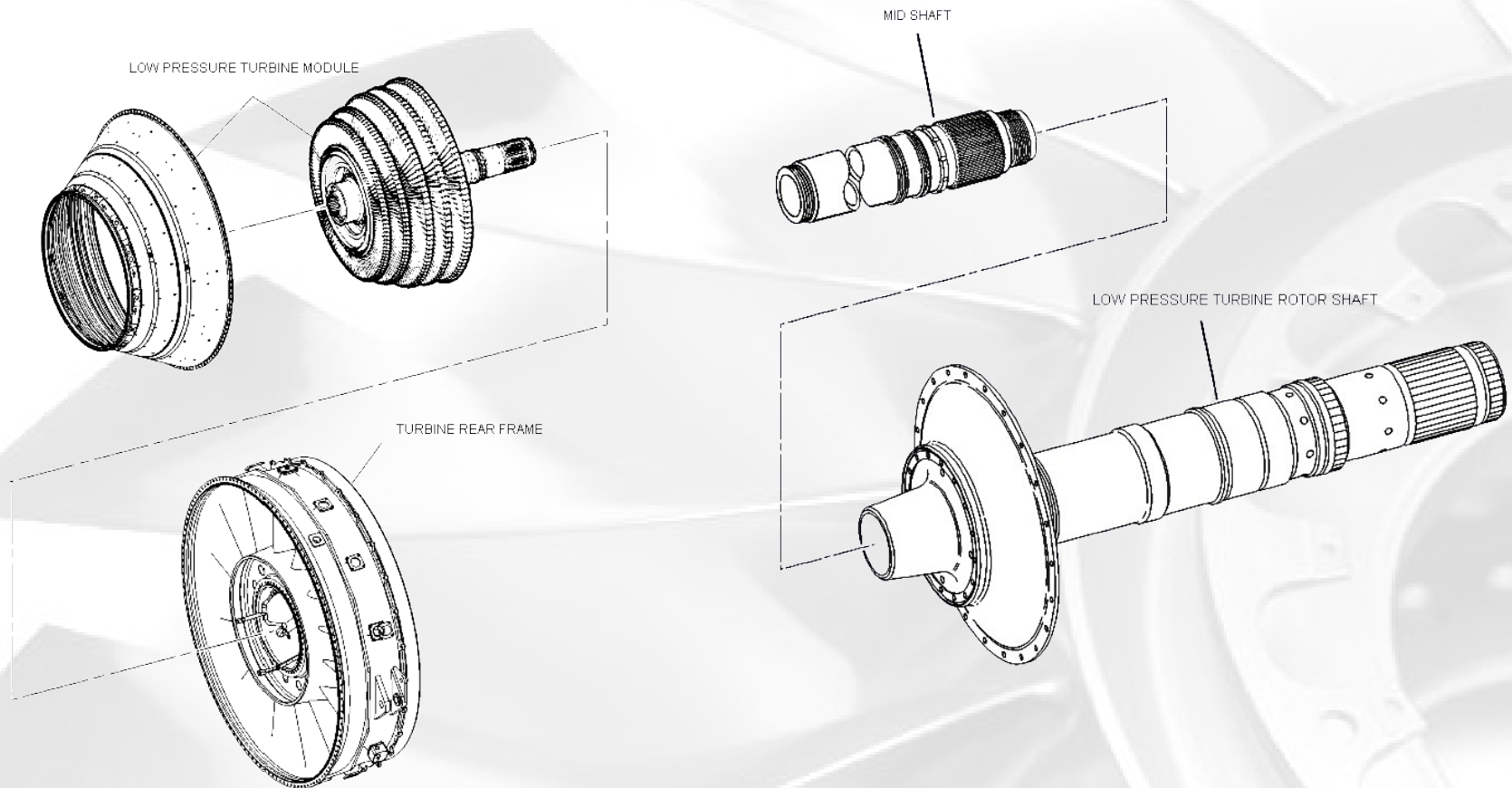
4. Major components of the LM6000

Modules overview



4. Major components of the LM6000

Modules overview



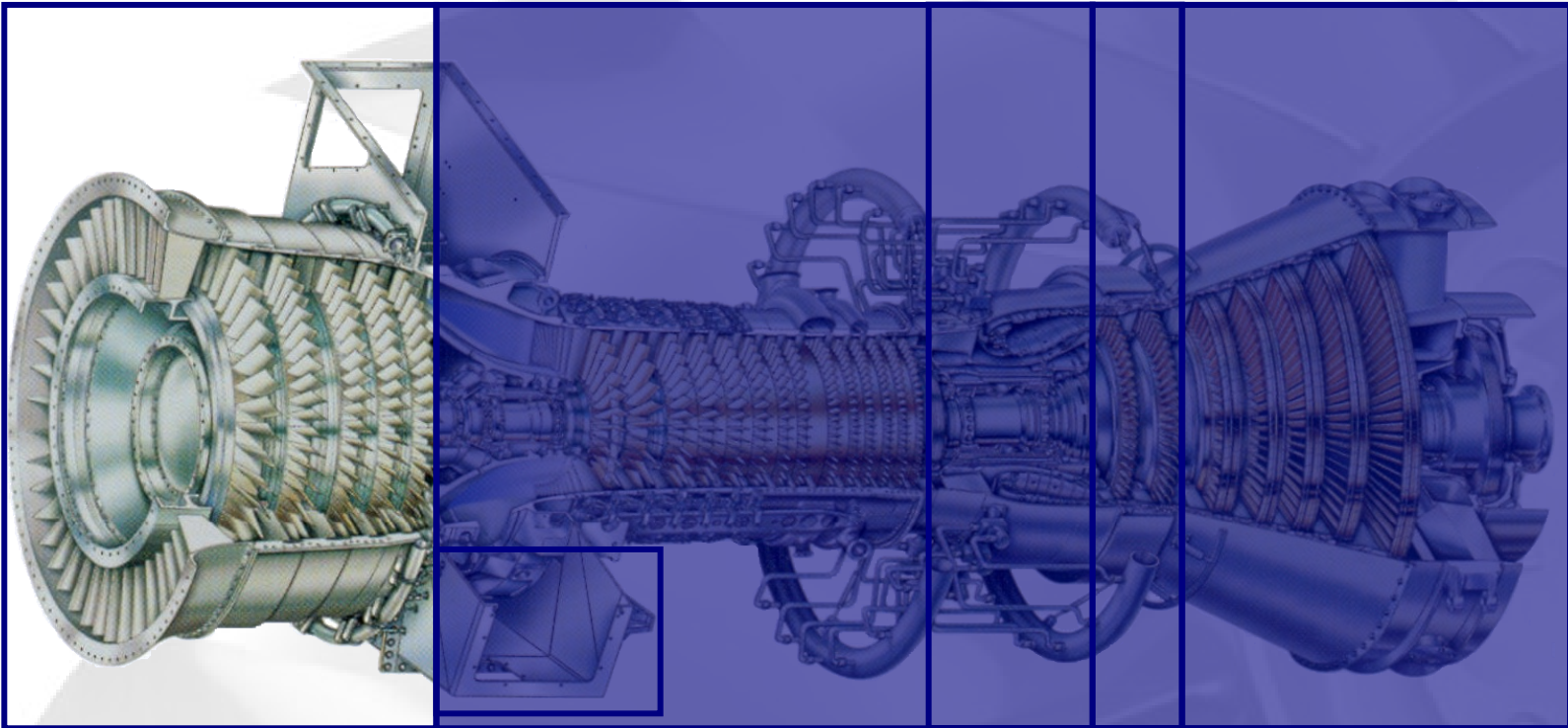
4. Major components of the LM6000

Table of contents

- | | |
|--|---|
| <ul style="list-style-type: none">1. Abbreviations and acronyms2. Gas turbine basics3. Introduction to the LM60004. Major components of the LM6000<ul style="list-style-type: none">a. Low Pressure Compressor (LPC)b. High Pressure Compressor (HPC)c. Combustord. High Pressure Turbine (HPT)e. Low Pressure Turbine (LPT)f. Accessory Drive (AGB, TGB, IGB)g. Engine Frames (CFF, CRF, TRF)h. Bearings and Sumps | <ul style="list-style-type: none">5. Parasitic Air Flow6. Auxiliary equipment and system<ul style="list-style-type: none">a. Lubrication Systemb. Variable Geometry Systemc. Fuel, Water and Steam Systemsd. Starting Systeme. Instrumentation |
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4. Major components of the LM6000

Low Pressure Compressor and Mid Shaft



4. Major components of the LM6000

Low Pressure Compressor (LPC)

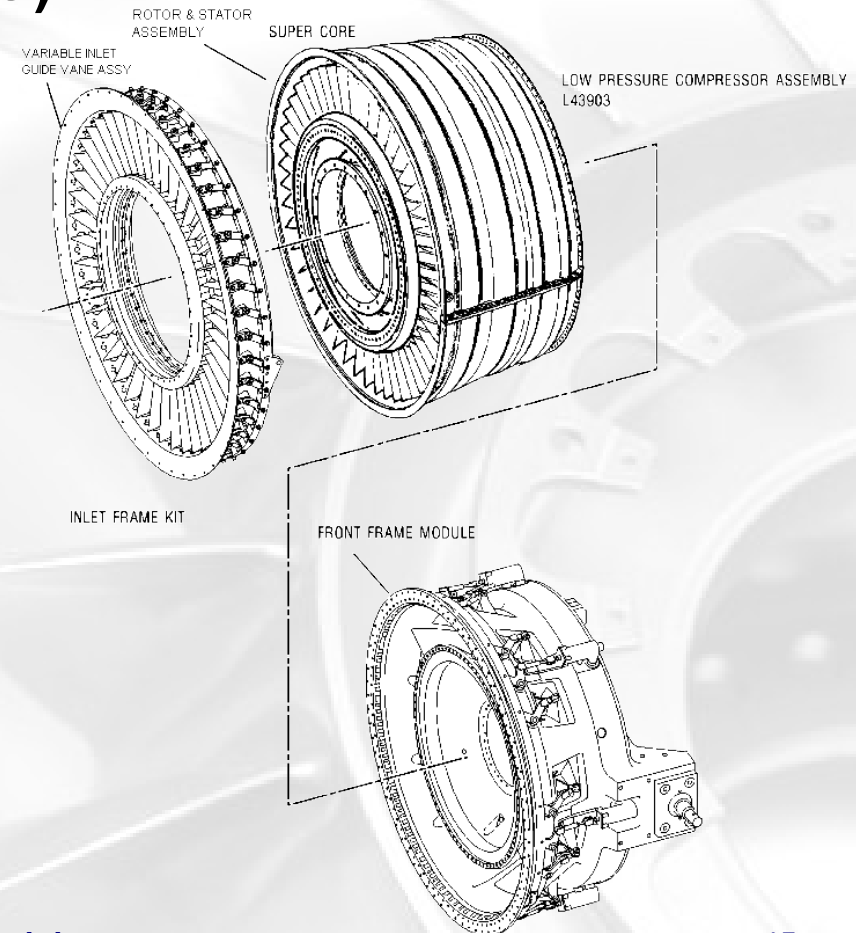
General

The LPC module consists of the (V)IGV, LPC stator and LPC rotor assemblies.

The LPC is a 5-stage axial flow compressor based on the LM5000 LPC which was derived from the CF6-50 booster.

The design is proven with demonstrated high reliability in industrial operation on the LM5000 gas turbine and has been further adapted for use on the LM6000.

To optimize the GT air inlet flow a (V)IGV module was added to the LM6000 LPC.



4. Major components of the LM6000

Low Pressure Compressor (LPC)

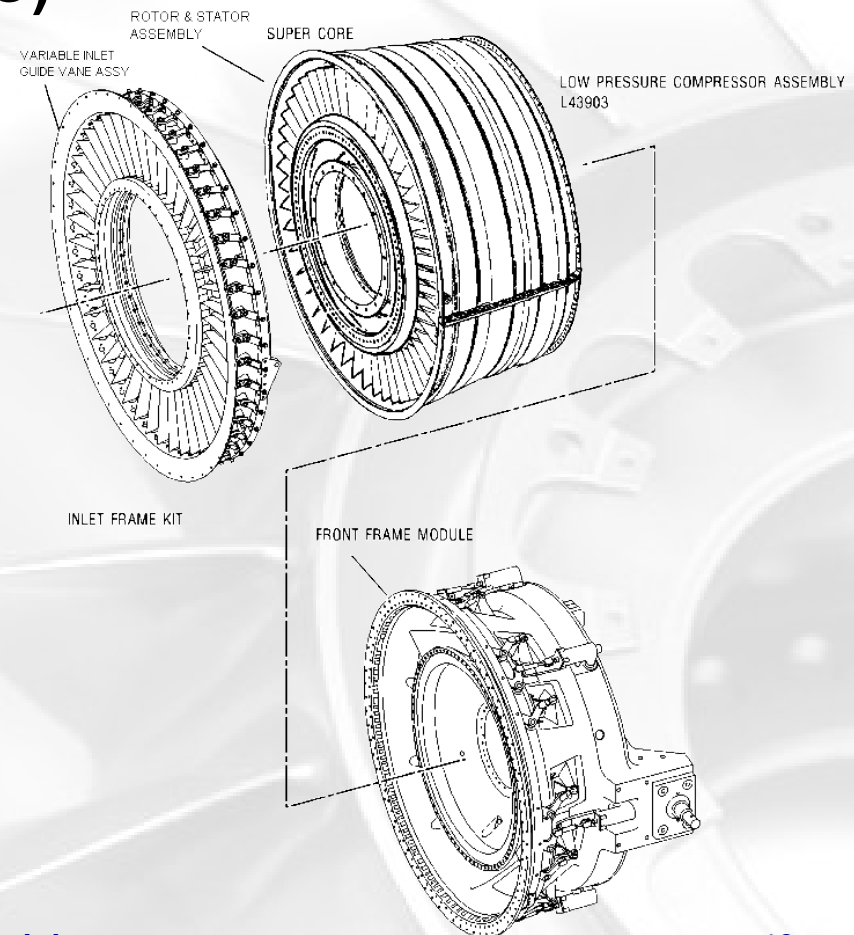
General (cont'd)

The LP rotor shaft (Mid Shaft) is bolted to the LP forward shaft and to the stage 0 and 1 disks.

The shaft transfers torque from the LPT to the LPC rotor and to the external driven load.

The current model of the LM6000 employs redesigned stator vanes and a new shaft material.

It also employs a modified LPC case including stator stages 0 to 3 vanes and eliminating the separate stg.3 stator case as used at the initial LM6000 configuration.



4. Major components of the LM6000

Inlet Guide Vanes

- the IGV assembly is located at the front of the LPC
- as variable version (VIGV) it allows flow modulation at partial power required for DLE combustion but also resulting in increased engine efficiency
- variable IGV's are obligatory for DLE versions but optional for SAC versions, most SAC engines are delivered with fixed IGV's



Variable IGV

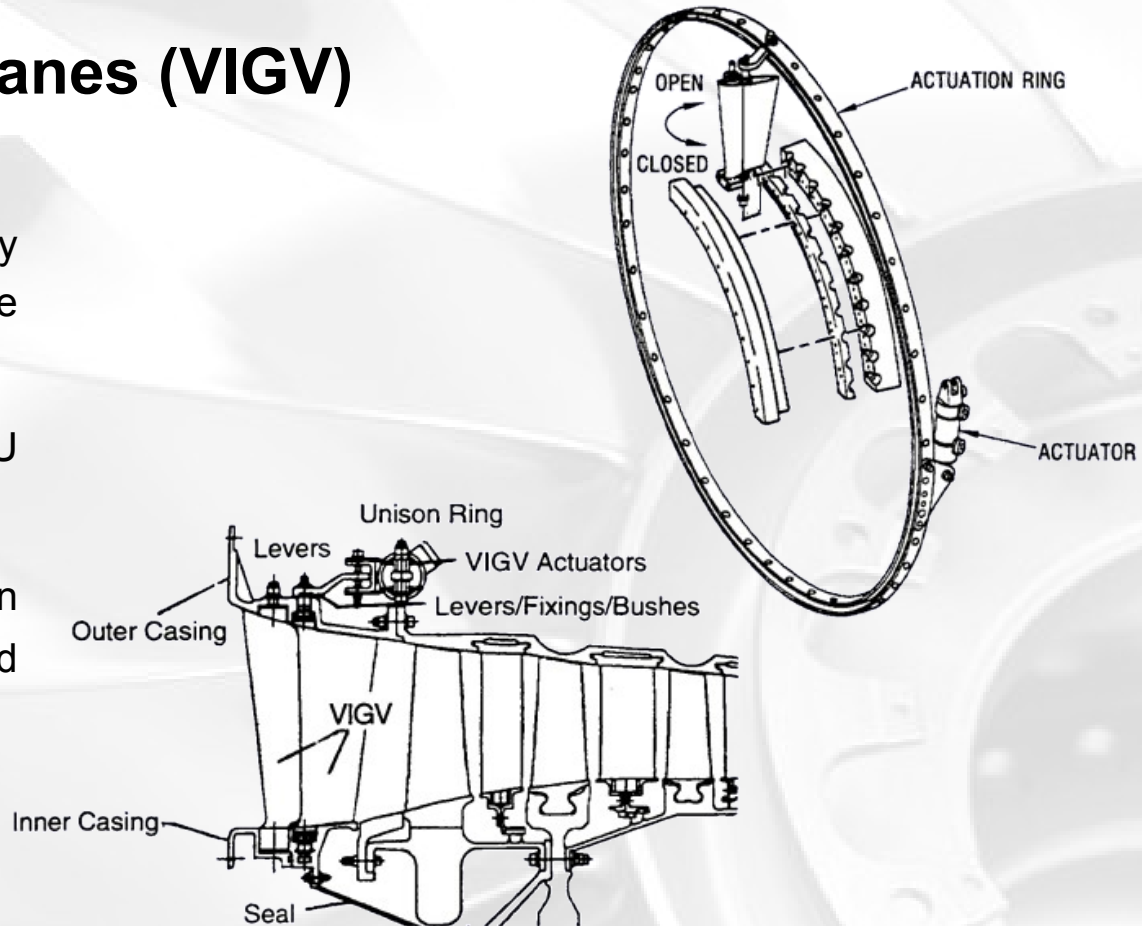


Fixed IGV

4. Major components of the LM6000

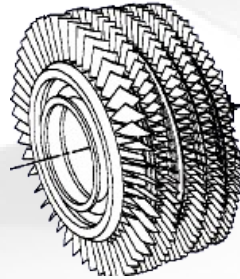
Variable Inlet Guide Vanes (VIGV)

- the VIGV consist of 43 stationary leading edge vanes and variable trailing flaps
- IGV flaps are positioned by the HCU as a function of PS3
- the IGV's are driven by twin hydraulic actuators at the 3:00 and 9:00 o'clock positions



4. Major components of the LM6000

LPC Rotor



General

The LPC rotor is an five stage, fixed vane, axial flow compressor. The assembly consists of the stage 0 disk, LP shaft, stage 1 disk, stage 2-4 spool, stage 0-4 blades, forward shaft, blade retainer, forward drive adapter and No. 1 bearing.



4. Major components of the LM6000

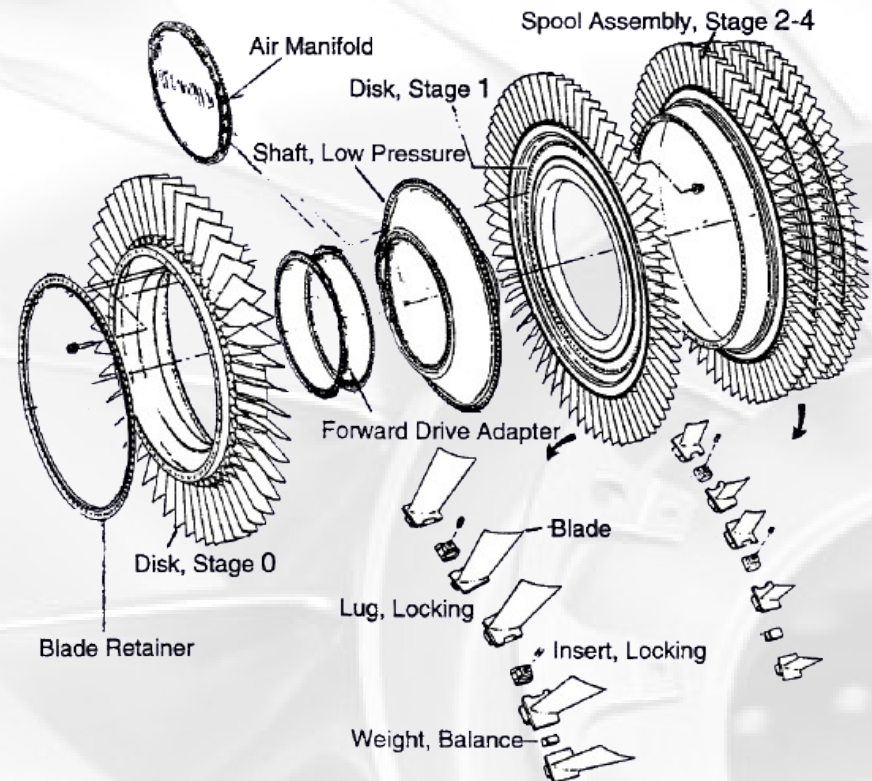
LPC Rotor

Stage 0 disk

The stage 0 disk is forged and machined from titanium and retains the 40 stage 0 blades. The disk includes air seal serrations, axial dovetail slots, and forward and rear flanges. The forward flange supports the blade retainer and the rear flange is bolted to the stage 1 disk.

Stage 1 disk

The stage 1 disk is forged and machined from titanium with a single circumferential dovetail slot to hold the stage 1 blades. The disk supports the stage 0 disk and the stage 2-4 spool and is bolted to the forward shaft.



LPC ROTOR ASSEMBLY

4. Major components of the LM6000

LPC Rotor

Stage 2-4 spool

The stage 2-4 spool is machined from titanium with circumferential dovetail slots. The spool retains stages 2 through 4 blades (76 blades in each stage) locking lugs and balance weights. Rotating air seal serrations are machined between stages on the outside diameter of the spool. The spool forward flange mates with the supporting stage 1 disk.

Forward shaft

The forward shaft is bolted to the LP forward shaft (Mid Shaft) and the stage 0 and 1 disk. The shaft transfers torque from the LPT to the LPC rotor.

Blade retainer

The blade retainer is bolted to the stage 0 disk and serves as a retainer for the stage 0 blades.

4. Major components of the LM6000

LPC Rotor

Forward drive adapter

The forward drive adapter bolts to the forward shaft and transmits torque to the customer interface.

LPC rotor blades

Stage 0 and 1 rotor blades are made of A286 steel and stage 2-4 are titanium. The stage 1-4 blades are retained in the circumferential dovetails slots secured by locking lugs. Stage 0 blades are retained in axial dovetails slots secured by a blade retainer.



LPC Stg. 0 Blades and Forward Drive Adapter

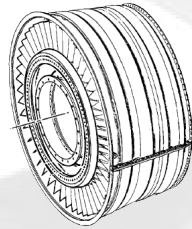
4. Major components of the LM6000

LPC Stator

Design

The five-stage LPC stator assembly consists of the following major components:

- stage 0-2 upper and lower cases (initial)
- stage 3 case (initial)
- stage 0-3 upper and lower cases (current)
- stage 0, 1, 2 and 3 shroud assemblies
- stage 4 support assembly
- stage 0 through 4 vanes



4. Major components of the LM6000

LPC Stator

Stage 0-3 Case Assemblies (Stage 0-2 for initial design LPC's)

The stage 0-3 casing halves are a matched set, machined from forged material. Circumferential dovetail slots machined in the case ID support stage 0-3 vanes. Lands between vane stages are coated with abradable material for close rotor blade clearances. The halves are bolted together at the horizontal split lines.

Stage 3 Case (initial design LPC's only)

The one-piece stage 3 case is machined from forged material and provides support for the stage 3 vanes. The stage 3 case land aft of the vanes is coated with abradable material for close stage 4 rotor blade clearances.

4. Major components of the LM6000

LPC Stator

Stage 0-3 Stator Vanes

The LPC stator consists of fixed vanes. Stage 0-3 (stage 0-2 for initial design LPC's) vanes fit into dovetail lines in the stage 0-3 castings.

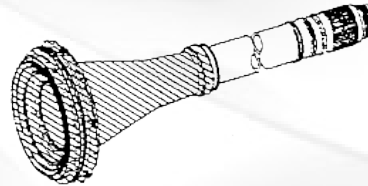
Initial design LPC's have got a separate Stage 3 case, it's vanes are bolted to the stage 3 case forward flange.

Stage 4 Stator Vanes

Stage 4 vanes are bolted to the stage 4 support. Shrouds on stage 0-3 vane ID tangs mate with LPC rotor seal teeth. The one-piece stage 4 support is machined from forged material. The support aft flange is mounted to the front frame.

4. Major components of the LM6000

LP Midshaft



The midshaft transmits the Low Pressure Turbine torque and power to the LPC Rotor and via the LPC Rotor to the driven equipment connected to the forward drive.

The midshaft clears the complete core engine concentric without any intermediate bearings.

The midshaft assembly consists of 2 main parts, the forward shaft and the mid shaft which are connected via splines secured by a lock nut.



Midshaft

4. Major components of the LM6000

LP Midshaft

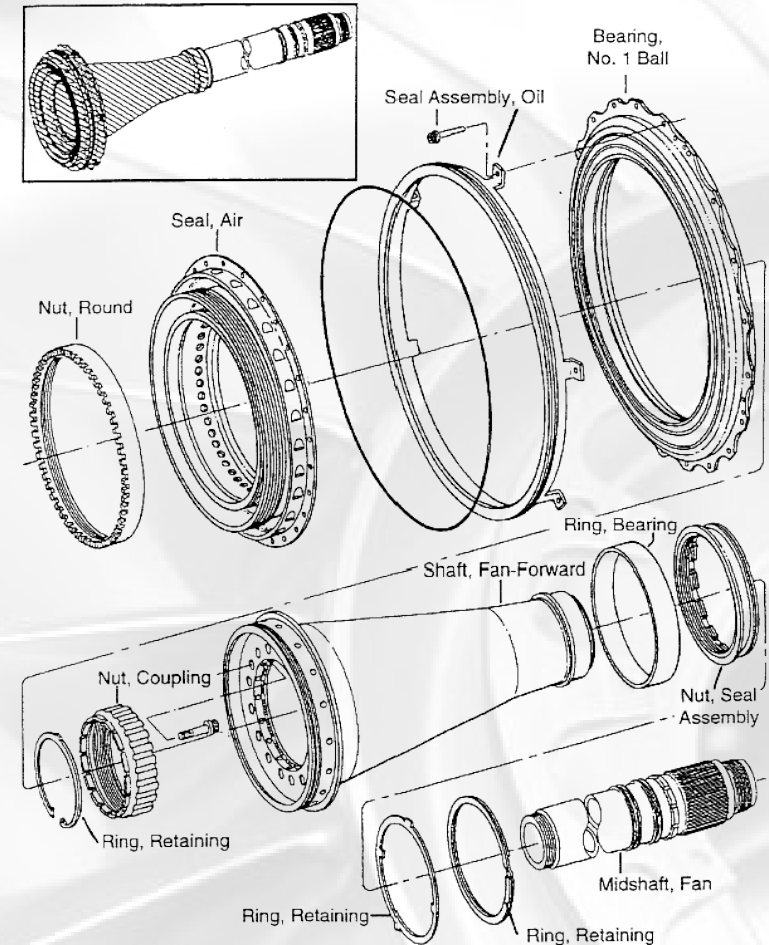
The forward LP shaft bearings No. 1 and 2 support the forward midshaft.

The Forward midshaft front flange is bolted to the LPC shaft.

The Low Pressure Turbine (LPT) is connected to the midshaft via splines, secured by a lock nut.

The midshaft is nebulon coated, hollow for light weight and with varying outside diameters that serve as balancing lands which can be ground.

The Center vent tube is threaded and sealed at the forward end of the midshaft, it provides an air passage from the LPC for the D-E sump pressurization.



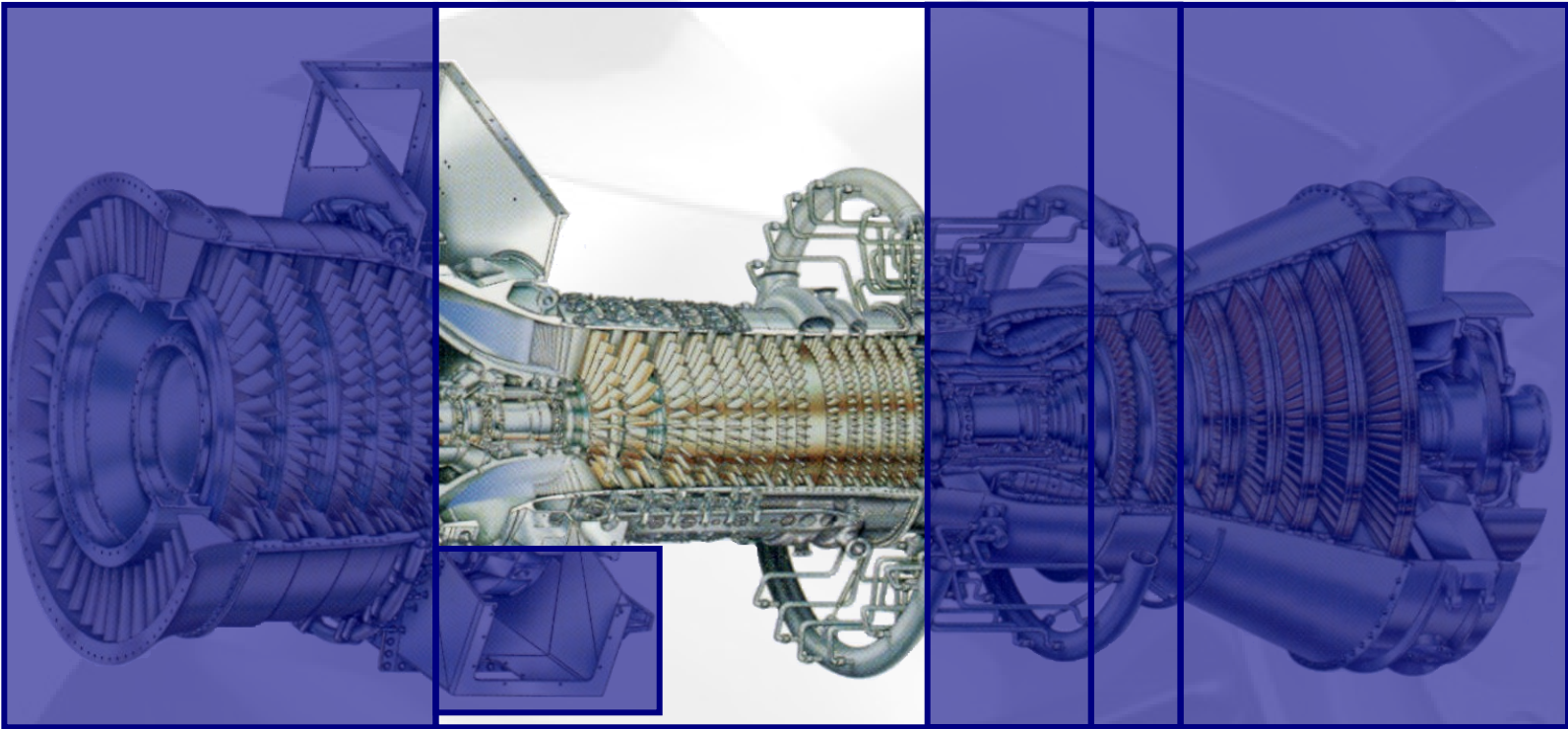
4. Major components of the LM6000

Table of contents

- | | |
|---|---|
| <ul style="list-style-type: none">1. Abbreviations and acronyms2. Gas turbine basics3. Introduction to the LM60004. Major components of the LM6000<ul style="list-style-type: none">a. Low Pressure Compressor (LPC)b. High Pressure Compressor (HPC)c. Combustord. High Pressure Turbine (HPT)e. Low Pressure Turbine (LPT)f. Accessory Drive (AGB, TGB, IGB)g. Engine Frames (CFF, CRF, TRF)h. Bearings and Sumps | <ul style="list-style-type: none">5. Parasitic Air Flow6. Auxiliary equipment and system<ul style="list-style-type: none">a. Lubrication Systemb. Variable Geometry Systemc. Fuel, Water and Steam Systemsd. Starting Systeme. Instrumentation |
|---|---|

4. Major components of the LM6000

High Pressure Compressor (HPC)

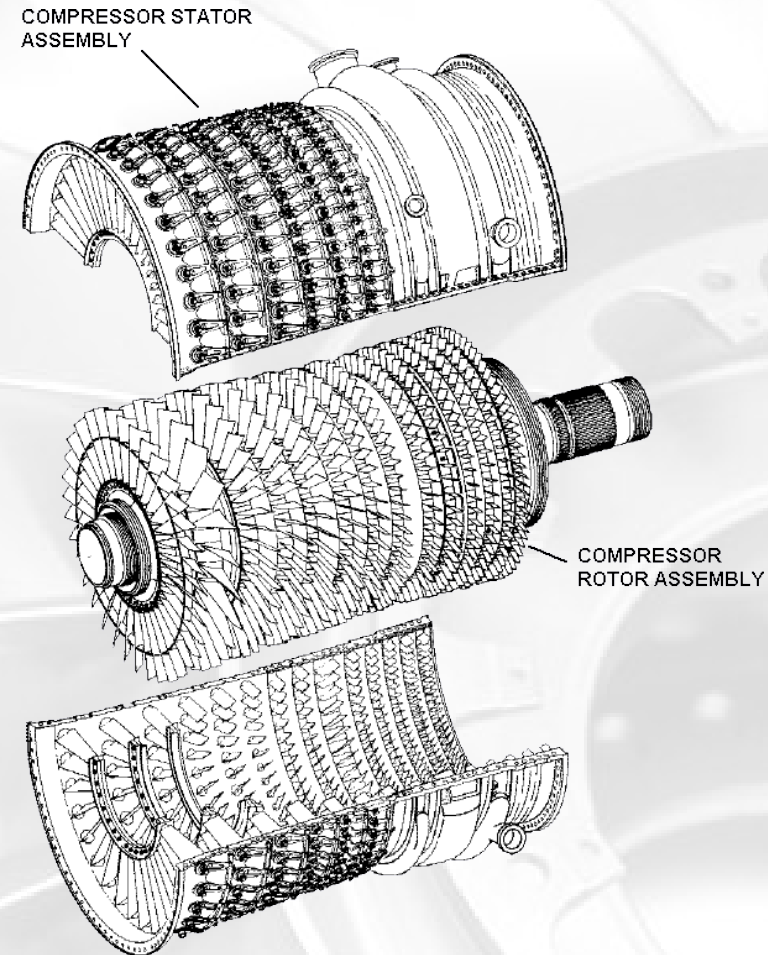


4. Major components of the LM6000

High Pressure Compressor (HPC)

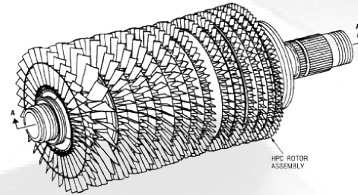
The HPC is a single spool, 14-stage variable stator design, axial flow compressor. It incorporates variable stator vanes (VSV) in stages IGV and 1 through 5 to provide stall-free operation and high efficiency throughout the starting and operating range.

The compressor provides several bleed ports for the GT's parasitic airflow (cooling, sump pressurization) and optional customer usage.



4. Major components of the LM6000

HPC Rotor

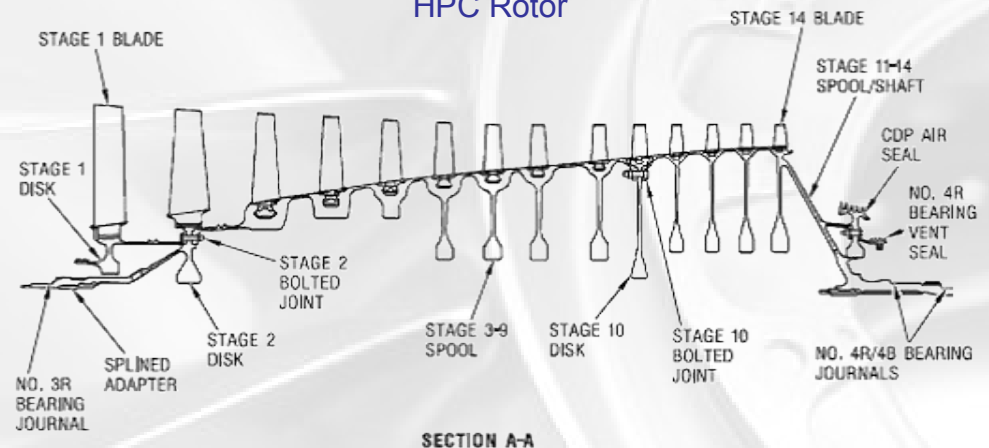


The HPCR is a bolted assembly of five major structural elements consisting of:

- stage 1 disk
- stage 2 disk with integral forward shaft
- stage 3-9 spool
- stage 10 disk
- 11-14 spool with integral rear shaft



HPC Rotor



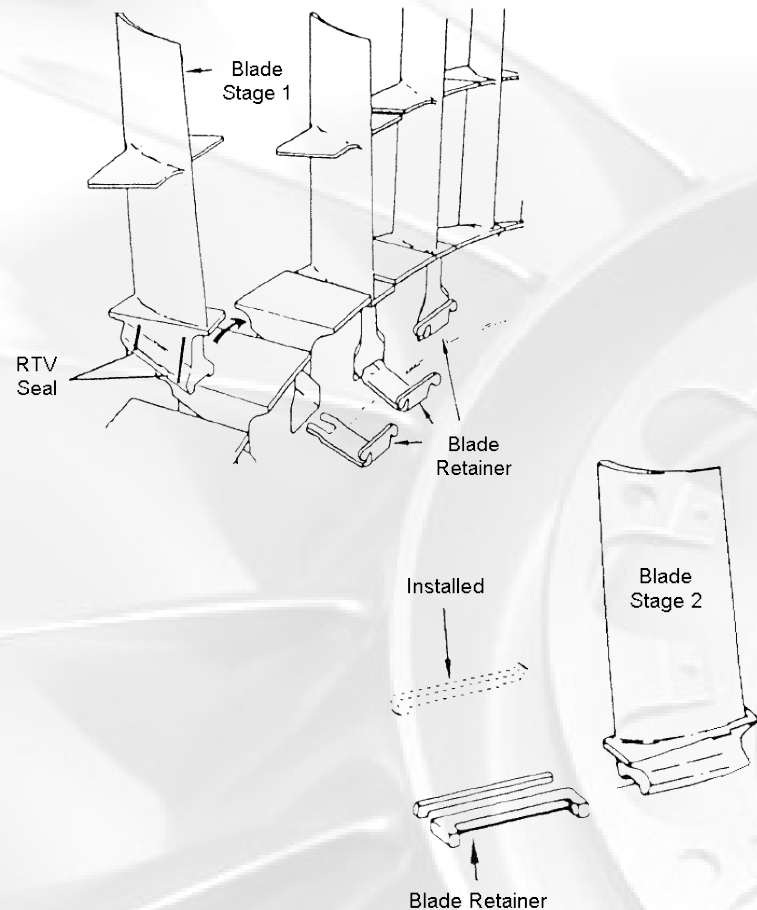
4. Major components of the LM6000

HPC Rotor (cont'd)

Stages 1 and 2 blades are individually retained in axial dovetail slots using blade retainers to keep the blades in place.

Stage 1 blades are shrouded at mid-span for the purpose of reducing vibratory stress.

All other blades are cantilevered from the rotor structure.

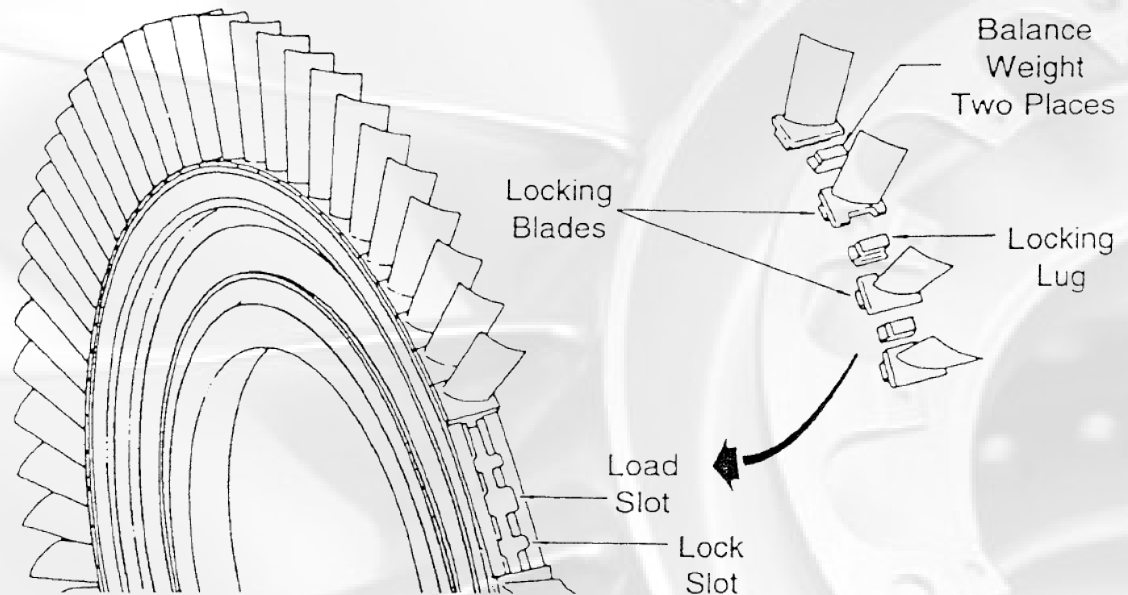


4. Major components of the LM6000

HPC Rotor (cont'd)

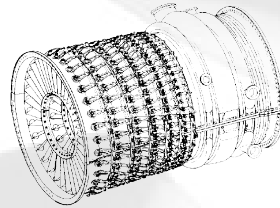
The blades of stages 3 to 14 are held in circumferential dovetail slots.

These features allow individual blade replacement without disassembly of the rotor.



4. Major components of the LM6000

HPC Stator



The HPC stator consists of a cast stator case that contains the compressor stator vanes.

The inlet guide vanes and the stages 1 through 5 vanes can be rotated about the axis of their mounting trunnions to vary the pitch of the airfoils in the compressor flow path.

Vane airfoils in the remaining stages are stationary. All fixed and variable vanes are non-interchangeable with other stages to prevent incorrect assembly. The casing is split along the horizontal split-line for ease of assembly and maintenance.



HPC Stator

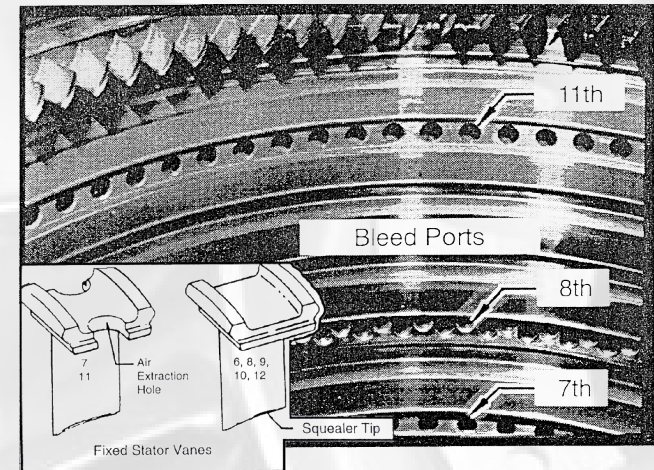
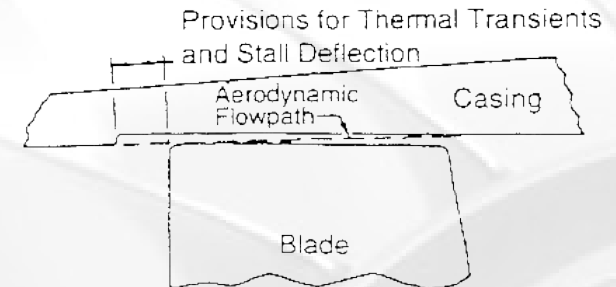
4. Major components of the LM6000

HPC Stator

The HPC stator casing halves are a matched set, machined from forged material.

Trenches for compressor rotor blades are machined into the inner surface at stages 3-14. These trenches eliminate the need for rub coatings and provide clearance for tip excursions during transients.

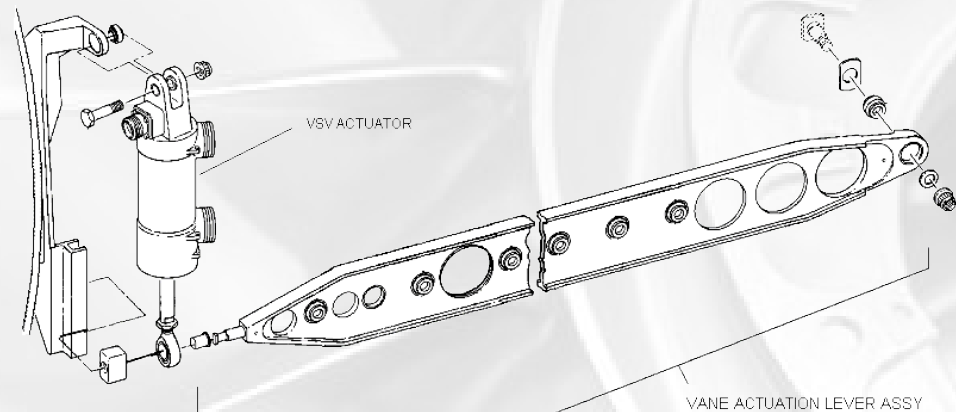
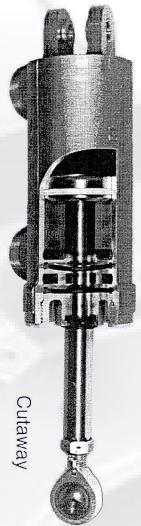
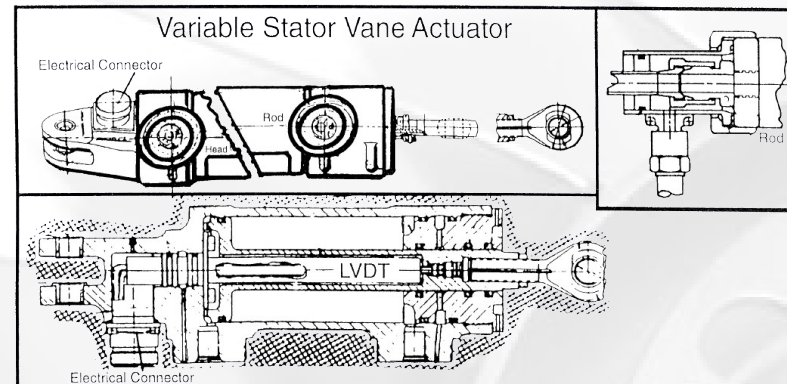
The HPC cases provide holes for bleed air extraction at stages 7 (only initial versions), 8 and 11 (all versions).



4. Major components of the LM6000

Variable Stator Vanes (VSV)

- 2 lever arms per engine
- Actuation rings connected at 3 and 9 o'clock
- IGV's and VSV's stages 1-5 are installed to the compressor stator cases by assembly of bushings, spacers and lever arms which permits the vanes to be rotated on the longitudinal axis



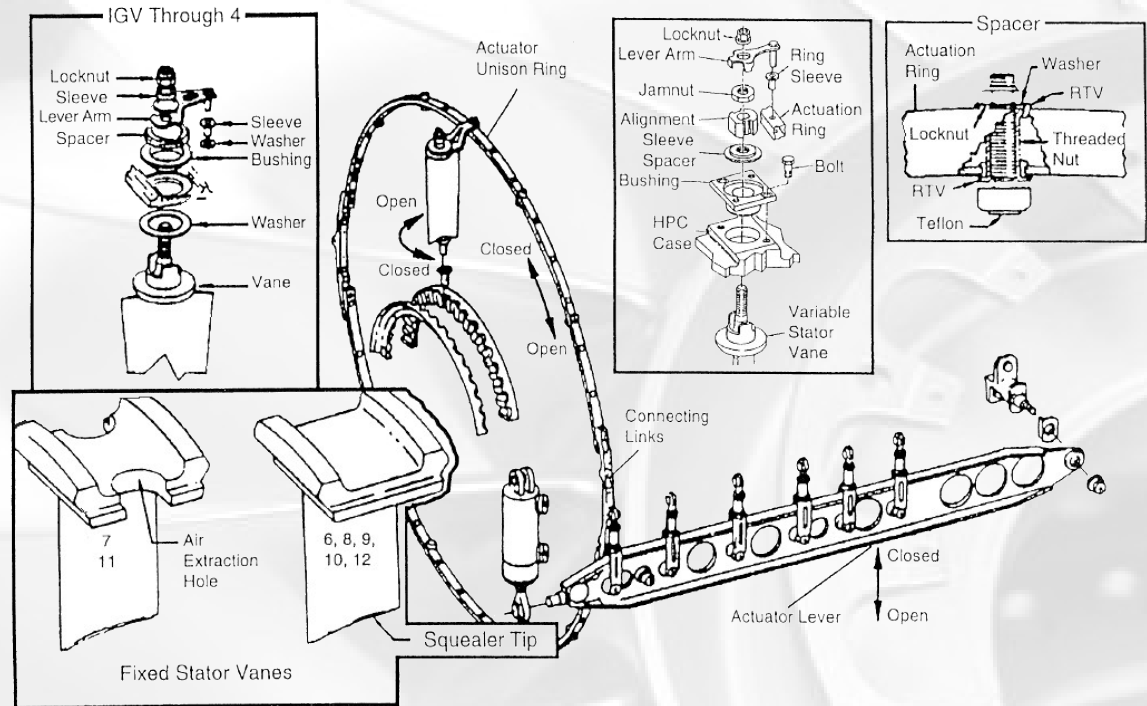
4. Major components of the LM6000

Variable Stator Vanes (VSV)

The HPC Variable Stator Vanes (VSV) Stages IGV, 1 and 2 have got “Low Boss” actuation bushings as of aircraft engine design.

The long IGV, stg. 1 & 2 vanes are additionally supported by inner shrouds.

The VSV stages 3 to 5 have got industrial design “High Boss” stainless steel teflon-bonded pivot bushings to provide a longer service life.



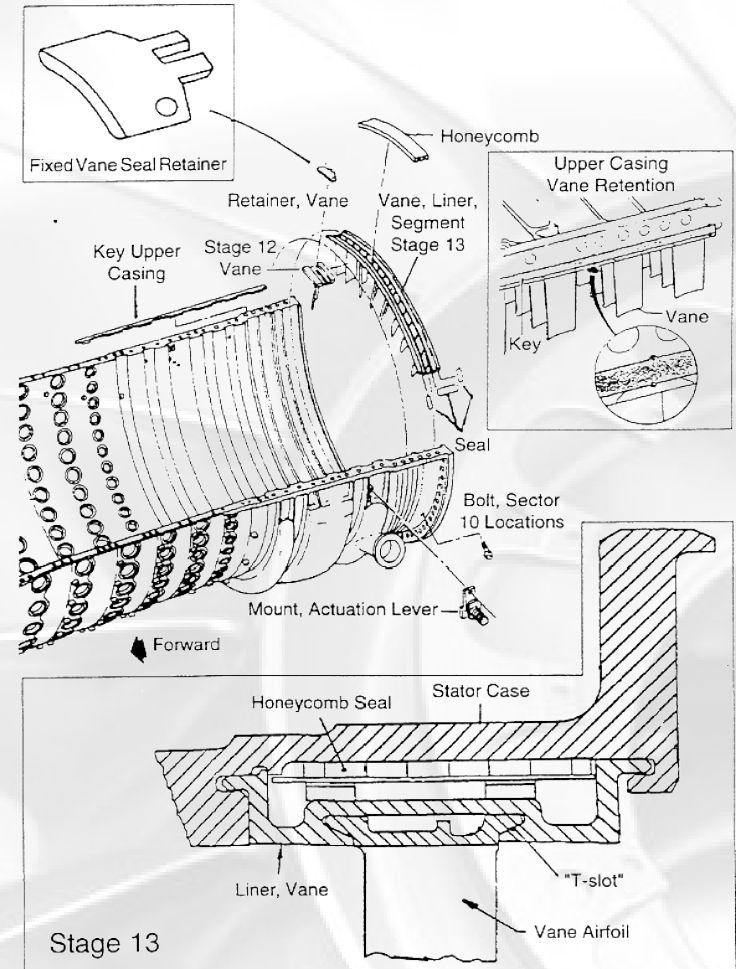
4. Major components of the LM6000

Fixed Stator Vanes

Murphy-proof circumferential dovetail slots are machined into the case for stage 6-12.

Stage 13 vanes are assembled to insulated liners which are bolted to the cases.

Rectangular keys “staked” into grooves of upper case horizontal flange prevent vanes 6-12 from migrating in the dovetail slots (ant rotation).



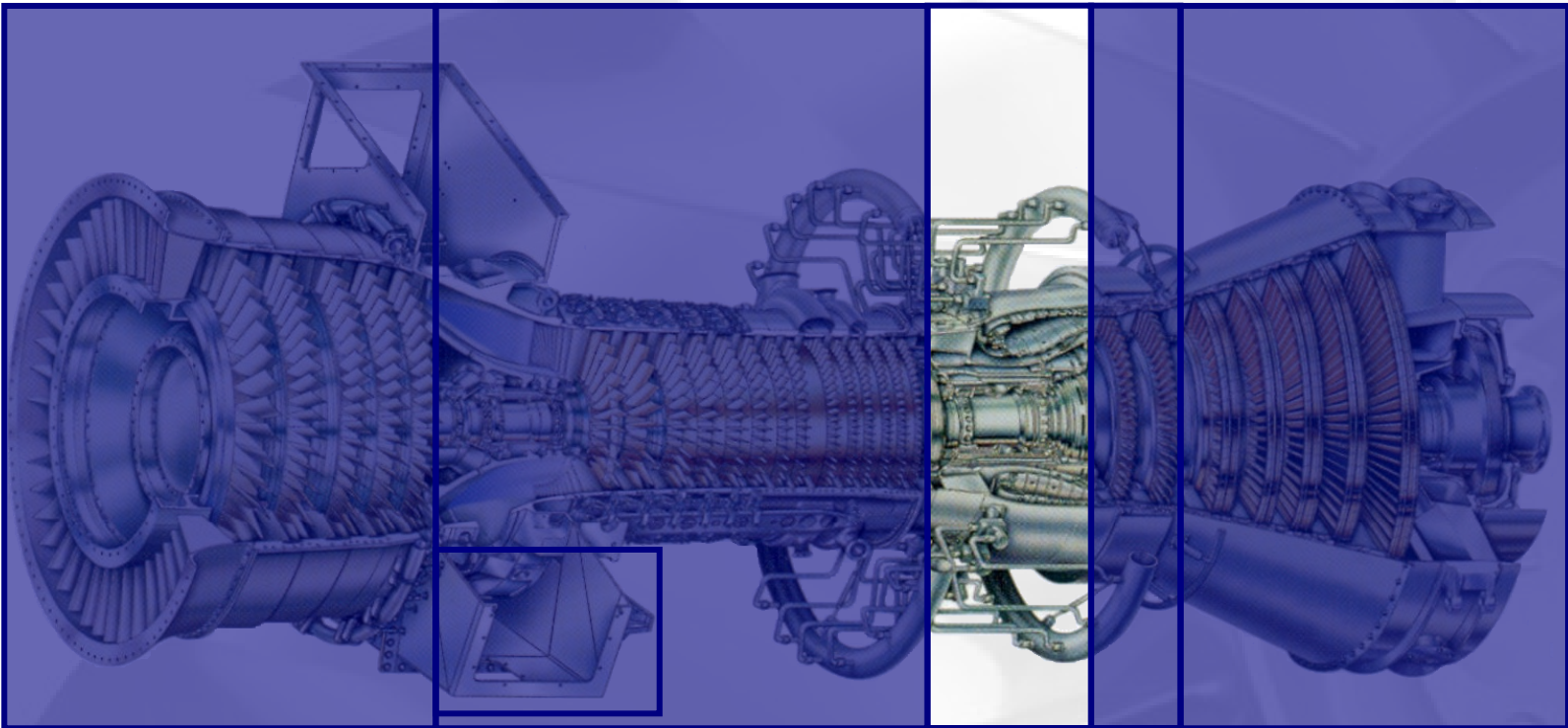
4. Major components of the LM6000

Table of contents

- | | |
|---|---|
| <ul style="list-style-type: none">1. Abbreviations and acronyms2. Gas turbine basics3. Introduction to the LM60004. Major components of the LM6000<ul style="list-style-type: none">a. Low Pressure Compressor (LPC)b. High Pressure Compressor (HPC)c. Combustord. High Pressure Turbine (HPT)e. Low Pressure Turbine (LPT)f. Accessory Drive (AGB, TGB, IGB)g. Engine Frames (CFF, CRF, TRF)h. Bearings and Sumps | <ul style="list-style-type: none">5. Parasitic Air Flow6. Auxiliary equipment and system<ul style="list-style-type: none">a. Lubrication Systemb. Variable Geometry Systemc. Fuel, Water and Steam Systemsd. Starting Systeme. Instrumentation |
|---|---|

4. Major components of the LM6000

Combustor



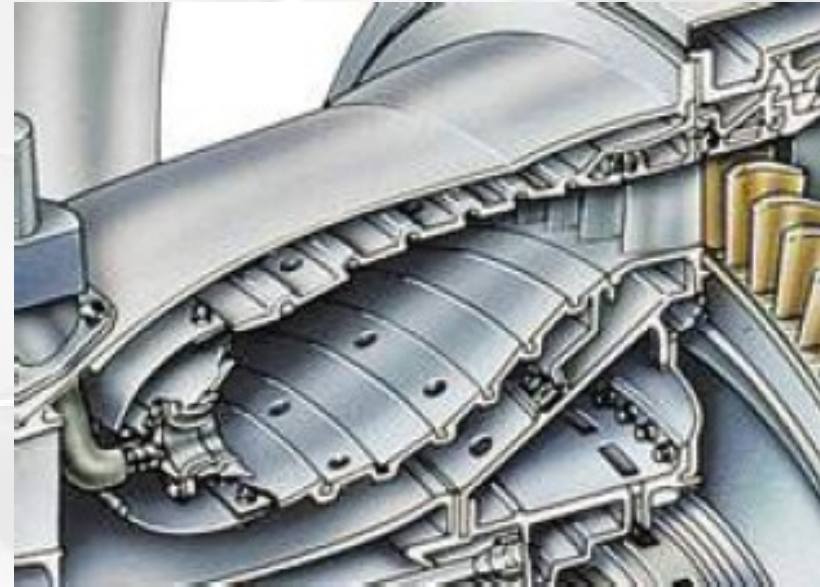
4. Major components of the LM6000

Single Annular Combustor (SAC)

The SAC combustor is furnished with 30 externally mounted fuel nozzles for liquid distillate fuel, natural gas fuel or dual fuel. Fuel systems may also be equipped for water or steam injection for NOX suppression.

Key features of the single annular combustor are the rolled-ring inner and outer liners, the low-smoke-emission swirl-cup dome design, and short burning length.

The swirl-cup design serves to lean-out the fuel/air mixture in the primary zone of the combustor. This eliminates the formation of the high-carbon visible smoke that can result from over-rich burning in this zone.



COMBUSTOR (SAC)

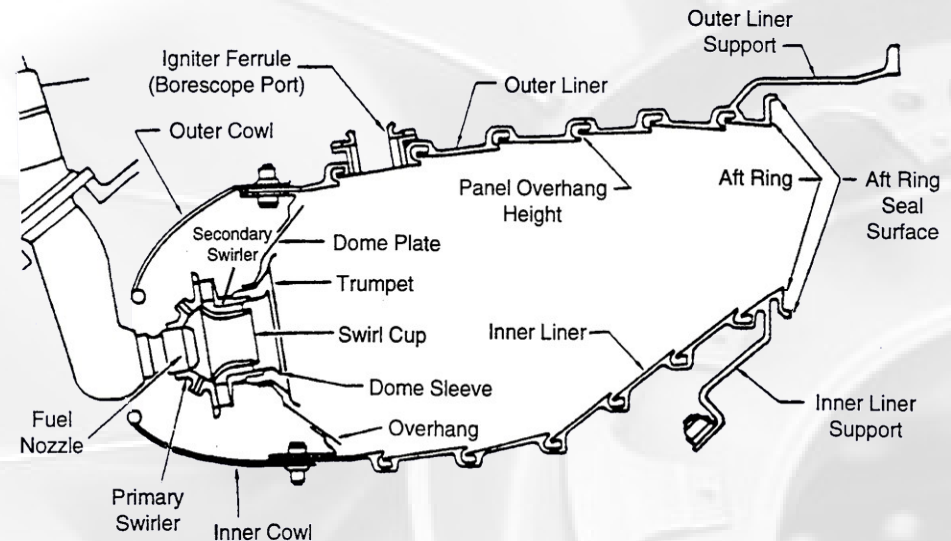
4. Major components of the LM6000

Single Annular Combustor (SAC)

The SAC combustor consists of a dome assembly and the outer and inner liners.

The dome and its swirlers provide mixing of fuel and air and flame stabilization.

The combustor liners are a series of overlapping rings joined by welded and brazed joints. They are protected from the high combustion heat by circumferential film cooling. Primary combustion and cooling air enters through closely spaced holes in each ring. These holes help to center the flame, and admit the balance of combustion air.



COMBUSTOR (SAC)

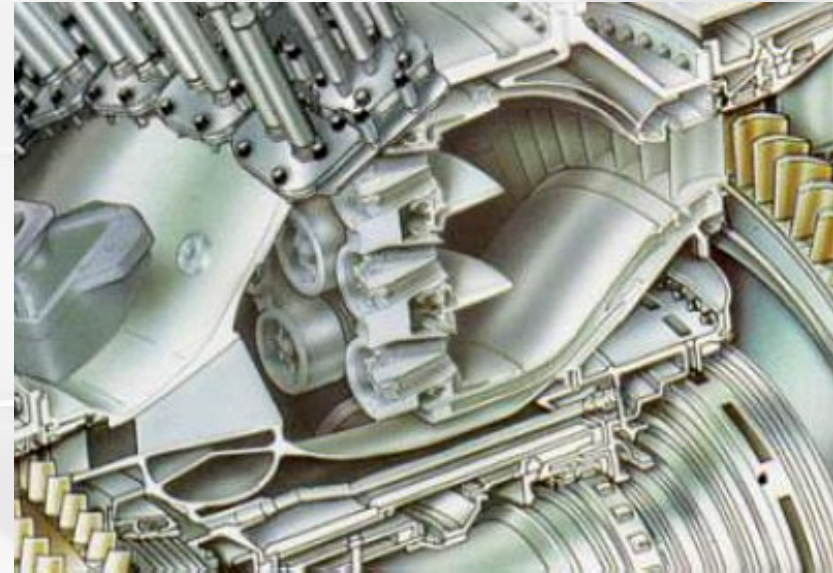
4. Major components of the LM6000

Dry Low Emissions Combustor (DLE)

The triple annular configuration enables the combustor to operate in a uniformly mixed lean fuel air ratio (premixed mode) across the entire power range, minimizing emissions.

The head end or dome of the combustor supports 75 segmented heat shields that form the three annular burning zones in the combustor, known as the outer or A-dome, the pilot or B-dome, and the inner or C-dome.

Gas fuel is introduced into the combustor via 75 air/gas premixers packaged in 30 externally removable and replaceable modules. Half of these modules have two premixers and the other half have three.



COMBUSTOR (DLE)

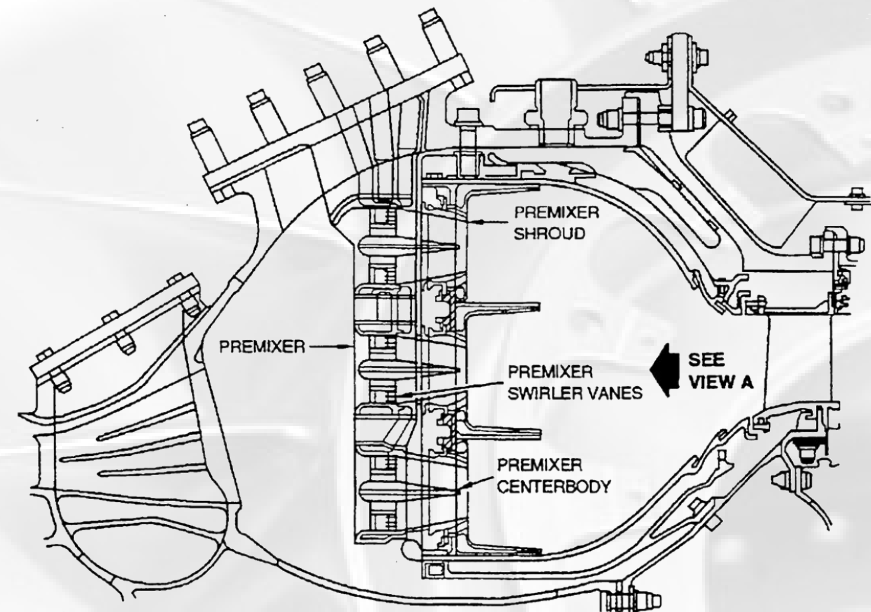
4. Major components of the LM6000

Dry Low Emissions Combustor (DLE)

The DLE combustor consists of a 3-ring dome assembly and the outer and inner liners.

The dome heat shields isolate the structural dome plate from the hot combustion gases. The heat shields are an investment-cast super alloy and are impingement and convection cooled.

The combustion liners are front mounted with thermal barrier coating (TBC) and no film cooling.

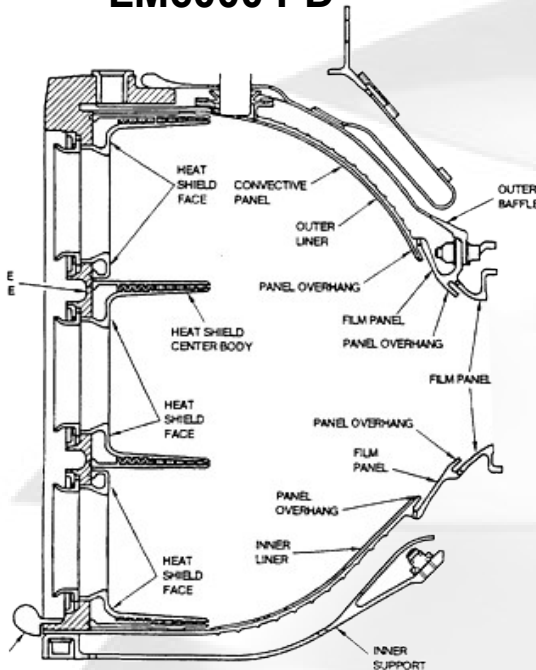


COMBUSTOR (DLE)

4. Major components of the LM6000

Dry Low Emissions Combustor (DLE)

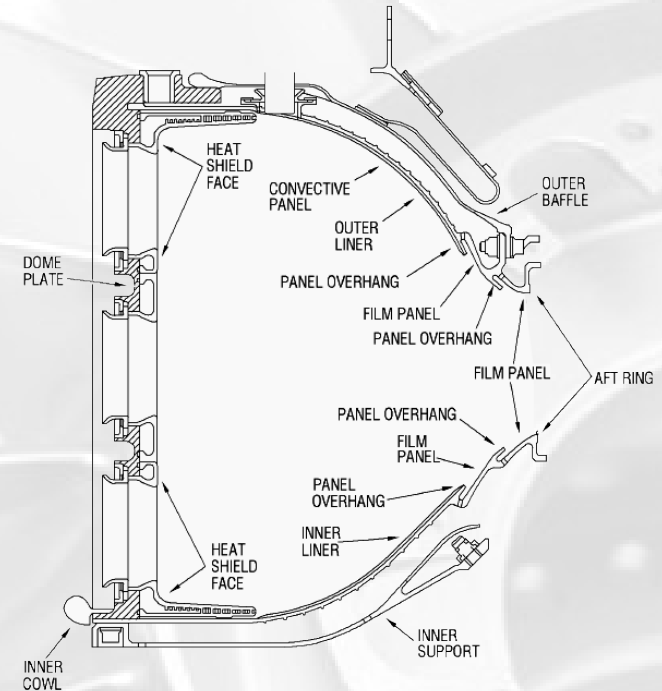
LM6000 PD



Changes in the DLE combustor design provide increased airflow for fuel premixing to operate with lower flame temperature and generate lower emissions (NOX):

- wingless center heat shields
- short wing inner and outer heat shields
- modified premixers to optimize fuel to air ratio

LM6000 PF



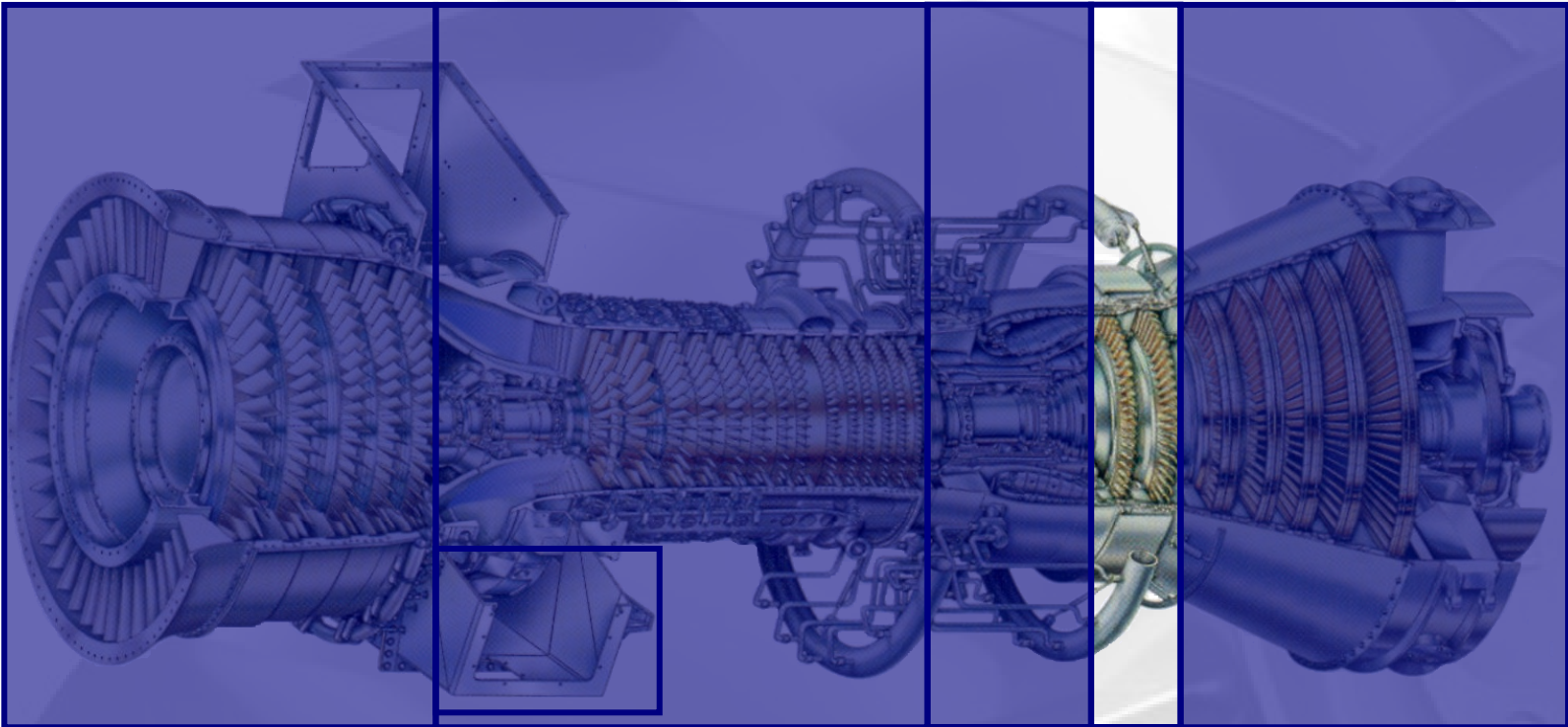
4. Major components of the LM6000

Table of contents

- | | |
|---|---|
| <ul style="list-style-type: none">1. Abbreviations and acronyms2. Gas turbine basics3. Introduction to the LM60004. Major components of the LM6000<ul style="list-style-type: none">a. Low Pressure Compressor (LPC)b. High Pressure Compressor (HPC)c. Combustord. High Pressure Turbine (HPT)e. Low Pressure Turbine (LPT)f. Accessory Drive (AGB, TGB, IGB)g. Engine Frames (CFF, CRF, TRF)h. Bearings and Sumps | <ul style="list-style-type: none">5. Parasitic Air Flow6. Auxiliary equipment and system<ul style="list-style-type: none">a. Lubrication Systemb. Variable Geometry Systemc. Fuel, Water and Steam Systemsd. Starting Systeme. Instrumentation |
|---|---|

4. Major components of the LM6000

High Pressure Turbine (HPT)



4. Major components of the LM6000

High Pressure Turbine (HPT)

The LM6000 HPT is an air-cooled, two stage design with high efficiency. The HPT system consists of the HPT rotor and the stage 1 and stage 2 HPT nozzle assemblies.

The turbine rotor extracts energy from the gas stream to drive the HPC rotor to which it is mechanically coupled.

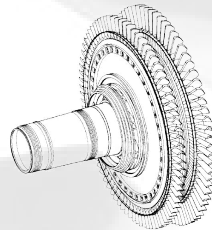
The turbine nozzles direct the hot gas flow onto the rotor blades at the optimum angle and velocity.



HPT Module

4. Major components of the LM6000

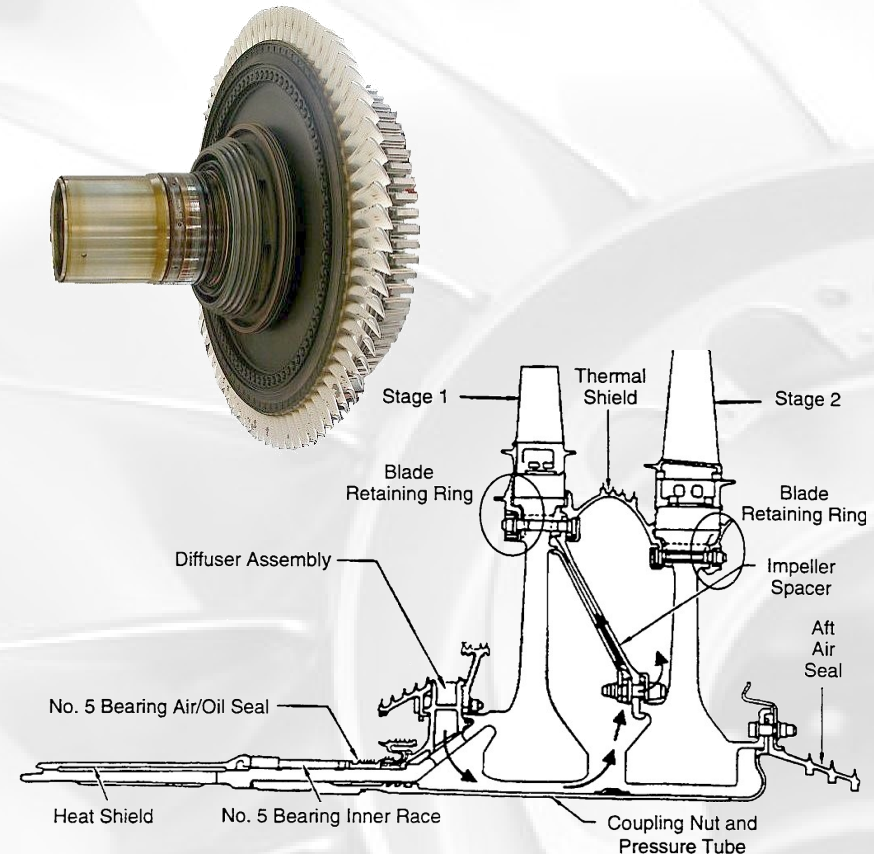
HPT Rotor



The HPT rotor assembly consists of the stage 1 disk and integral shaft, a conical impeller spacer with cover, a thermal shield, and the stage 2 disk.

Forward and aft rotating air seals are assembled to the HPT rotor and provide air-cooled cavities around the rotor system. An integral coupling nut and pressure tube form and seal the internal cavity.

The rotor disks and blades are cooled by a continuous flow of compressor discharge air. This air is directed to the internal cavity of the rotor through diffuser vanes that are part of the forward seal system.



HPT ROTOR

4. Major components of the LM6000

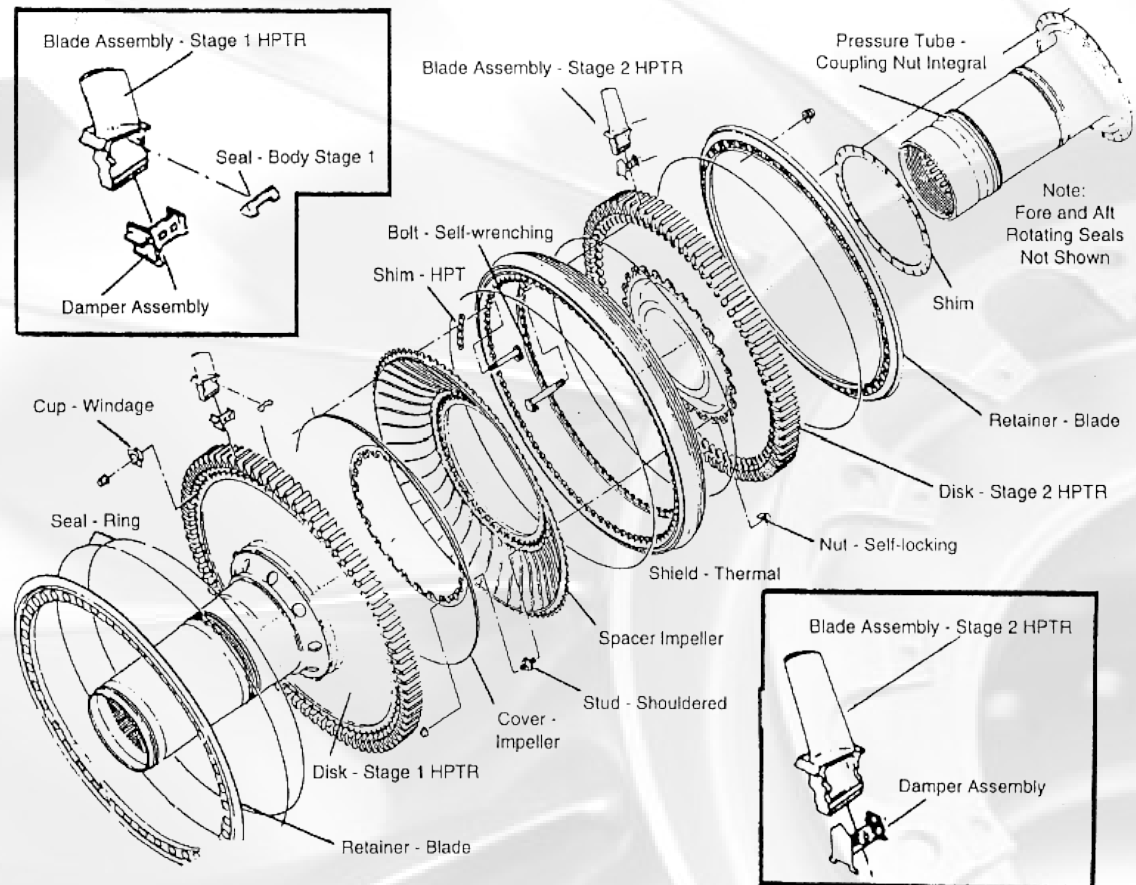
HPT Rotor

The vaned spacer impeller increases the air pressure towards the stg. 1 blade dovetails to cool the blade airfoils.

the remaining air is centrifuged through the stg. 2 blade dovetails to cool the blade airfoils.

The stage 1 disk/shaft design combines the rotor shaft and stage 1 disk into a single unit.

Torque is transmitted to the compressor rotor through an internal spline at the forward end of the shaft.



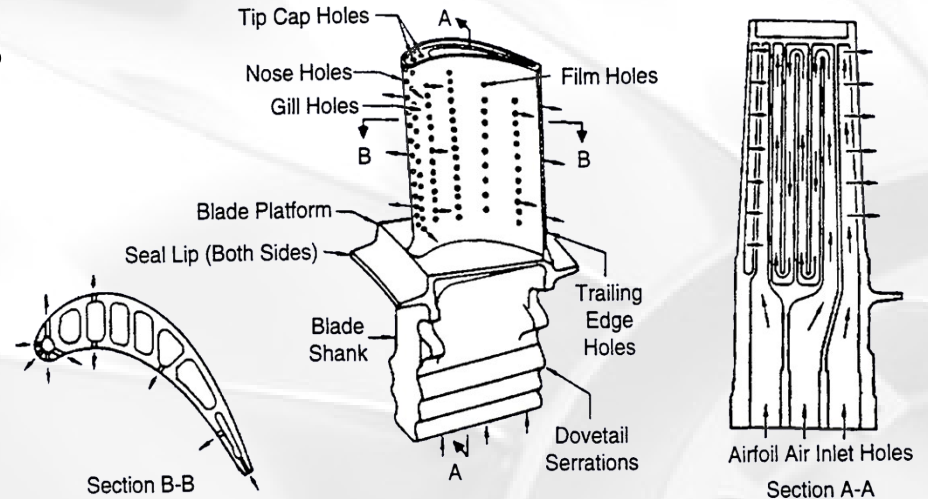
4. Major components of the LM6000

HPT Rotor Stage 1 Blades

The stage 1 blades are cooled by compressor discharge air directed through the blade dovetails.

Stg. 1 blade cooling is a combination of:

- internal convection of the midchord region through serpentine passages and of the trailing edge by air flowing over pinned fins and through trailing edge exit holes
- internal impingement of cooling air against the inside surface of the leading edge
- external film cooling by air directed through airfoil holes



HPT Blade Stg. 1 cooling



HPT Blade Stg. 1

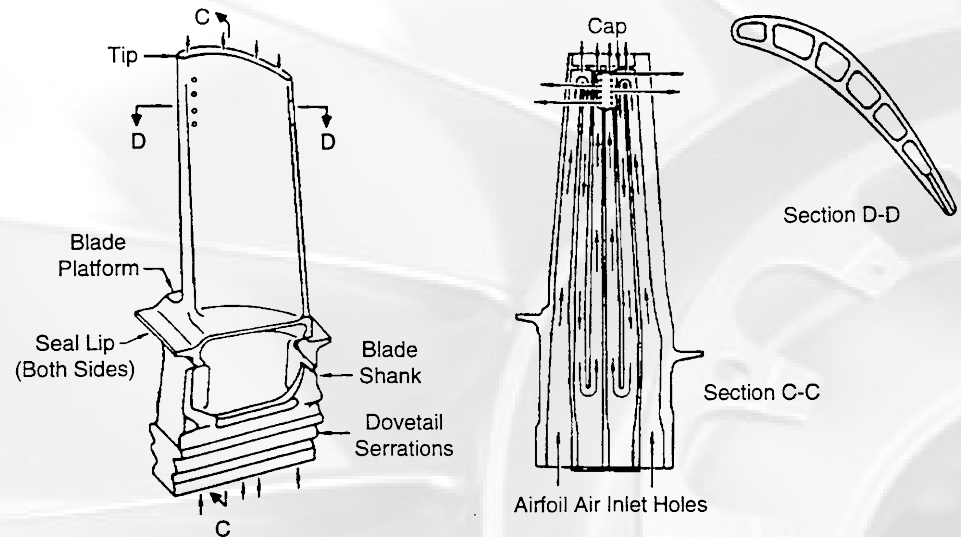
4. Major components of the LM6000

HPT Rotor Stage 2 Blades

The stage 2 blades are cooled by compressor discharge air directed through the blade dovetails.

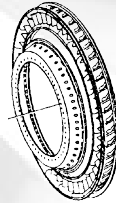
Stage 1 blade are entirely cooled by internal convection through serpentine passages.

All cooling air is discharged through holes in the blade tip and through outer region ejection holes.



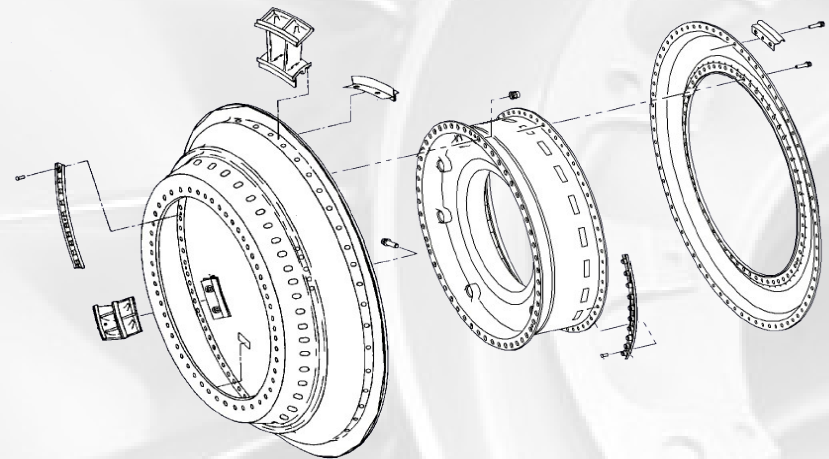
4. Major components of the LM6000

HPT Nozzle Stage 1



The stage 1 HPT nozzle consists of 23 two-vane segments bolted to a nozzle support attached to the hub of the CRF.

The stage 1 HPT nozzle assembly accelerates and directs the force of hot, high-velocity, high pressure gases discharging from the combustor onto the stage 1 HPT rotor blades to cause rotation.



HPT STG. 1 NOZZLE ASSEMBLY

4. Major components of the LM6000

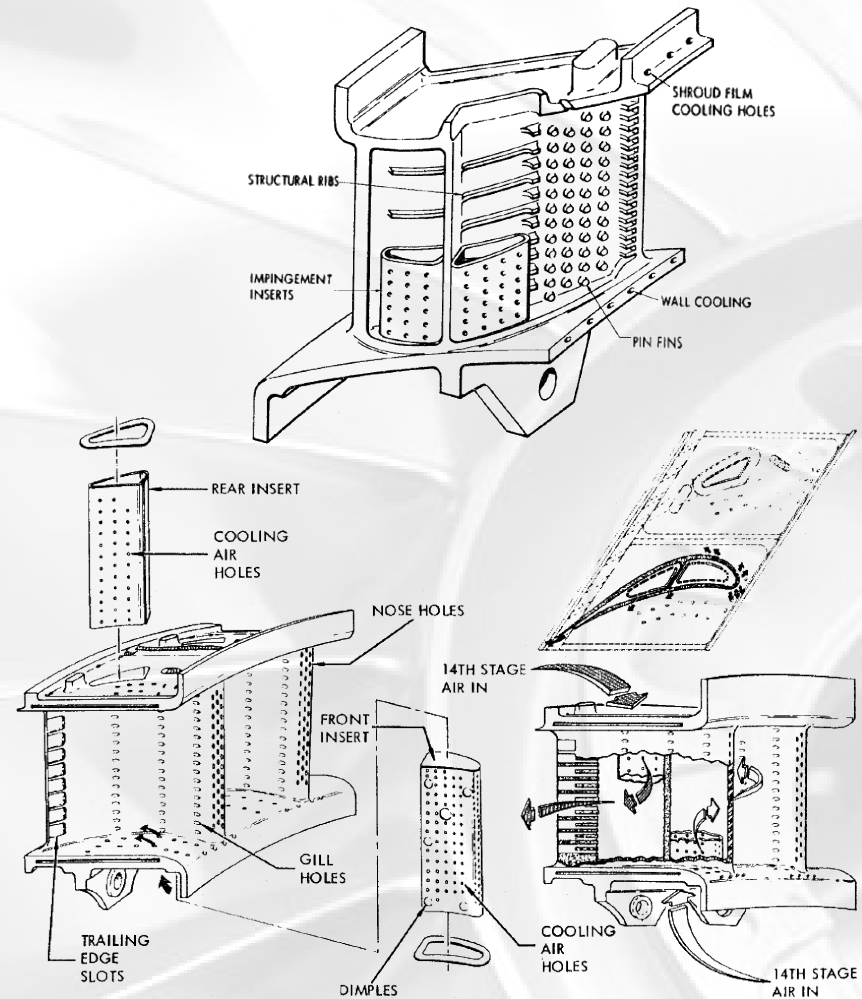
HPT Nozzle Stage 1

Compressor discharge air is used to cool the nozzle vanes and support bands to keep the metal temperatures at safe working level.

The outer platform and aft half of the vane are cooled by the outer CDP air flow (trailing edge and aft concave panel holes).

The inner platform and leading edge of the vane are cooled by the inner CDP air flow (nose, gill, fwd. concave and convex panel holes).

Two metal sheet perforated tubular inserts provide impingement cooling effect to the inside of the vane surfaces.



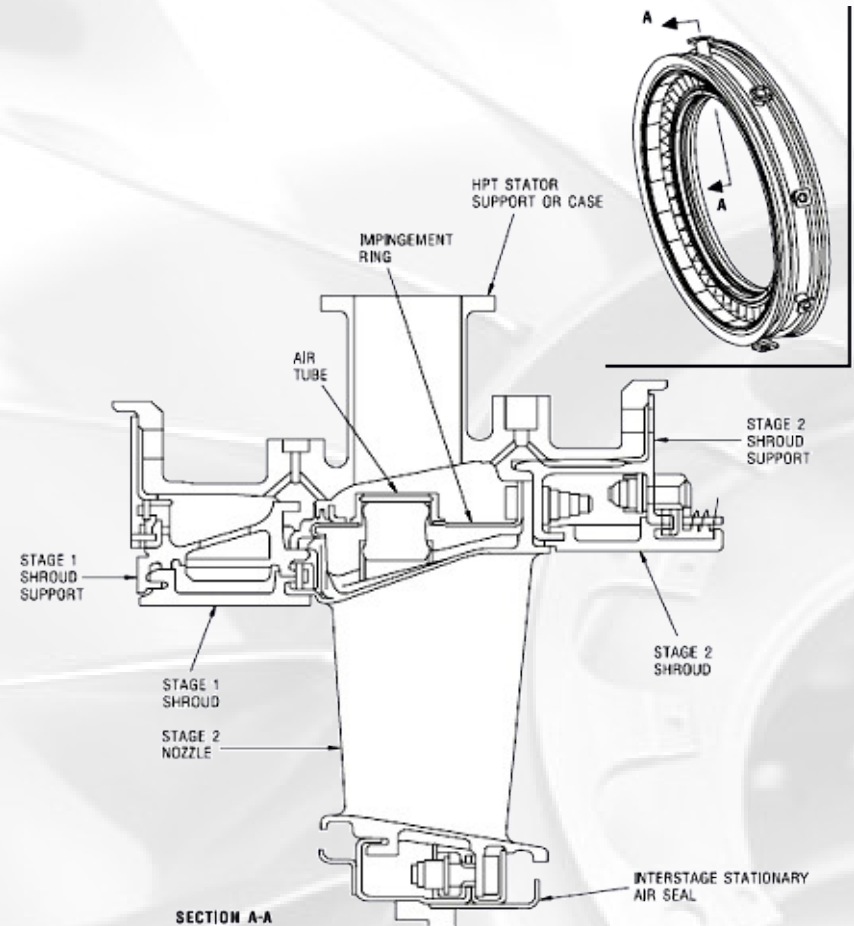
4. Major components of the LM6000

HPT Nozzle Stage 2



The stage 2 HPT nozzle assembly consists of 24 two-vane nozzle segments, stages 1 and 2 HPT shrouds and shroud supports, HPT stator support (case), and interstage seals.

The stage 2 nozzles are supported by the stage 1 shroud support. They are also bolted to the stage 2 shroud support forward leg, which is attached, by a flange, to the outer structural wall. The stage 1 shroud system features segmented supports and shroud segments to maintain turbine clearance.



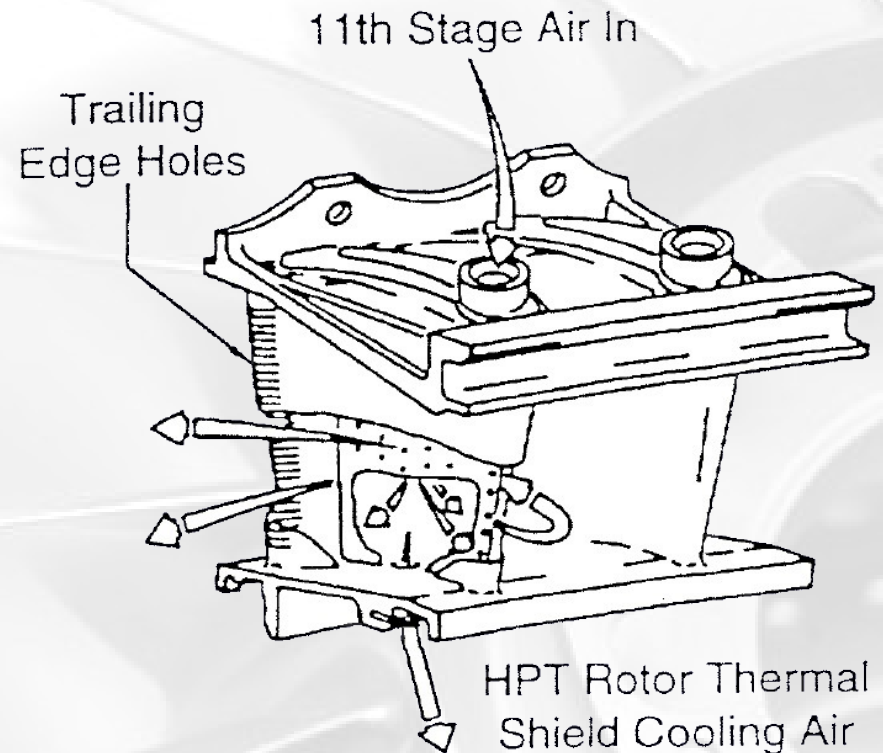
HPT STG. 2 NOZZLE

4. Major components of the LM6000

HPT Nozzle Stage 2

Sheet metal air seals are inserted to slots cast in the nozzle inner and outer platforms to seal the flowpath to minimize between vane leakage.

The nozzle vanes are cooled by internal impingement air taken from the HPC 11th stage which enters through bosses in the outer ends of the vanes. A portion of the air is discharged through ports in the inner end of the vanes for interstage seal cavity.

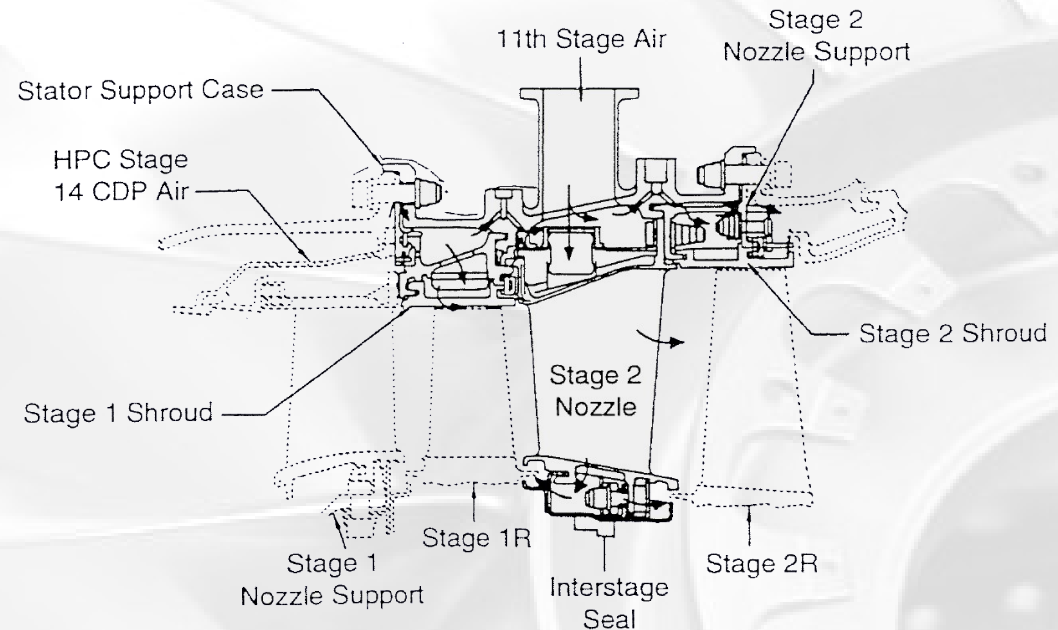


HPT STG. 2 NOZZLE COOLING

4. Major components of the LM6000

HPT Nozzle Stage 2

Stage 14 or CDP airflow circulates across the stage 1 shroud support from front to rear through oversize bolt holes and channels in the flanges. Stage 11 air flow circulates across the stage 2 shroud support in the same manner as the stage 1 shroud support, thus cooling the flanges, vane support components, stage 1 and 2 shrouds, and the stage 2 vane segments and interstage seal.



HPT STG. 2 NOZZLE COOLING

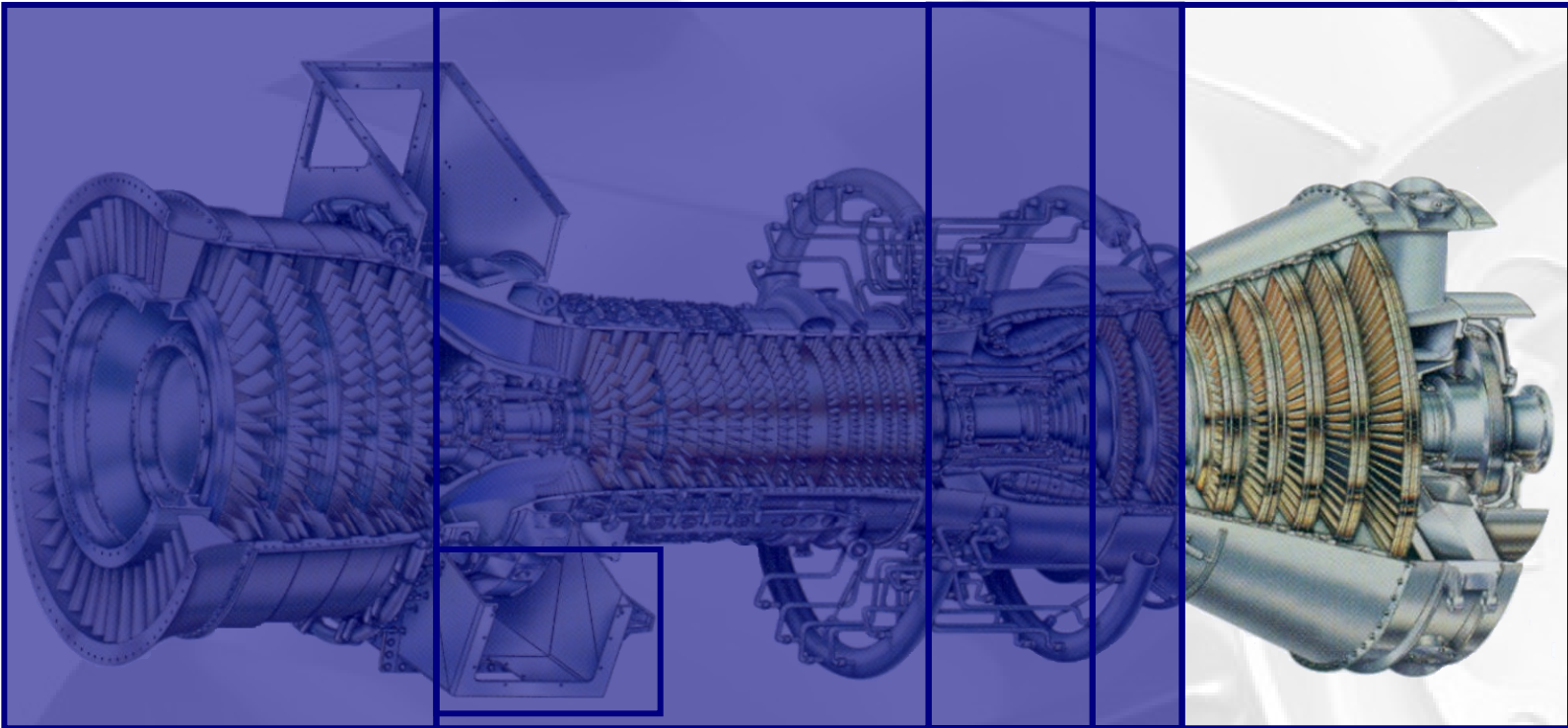
4. Major components of the LM6000

Table of contents

- | | |
|---|---|
| <ul style="list-style-type: none">1. Abbreviations and acronyms2. Gas turbine basics3. Introduction to the LM60004. Major components of the LM6000<ul style="list-style-type: none">a. Low Pressure Compressor (LPC)b. High Pressure Compressor (HPC)c. Combustord. High Pressure Turbine (HPT)e. Low Pressure Turbine (LPT)f. Accessory Drive (AGB, TGB, IGB)g. Engine Frames (CFF, CRF, TRF)h. Bearings and Sumps | <ul style="list-style-type: none">5. Parasitic Air Flow6. Auxiliary equipment and system<ul style="list-style-type: none">a. Lubrication Systemb. Variable Geometry Systemc. Fuel, Water and Steam Systemsd. Starting Systeme. Instrumentation |
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4. Major components of the LM6000

Low Pressure Turbine (LPT)

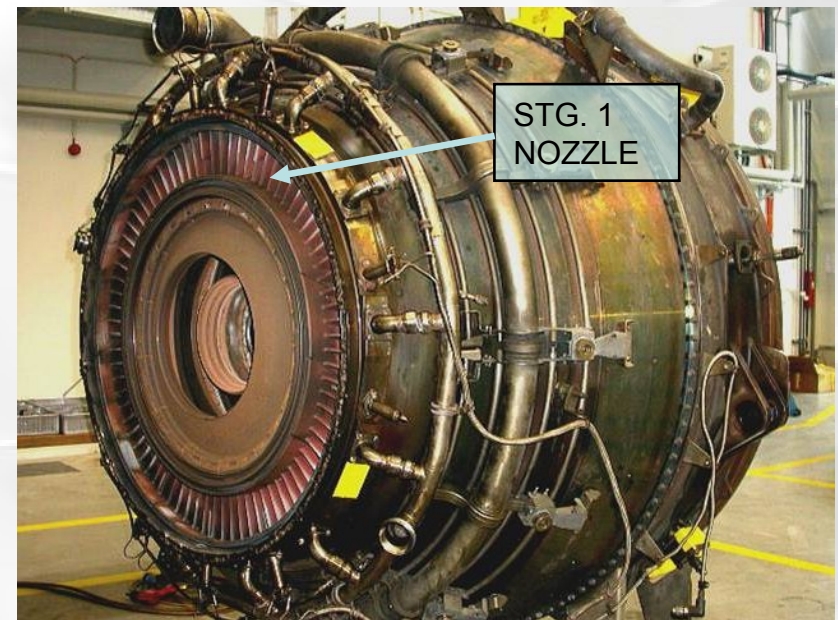


4. Major components of the LM6000

Low Pressure Turbine (LPT)

The LPT drives the LPC and load device using the core gas turbine discharge gas flow for energy.

The principal components of the LPT module are a five-stage stator, a five-stage rotor supported by the No. 6R and No. 7R bearings, and a cast TRF supporting the stator casing and the No. 6R and No. 7R bearings.



LPT Module

4. Major components of the LM6000

LPT (PC/PD upgrade)

To increase long term reliability and power output a new LPT module was introduced with LM6000 versions PC and PD.

This upgrade-LPT includes mainly new stage 3-5 Blades, 4-5 vanes and disks as well as a new stator case and TRF.

The LPT outlet diameter has been increased to prevent gasflow caused stage 5 blade failures at high power operation.

The upgrade also includes a new Midshaft to meet the higher torque.

Heritage

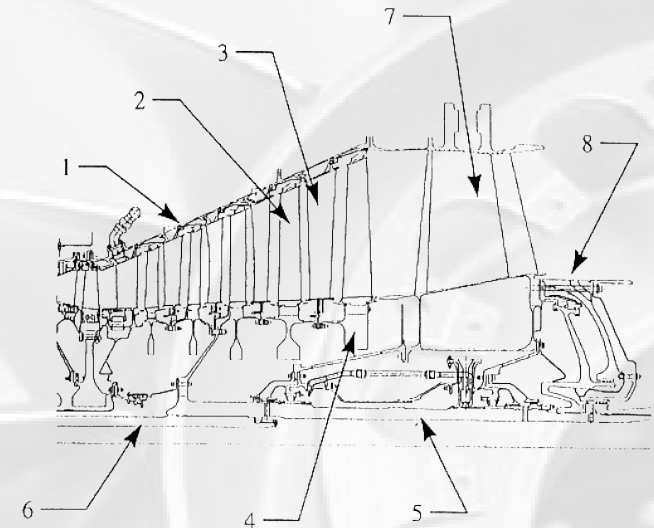
CF6-80C2/80E1

LM6000PA/PB changes:

- Stage 5 blade mat'l changed: R77 to DSR108
- New TRF
- added 7R bearing and sump
- added Balance Piston Ass'y
- added rear drive adapter

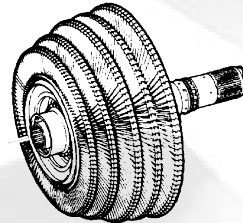
LM6000PC/PD Changes

- 1 - Case
- 2 - Stage 3-5 Blades
- 3 - Stage 4 & 5 Vanes
- 4 - Stages 4 & 5 Disks
- 5 - Aft Shaft
- 6 - Mid-shaft
- 7 - Turbine Rear Frame
- 8 - Balance Piston Stator



4. Major components of the LM6000

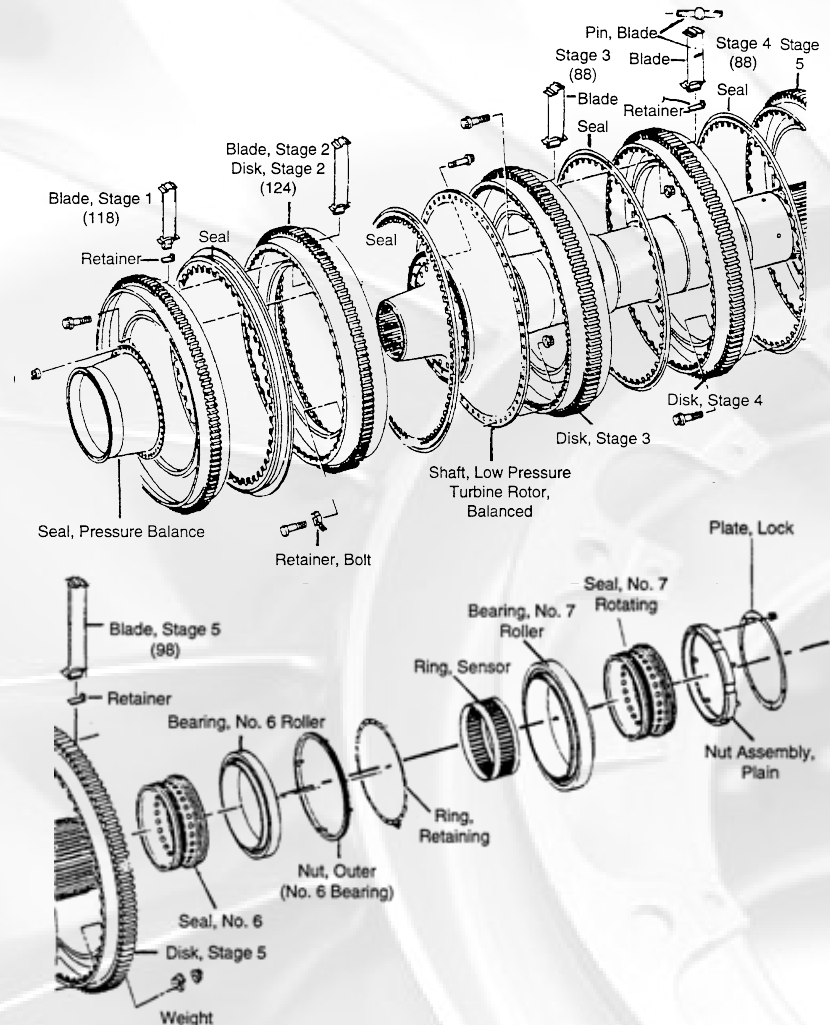
LPT Rotor



The LPT rotor assembly drives the LPC and the load either through Midshaft and Forward Drive Adapter (Cold End Drive) or directly through the Rear Drive Adapter (Hot End Drive).

The LPT rotor assembly is made of five stages of bladed disks and a shaft subassembly.

The rotor is supported by the No.6R and No. 7R bearings in the D- and E-sump of the TRF.



4. Major components of the LM6000

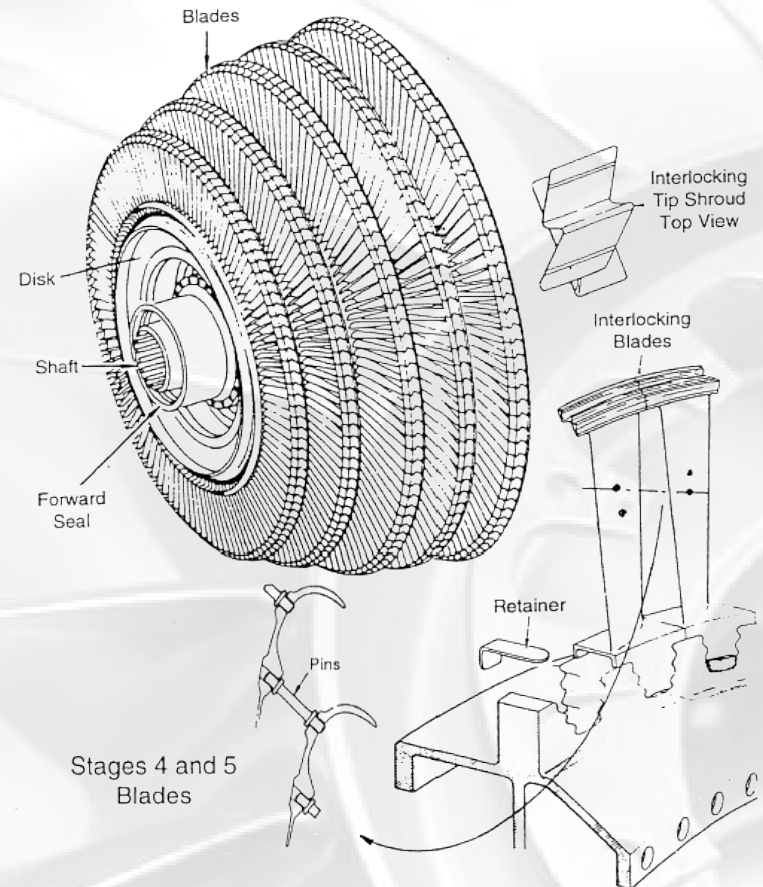
LPT Rotor

All five stages LPT blades are cast with an interlock tip shroud.

These tip shrouds prevent the blades from twisting and by the hot gas stream.

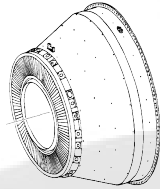
All blades are individually retained in place by sheet metal clips which are bent upward after blade installation.

The long stage 4 and 5 blades of the older LPT versions (LM6000 PA and PB) have anti-vibration pins installed to provide additional structural support.



4. Major components of the LM6000

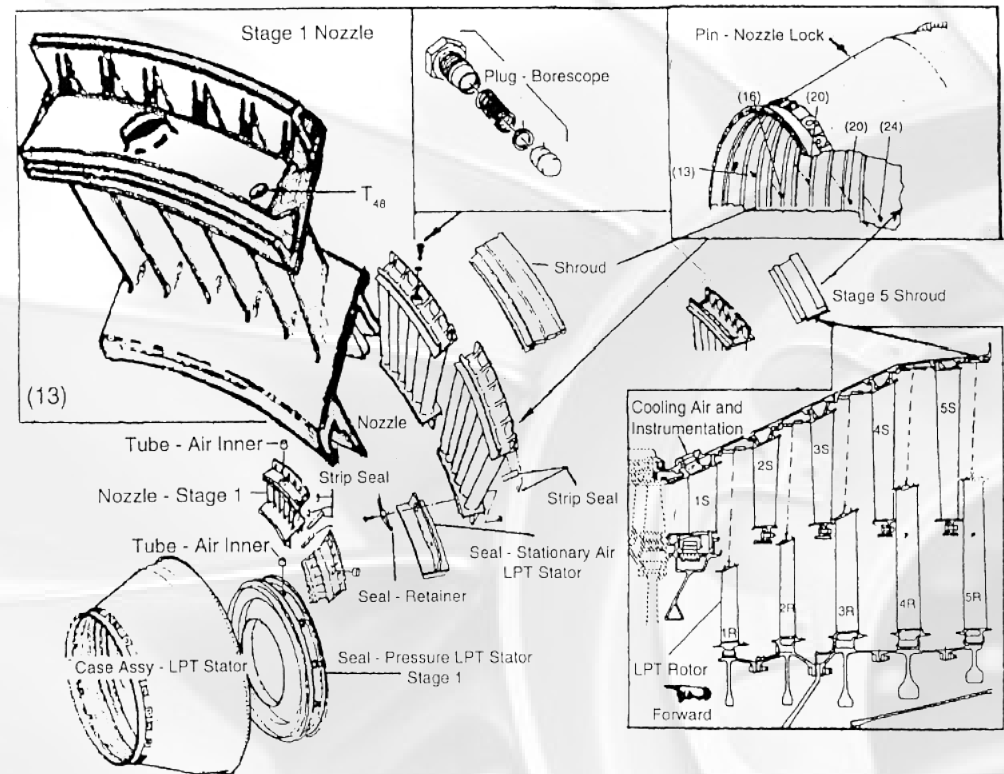
LPT Stator



The LPT stator assembly consists of a one-piece tapered casing, five stages of interlocking tip shrouds, a turbine case cooling manifold, air-cooled first stage nozzle segments with a pressure balance seal, and four additional stages of nozzle segments with interstage seals.

The honeycomb tip shrouds and interstage seals minimize the air leakages between stator and rotor.

All stages contain 13 to 24 nozzle segments with 6 vanes each.



4. Major components of the LM6000

LPT Stator

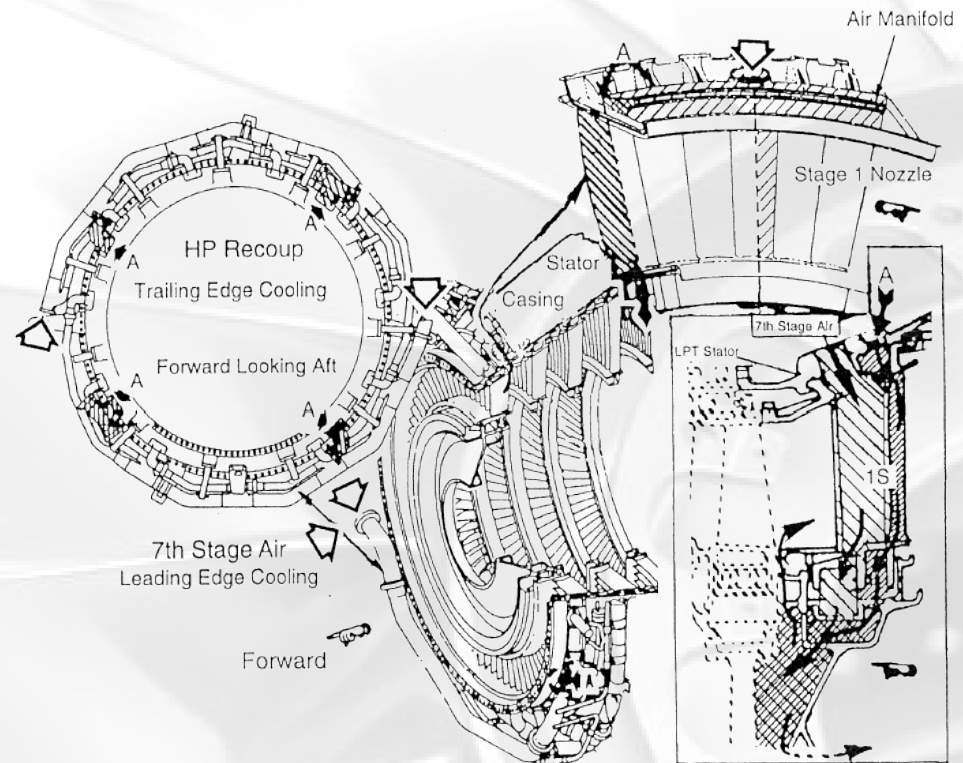
The LPT stage 1 nozzle segments are air cooled.

The leading edges are cooled by either HPC stg. 7 bleed air (PA & PB models) or stg. 8 bleed air (all later models).

The trailing edges are cooled by HP Recoup air.

All cooling air is piped via external manifolds into the LPT stg. 1 nozzles.

LPT Stages 2-5 nozzles do not have additional cooling.



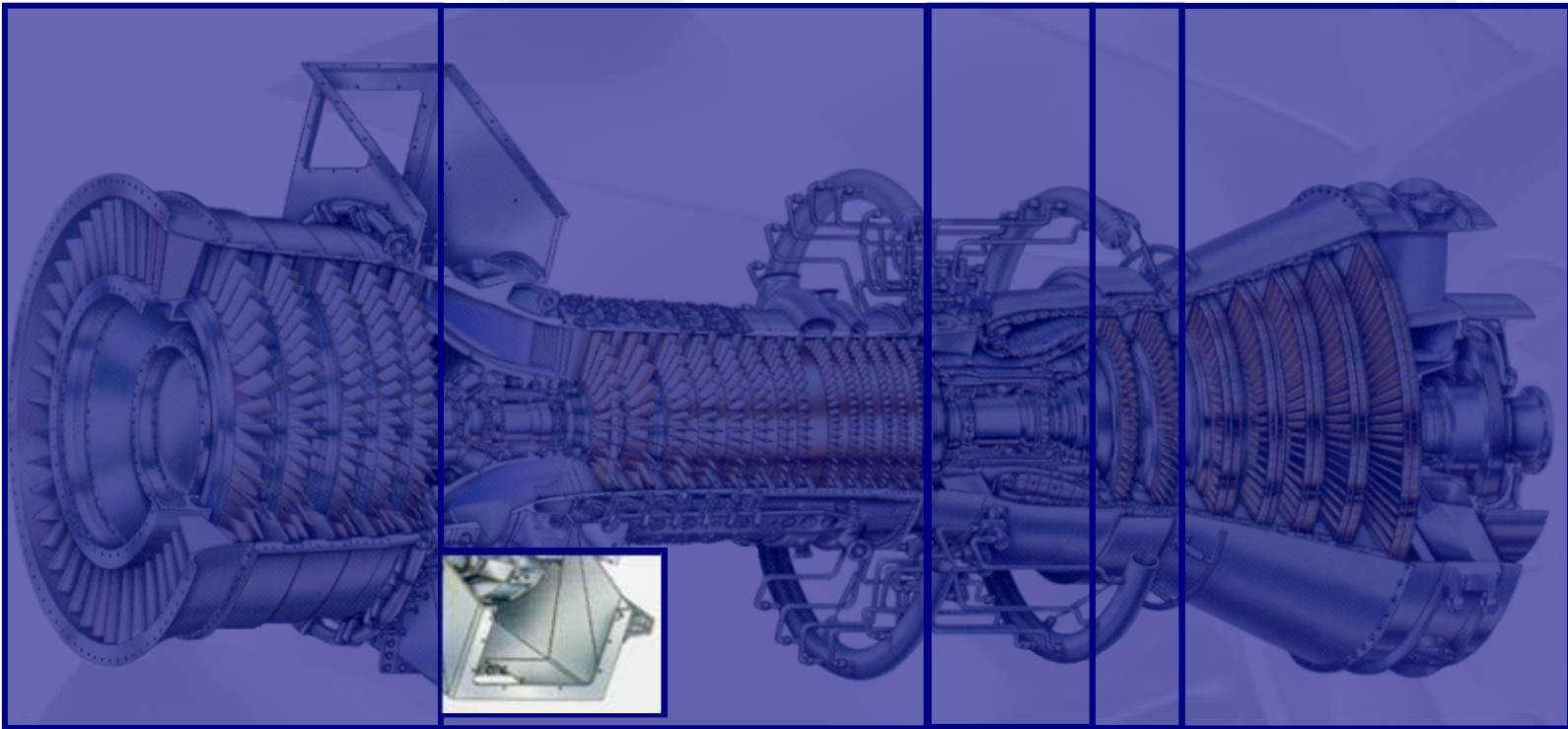
TECHNICAL TRAINING

Table of contents

1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
- 4. Major components of the LM6000**
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB, TGB, IGB)**
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
5. Parasitic Air Flow
6. Auxiliary equipment and system
 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

4. Major components of the LM6000

Accessory Drive System



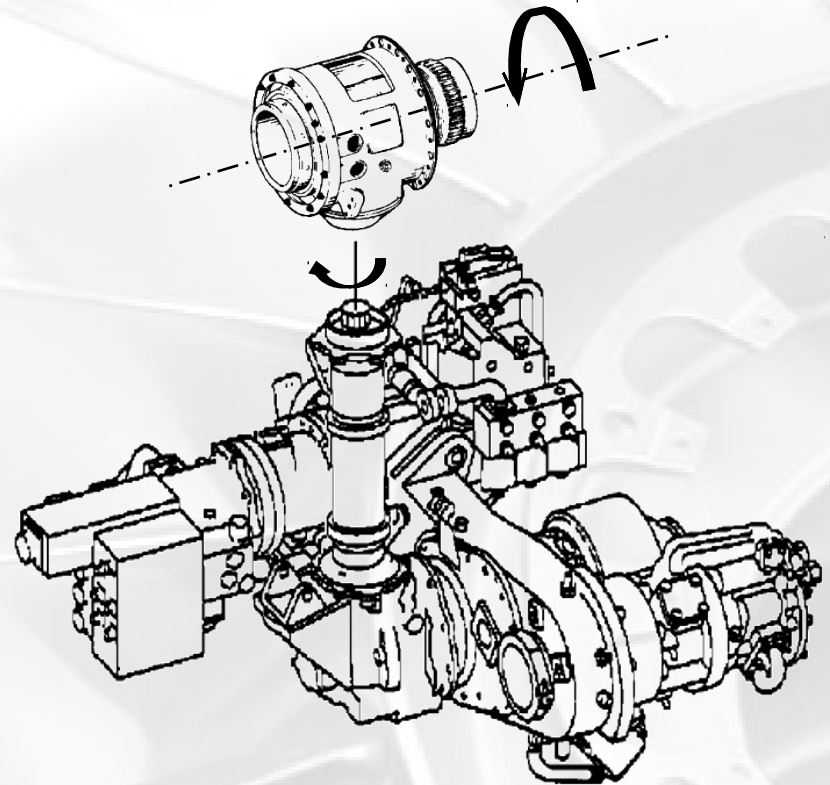
4. Major components of the LM6000

Accessory Drive System

The accessories mounted to the Accessory Gearbox (AGB) are driven from the high pressure rotor system by the Inlet Gearbox (IGB), a radial drive shaft, and the Transfer Gearbox (TGB) assembly.

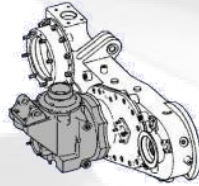
The starter motor, lube and scavenge pump, VG hydraulic pump, and the hydraulic control unit are mounted and driven through the AGB.

Optionally mounted driven accessories are a liquid fuel pump and/or a 8 gpm hydraulic pump.



4. Major components of the LM6000

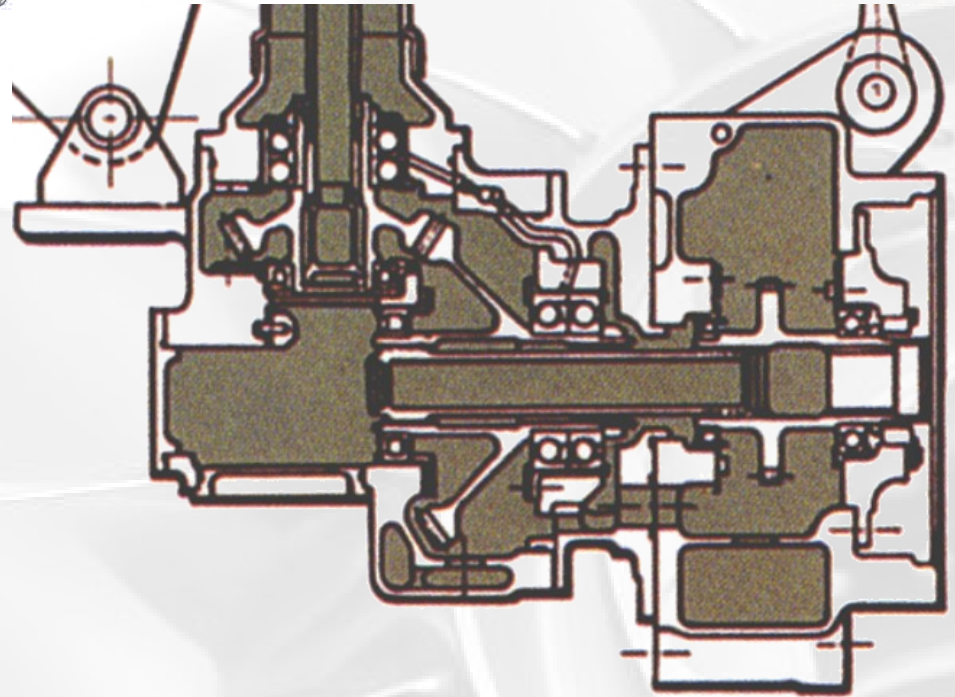
Transfer Gearbox (TGB)



The TGB transfers the IGB radial drive into horizontal direction to drive the accessory gearbox assembly.

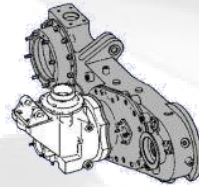
It consists of a 3-piece cast aluminium casing, a set of bevel gears and it's associated bearings and oil jets.

the vertical bevel gear is splined to the radial drive shaft, the horizontal one to is splined to the AGB's horizontal drive shaft.



4. Major components of the LM6000

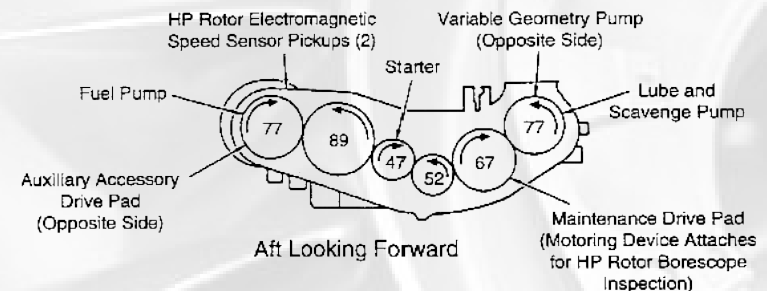
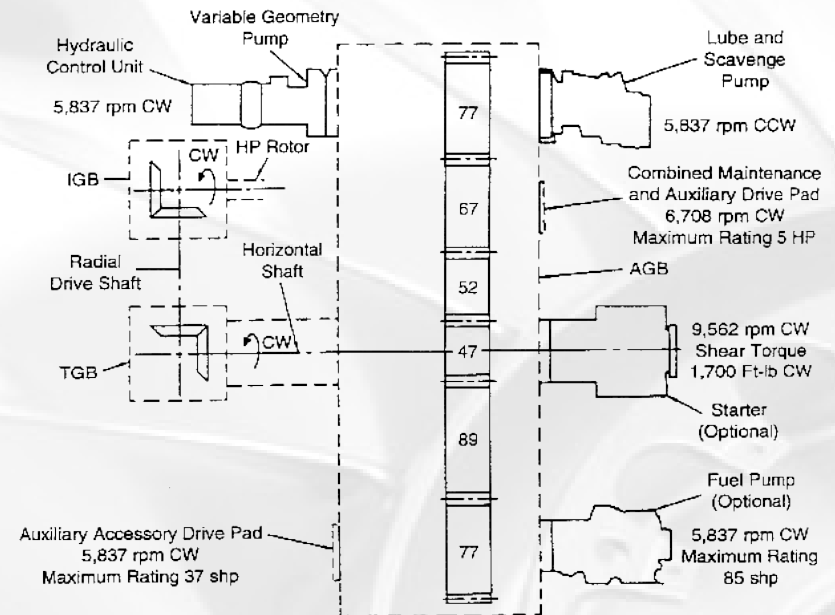
Accessory Gearbox (AGB)



The AGB provides the drive interface for all engine driven accessories such as pumps and control units. It is also the starter device interface to drive the GT's HP shaft.

The AGB consists of a 1-piece cast aluminium casing, aluminium adapters, spur gears and associated bearings, seals and oil jets.

The AGB design features a “plug in” gear concept on all accessory pads which allows that an entire gear, bearing, seal and pad assembly may be removed and replaced without disassembling the gearbox module.



Notes: 1. All pad speeds are given at core engine speed of 10,000 rpm.
2. Rotational directions are looking at gearbox pads.

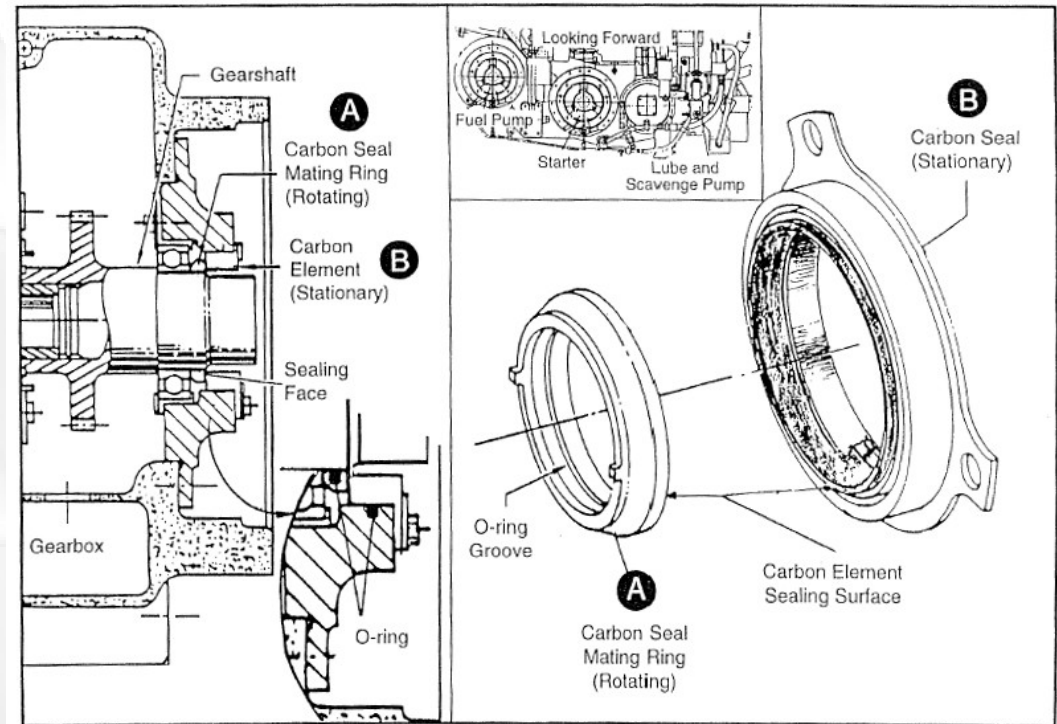
4. Major components of the LM6000

AGB carbon seals

There are 3 rubbing / non-labyrinth seals at the AGB module starter pad and both LH-side pads (liquid fuel pump / blank pads).

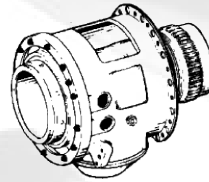
The carbon seal assembly consists of a rotating mating ring and the stationary carbon seal, both part's sealing surfaces are spring loaded together during operation.

each carbon seals can be replaced but must be changed as a matched rotating/stationary set at the same time.



4. Major components of the LM6000

Inlet Gearbox (IGB)

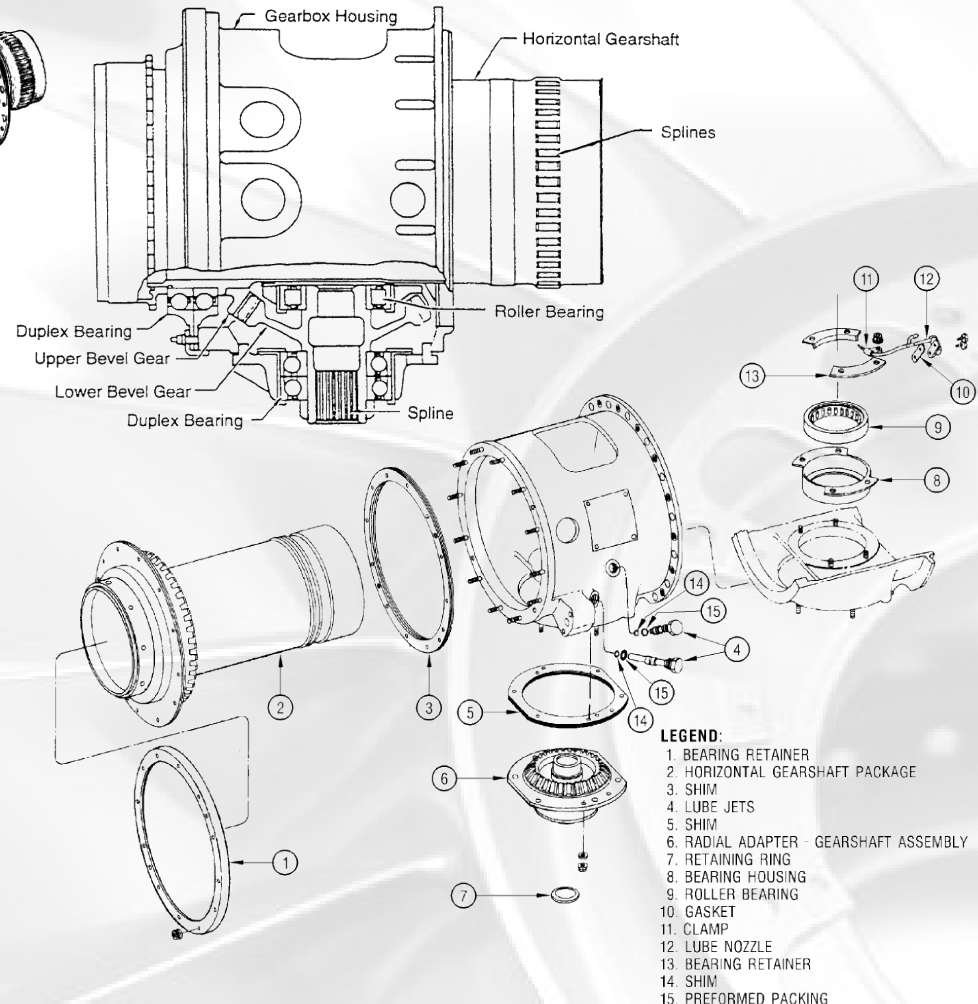


The IGB transfers the HP shaft drive from horizontal to vertical direction via the Radial Drive Shaft (RDS) towards the TGB / AGB.

The IGB consists of a cast aluminium casing, a set of bevel gears and it's associated bearings and oil jets.

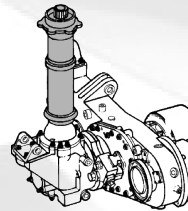
The horizontal gearshaft is splined at the aft end to the integral HPC forward shaft stage 2 disk. There is a replaceable drive spline installed to the HPC forward shaft secured by a retainer.

The vertical gearshaft is splined to the RDS.



4. Major components of the LM6000

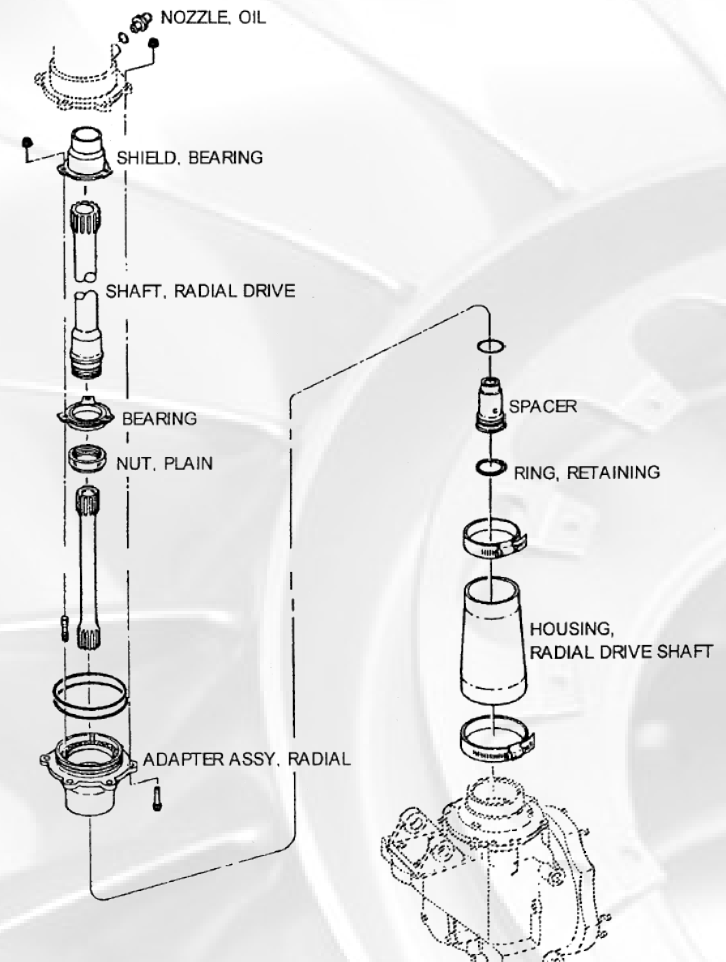
Radial Drive Shaft (RDS)



The Radial Drive Shaft (RDS) serves to transmit torque between IGB and TGB through Front Frame strut No.4.

The RDS consists of 2 tubular steel shafts, a housing and a bearing. The 2 shaft halves are coupled with splines. The relatively long RDS assembly is supported by an intermediate ball bearing at the bottom end of the upper shaft.

The housing around the RDS is also used as the A-sump lube oil scavenge line through TGB and then back to the Lube and Scavenge Pump.



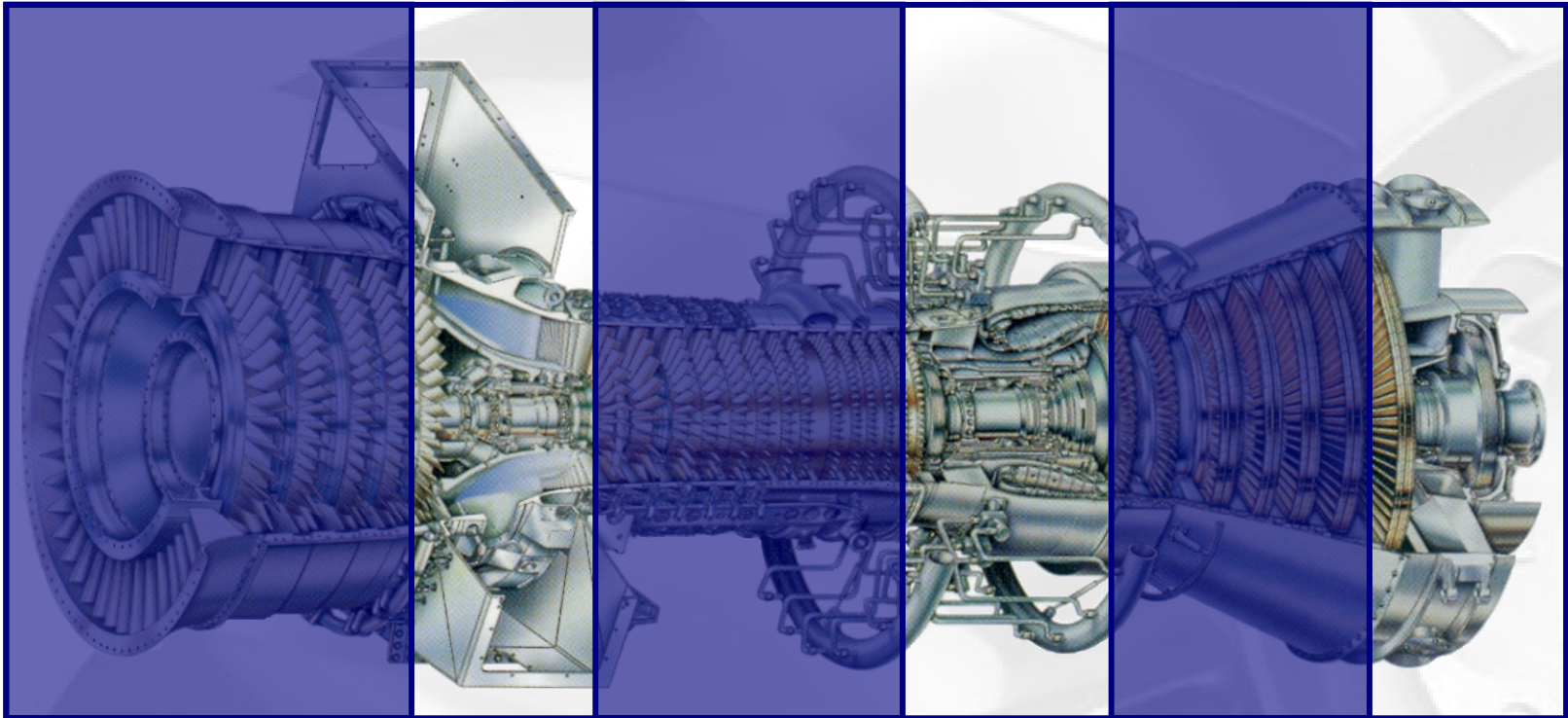
TECHNICAL TRAINING

Table of contents

1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
- 4. Major components of the LM6000**
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB; TGB; IGB)
 - g. Engine Frames (CFF, CRF, TRF)**
 - h. Bearings and Sumps
5. Parasitic Air Flow
6. Auxiliary equipment and system
 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

4. Major components of the LM6000

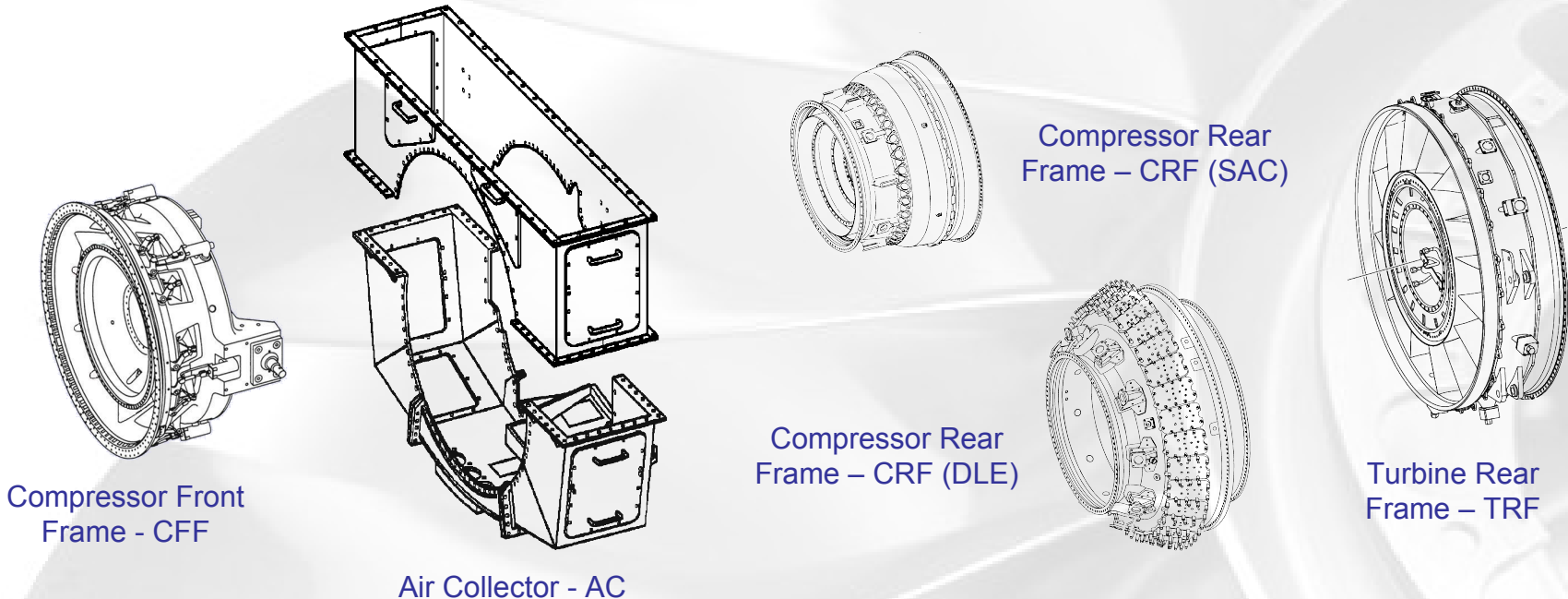
Engine Frames and Air Collector



4. Major components of the LM6000

Engine Frames and Air Collector

Three structural frames provide the bearing support LP and the HP Rotor. The frame configuration provides a gas turbine system with excellent dynamic and mechanical stability. It also controls compressor and turbine blade and vane tip clearances.



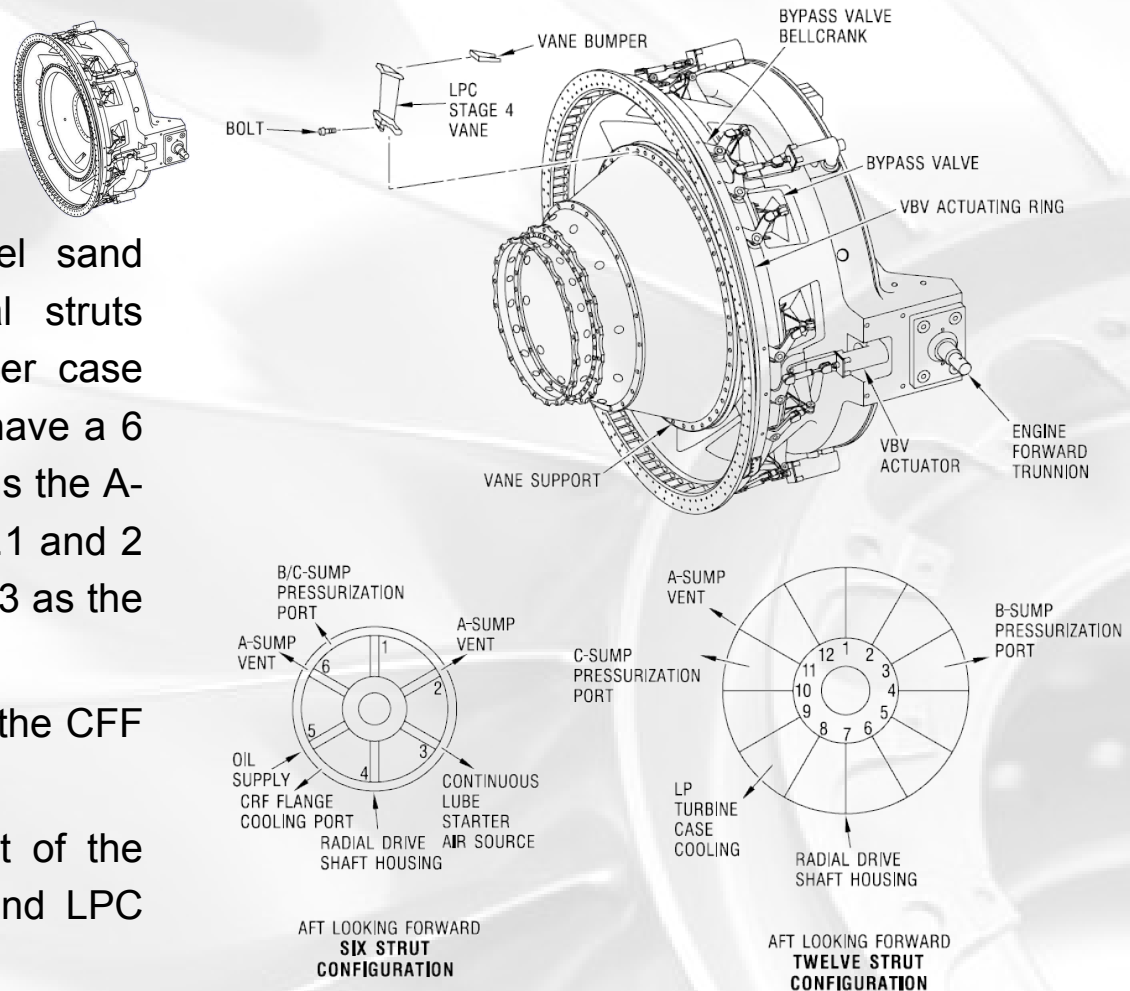
4. Major components of the LM6000

Compressor Front Frame (CFF)

The CFF is a high strength steel sand casting. 12 equally spaced radial struts support the inner hub and the outer case (some older PA & PB models may have a 6 strut configuration). The CFF contains the A-ump with the IGB and bearings No.1 and 2 to support the LPC rotor bearing No.3 as the HP shaft front support.

The GT front mounts are integral to the CFF and the axial fix points for the GT.

The stg. 4 LPC stator case is part of the frame casting for added stiffness and LPC clearing control.

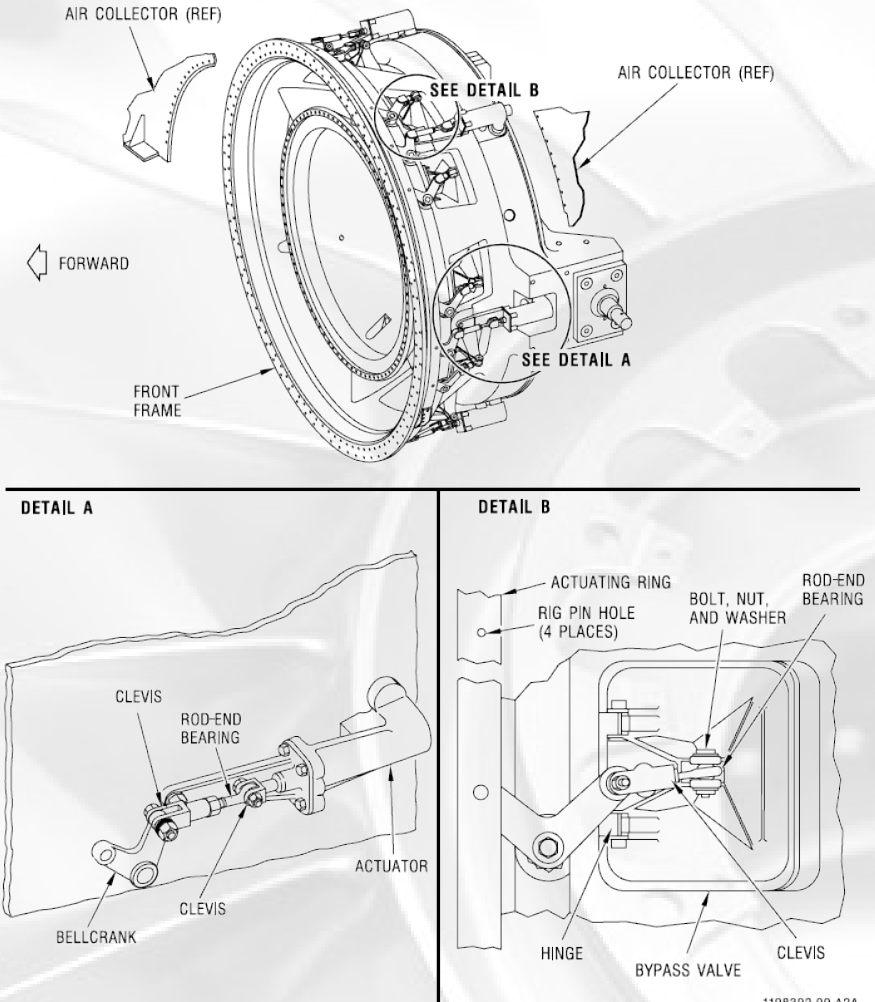


4. Major components of the LM6000

Compressor Front Frame (CFF)

The CFF also contains 12 hydraulically operated variable position bleed doors – Variable Bleed Valves (VBV) – located on the outer case to discharge excessive LPC airflow via the air collector.

The VBV's are operated by 6 hydraulic actuators interconnected by an actuating ring.



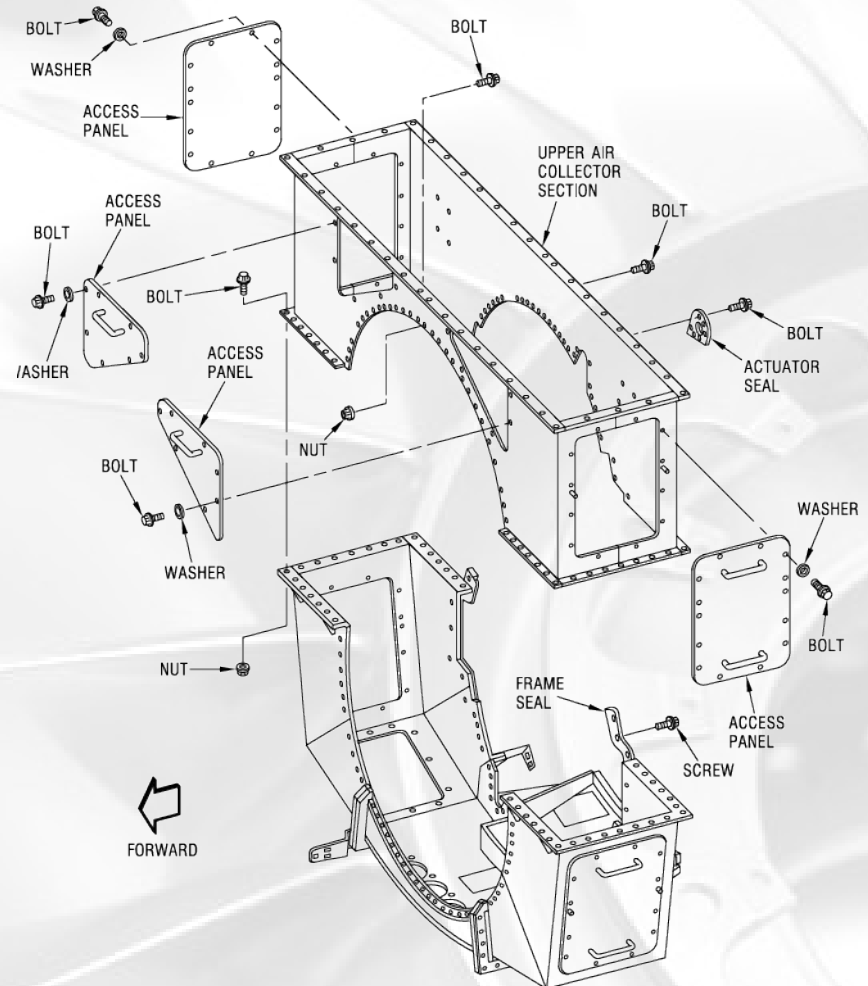
4. Major components of the LM6000

Air Collector (AC)

The Air Collector collects the bleed-off air from the 12 VBV doors around the front frame and route this air out of the enclosure via a package mounted VBV duct.

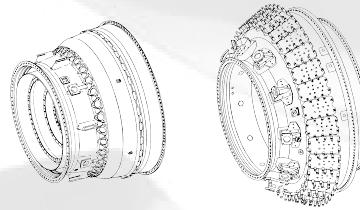
The AC is mounted to the CFF front and rear flanges.

It contains access panels all around to provide inspection and maintenance access to the front frame and VBV components.



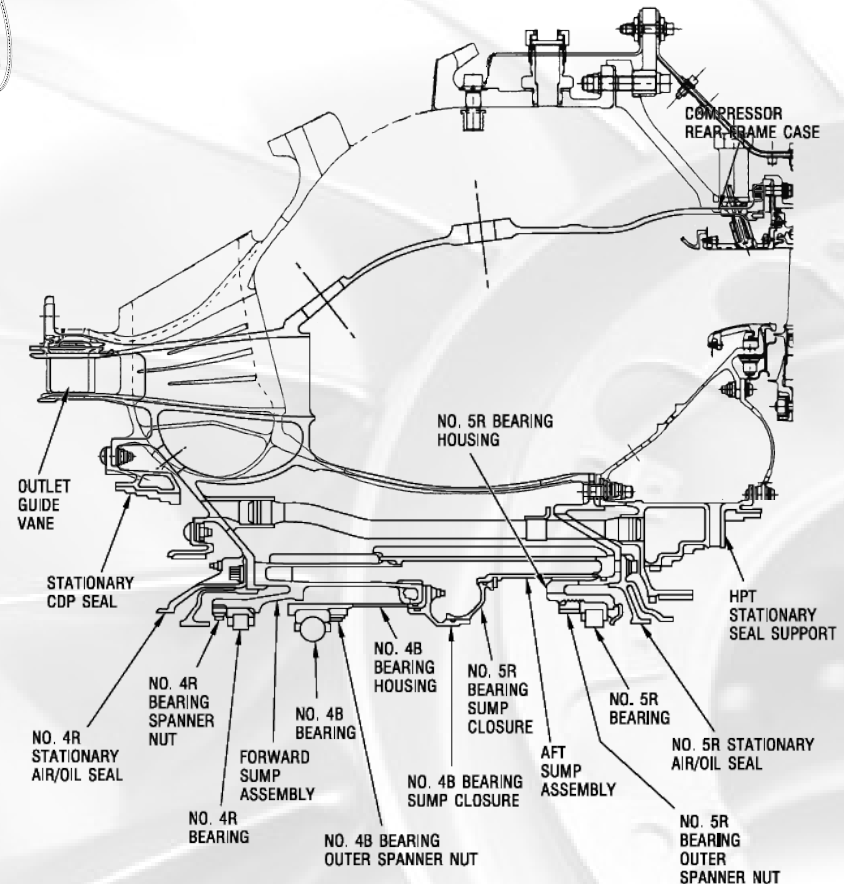
4. Major components of the LM6000

Compressor Rear Frame (CRF)



There are two principally different CRF configurations, one for SAC combustor models and one for DLE combustor models.

The CRF consists of an outer case, ten struts and the B-C sump housing. The B-C sump contains bearings No. 4R and 5R for rear HP shaft radial support and No. 4B for HP shaft axial support. The HPC stg. 14 outlet guide vanes (OGV's), the combustion chamber and the HPT stage 1 nozzle are mounted into the CRF. B-C sump service lines are contained in and pass through the CRF struts.



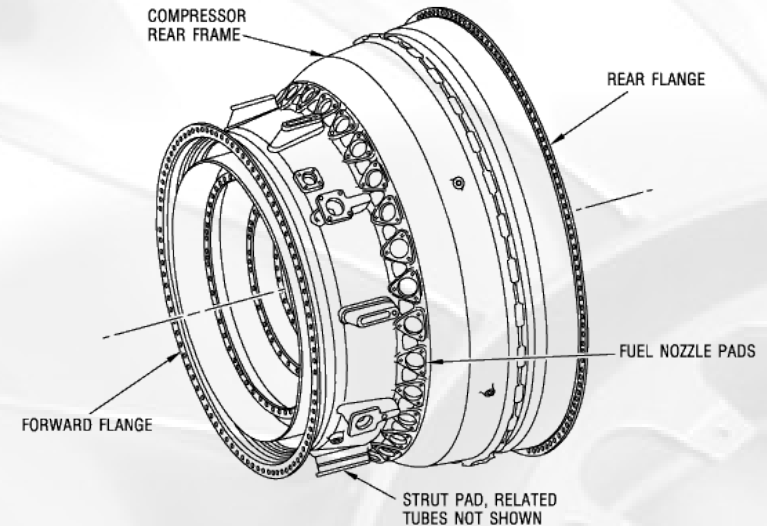
4. Major components of the LM6000

CRF – SAC version

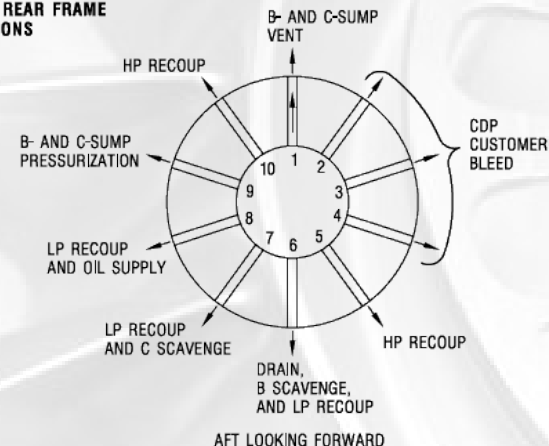
The SAC version CRF is similar to the frame used on the CF6-80C2 turbofan engine.

The one-piece outer casing serves as the structural load path between the HPC case and the HPT Stage 2 Nozzle case.

The CRF outer case provides 1 T3 Thermocouple port, 30 Fuel Nozzle ports, 2 Igniter ports, 6 combustor borescope / flame detection ports and 1 HPTN1 borescope port.



**COMPRESSOR REAR FRAME
STRUT FUNCTIONS**



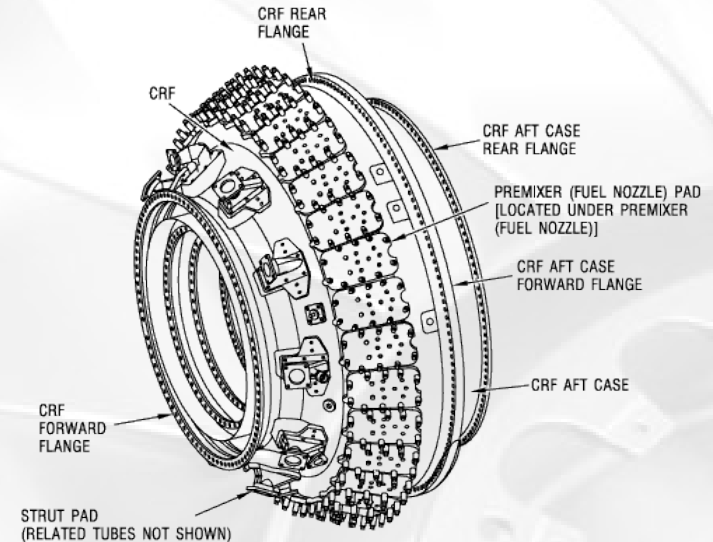
4. Major components of the LM6000

CRF – DLE version

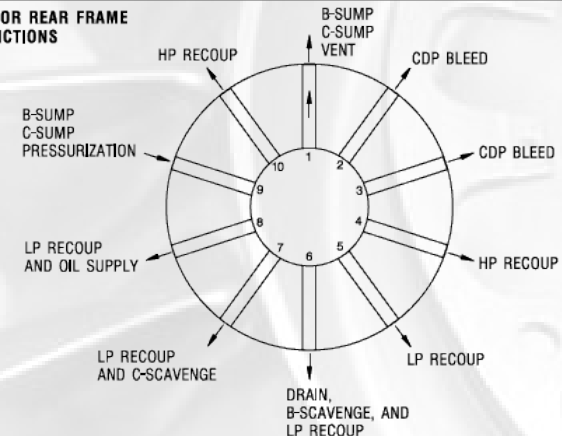
The DLE version CRF has been designed to house the 3 annular combustor and to provide the required ports for Premixers and additional sensors.

The outer casing consists of two pieces (main frame and rear case) to enable combustor installation.

The CRF outer case provides 2 T3 Thermocouple port, 30 Premixer ports, 2 Igniter ports, 2 flame detection ports, 2 acoustic sensor ports in the main frame and 1 HPTN1 borescope port in the rear case.



**COMPRESSOR REAR FRAME
STRUT FUNCTIONS**



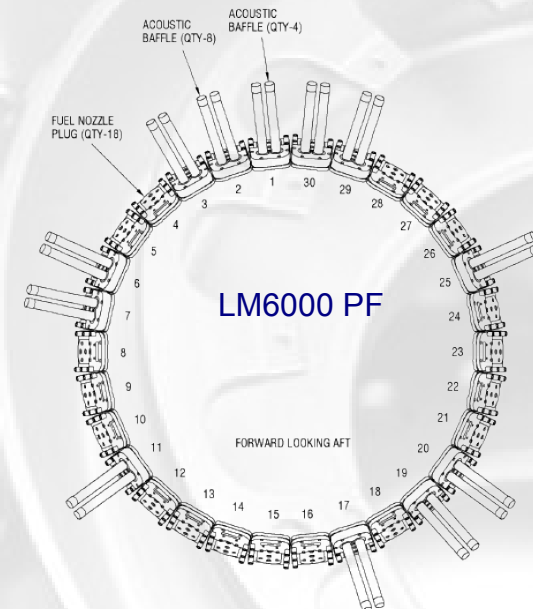
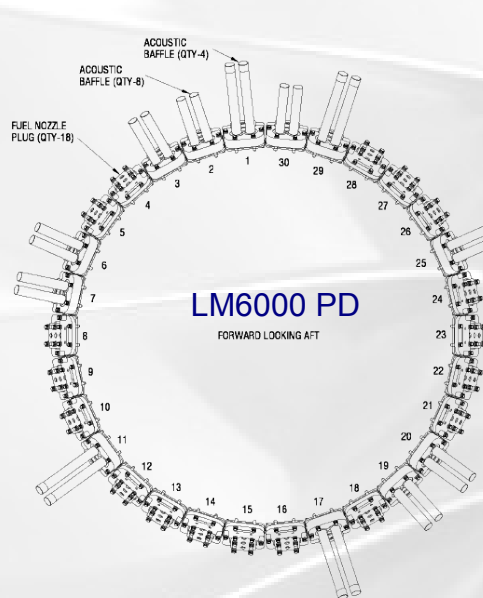
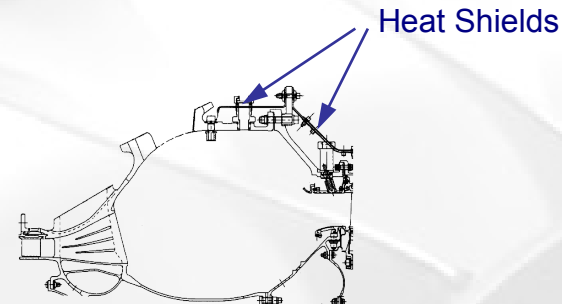
4. Major components of the LM6000

CRF – DLE version

The DLE version CRF case is equipped with heat shields to minimize the influence of the enclosure ventilation cooling effect to the CRF case and combustion chamber.

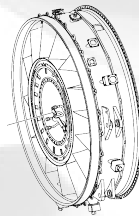
Acoustic Baffles are installed at the Premixer base plates at the front part of the CRF. These acoustic baffles reduce amplitudes of critical combustion acoustic frequencies.

The installation pattern is dependent on the LM6000 DLE model.



4. Major components of the LM6000

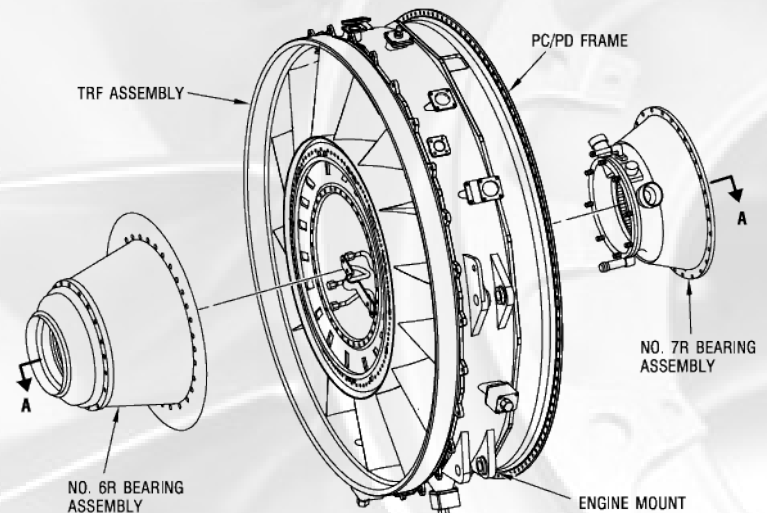
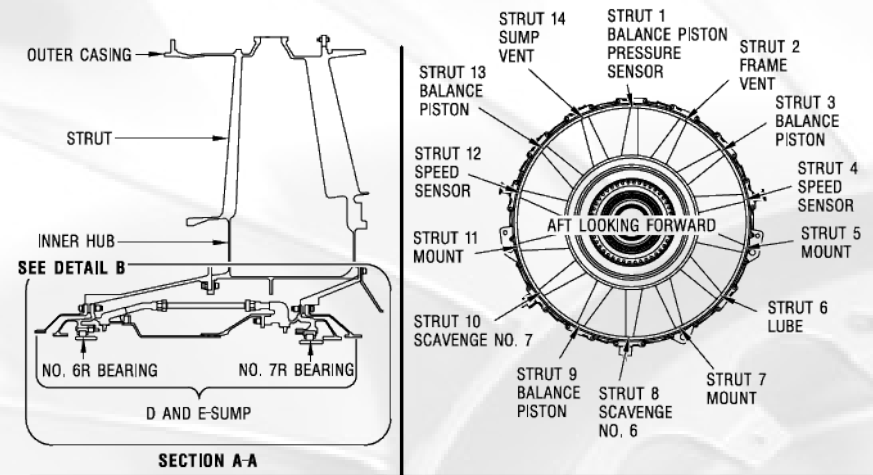
Turbine Rear Frame (TRF)



The TRF is a one-piece casting which provides the gas turbine exhaust flow path and the supporting structure for the D- and E-sump, the LPT rotor thrust balance assembly, the LPT rotor shaft, and the aft drive adapter.

14 radial struts function as outlet guide vanes to straighten the exhaust air flow into the exhaust diffuser for enhanced performance.

Lubrication oil supply and scavenge lines for the D- and E-sumps and LPT rotor speed sensors are routed through the struts.



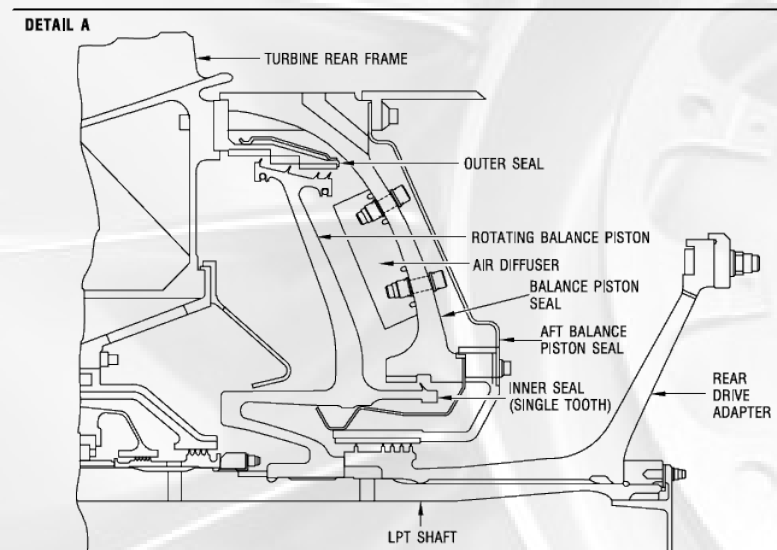
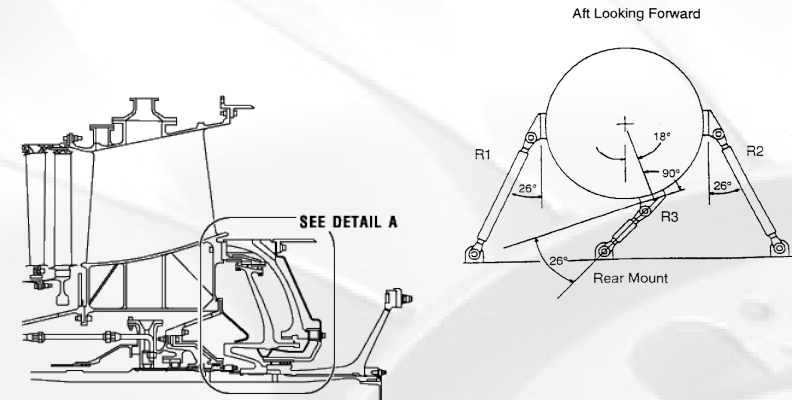
4. Major components of the LM6000

Turbine Rear Frame (TRF)

The TRF D-E sump contains the bearings No. 6R and 7R which provide LPT rotor and rear LP shaft radial support.

The TRF also contains the static balance piston seals which form the balance chamber to maintain the axial thrust loading of the No.1B bearing.

The TRF provides 3 mounts for the 2 GT rear vertical support links and the anti-torque link.



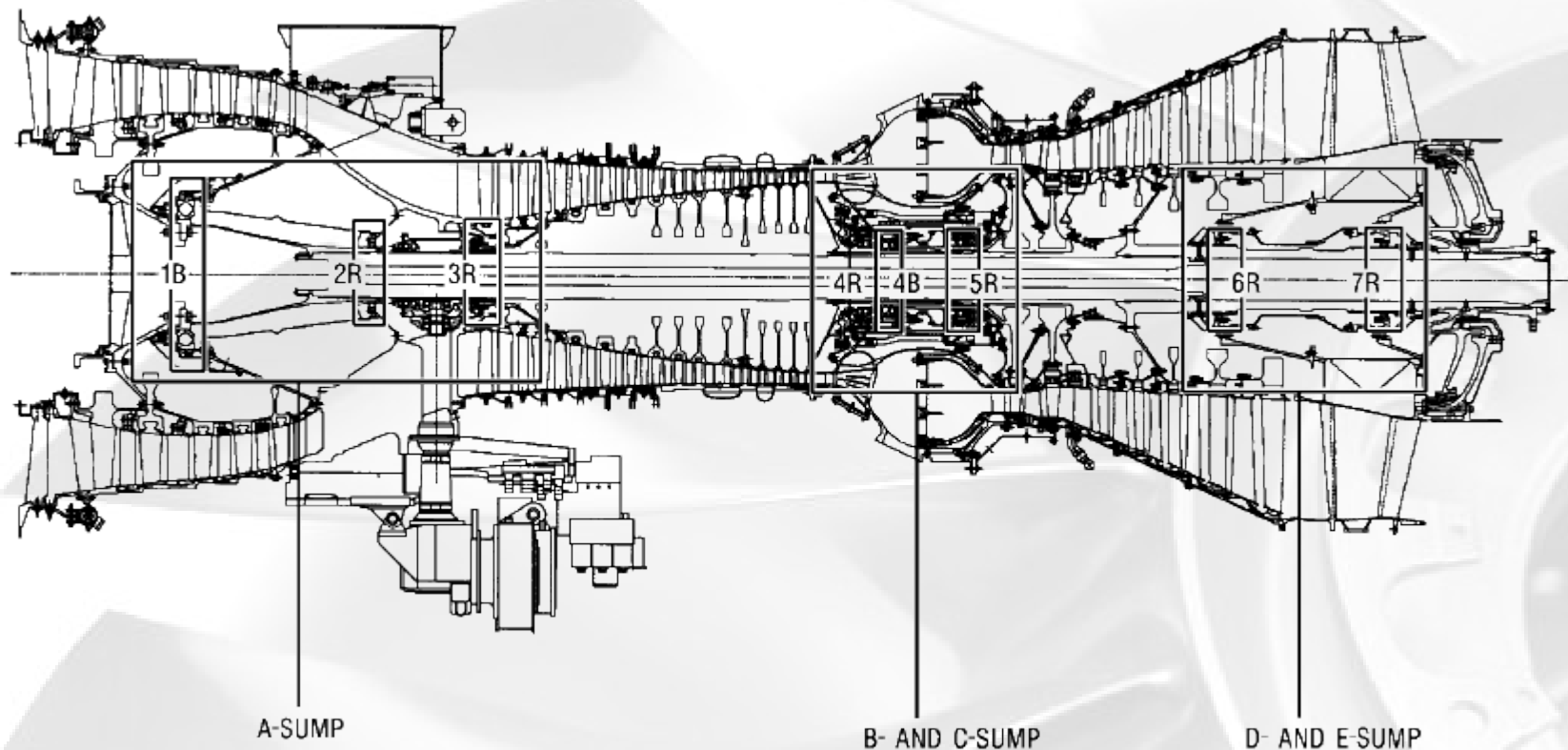
TECHNICAL TRAINING

Table of contents

1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
- 4. Major components of the LM6000**
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB; TGB; IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps**
5. Parasitic Air Flow
6. Auxiliary equipment and system
 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

4. Major components of the LM6000

Bearings and Sumps



4. Major components of the LM6000

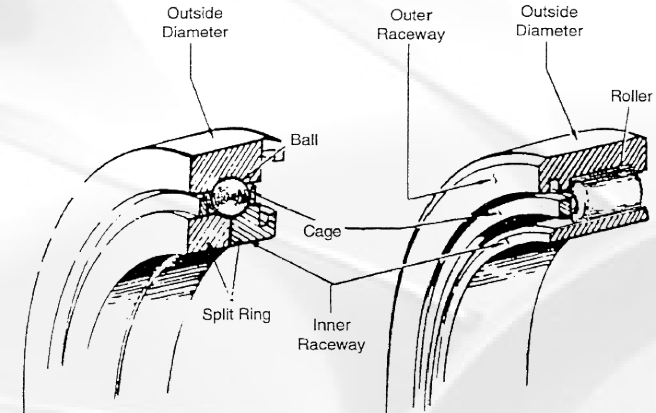
Bearings

All LM6000 main bearings are either roller or ball bearings made of M50 steel, premium grade.

The roller bearings (2R, 3R, 4R, 5R, 6R and 7R) provide radial rotor support. The two ball bearings provide the axial thrust load support for the LP shaft (1B) and the HP shaft (4B).

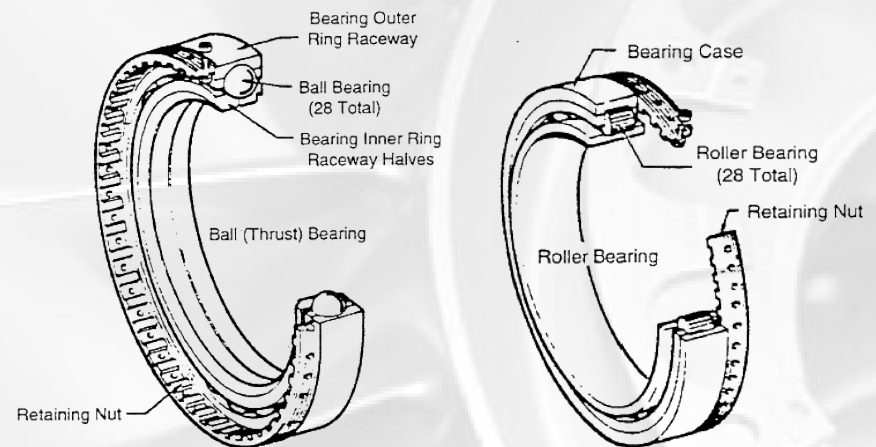
The inner races are interference fit to the shafts and secured from creeping by coupling nuts.

The outer races are secured in place by either a bolted flange or squeezed in a housing by a coupling nut.



Split Ring Ball Bearing

Typical Roller Bearing



4. Major components of the LM6000

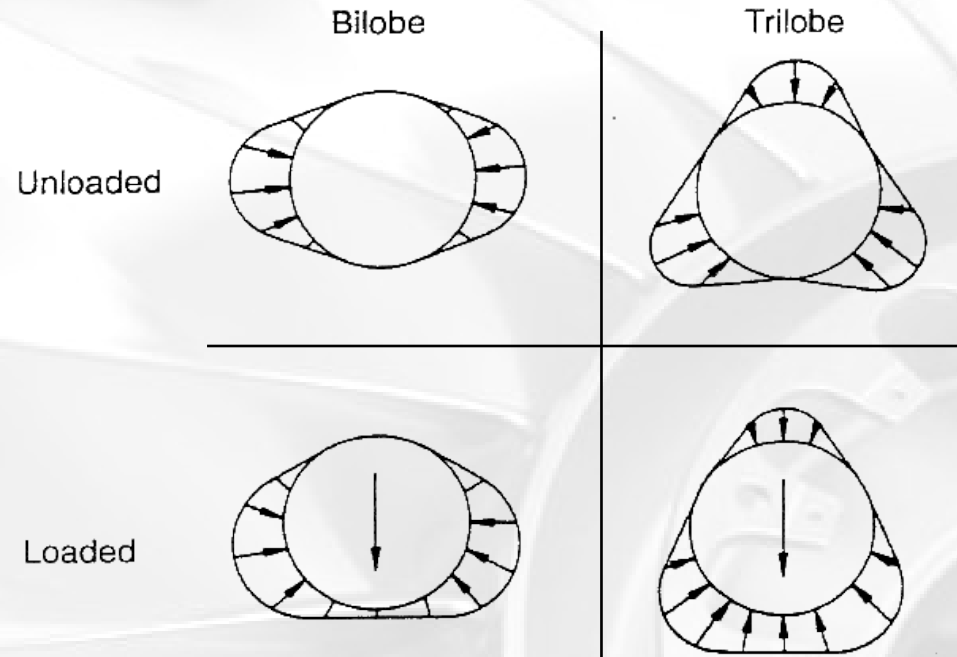
Bearing preload

The LM6000 roller bearings are preloaded to prevent roller slip due to too low traction.

This preload is achieved by using bilobe or trilobe bearings which guarantee a minimum load regardless of the externally applied loads.

Bilobe bearings consist of a accurately ground profile in the outer raceway to give a radial pinch at 2 points.

Trilobe bearings are similar in concept but used if higher preloads are required. The trilobe 3-point bearing rings have a 5-times higher bending stiffness vs. 2-point bending.



NOTE:

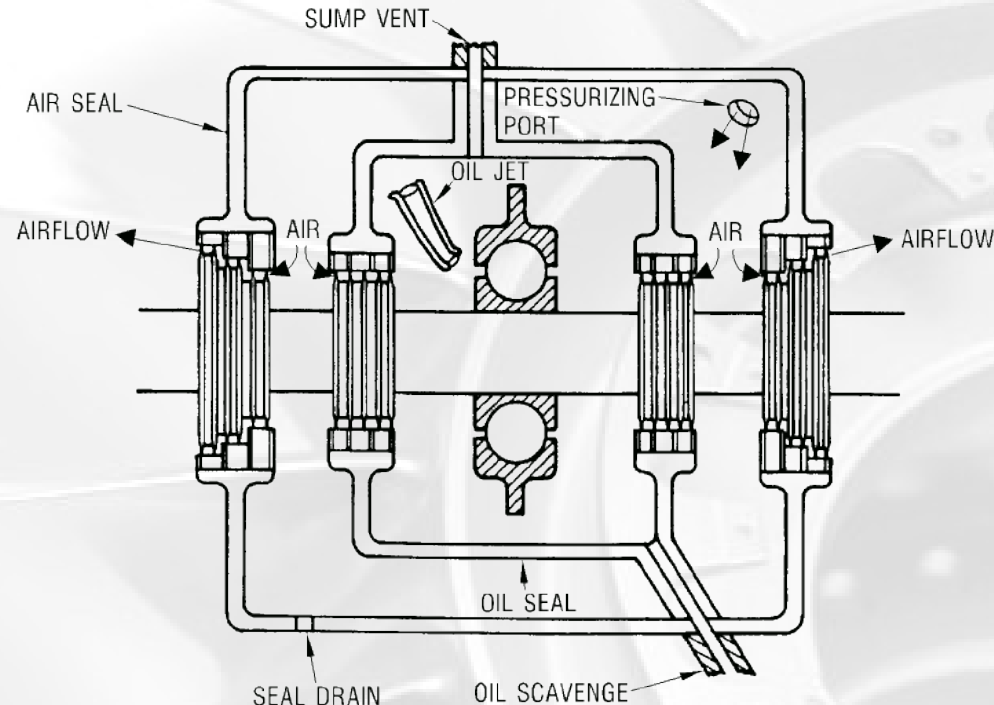
The interference fit of the bilobe and trilobe bearings requires the HPT rotor be turning during removal or installation to prevent damage of inner race or bearing

4. Major components of the LM6000

Sump Philosophy

The LM6000 uses the dry sump system to provide lubrication of the main bearings. This system includes 5 subsystems:

1. Oil supply through jets pressurized and delivered by a supply pump
2. Oil scavenge by applying suction to a port in the lowest point of the sump by a scavenge pump
3. Seal pressurization provided by parasitic air bleed directed to the sump
4. Sump vent maintains a positive sump inward flow of pressurized air by venting the oil wetted cavity out the top to ambient
5. Seal drain carries oil leaked out the seals to a drainage



4. Major components of the LM6000

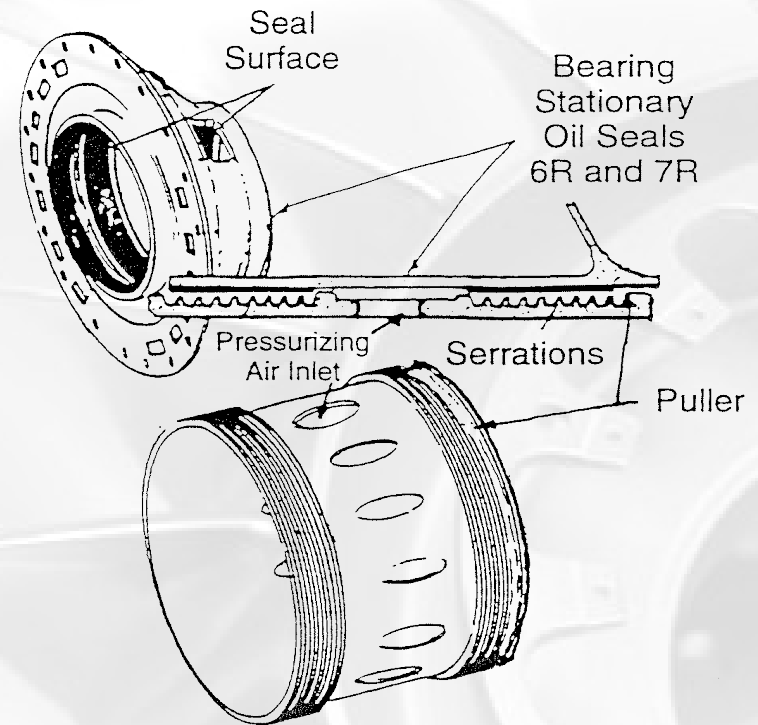
Oil Seals

All oil seals are labyrinth type seals containing of a rotating and a stationary part.

The rotating part are all of a multiple knife edge serration type.

The stationary oil seals have got shroud surfaces opposite to the knife serrations to provide a very small gap to let the pressurization air flow through towards the sump carrying the leaking oil back inside.

The sump inflowing pressurization air is removed both by sump vent system and the scavenge oil.



4. Major components of the LM6000

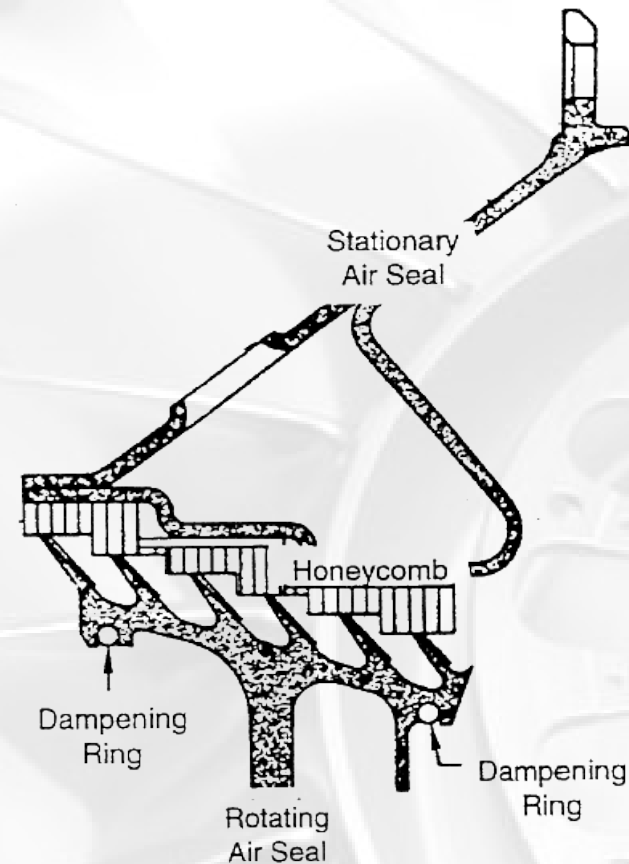
Air Seals

All air seals are labyrinth type seals containing of a rotating and a stationary part.

The rotating part are all of a multiple knife edge serration type.

The stationary air seals are commonly honeycomb type. During initial operation the knife serrations cut small grooves inside the honeycombs creating a labyrinth air flow passage. This labyrinth works like an orifice creating a flow resistance and a pressure drop.

The pressurization air flowing through the air seals is removed through seal vent to ambient or into the main gas path.

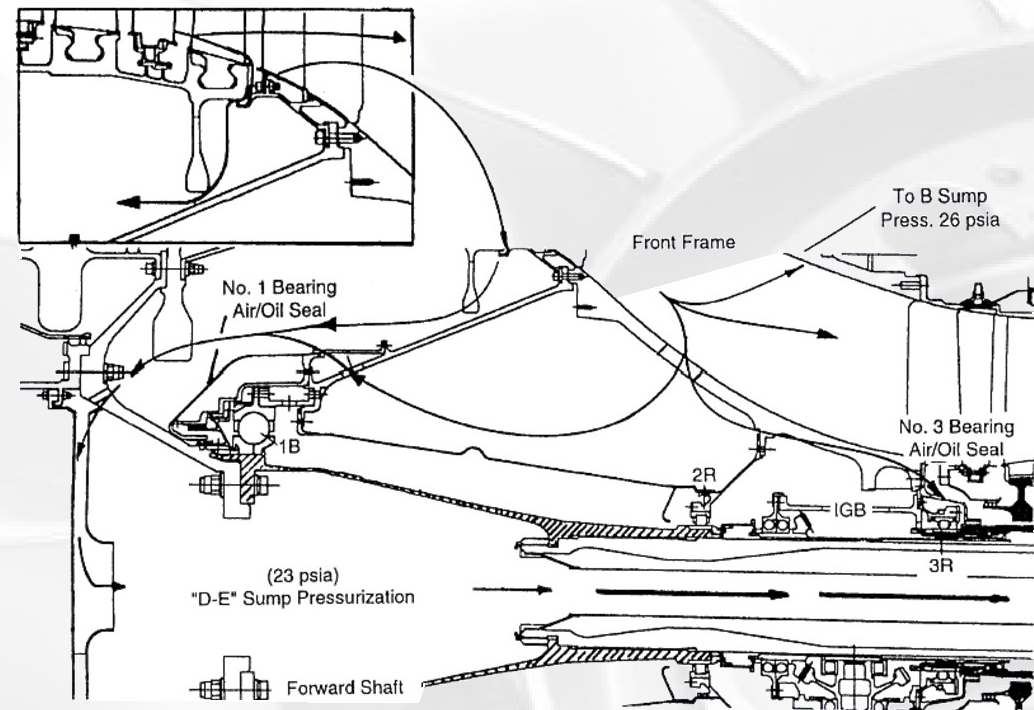


4. Major components of the LM6000

A-Sump Philosophy

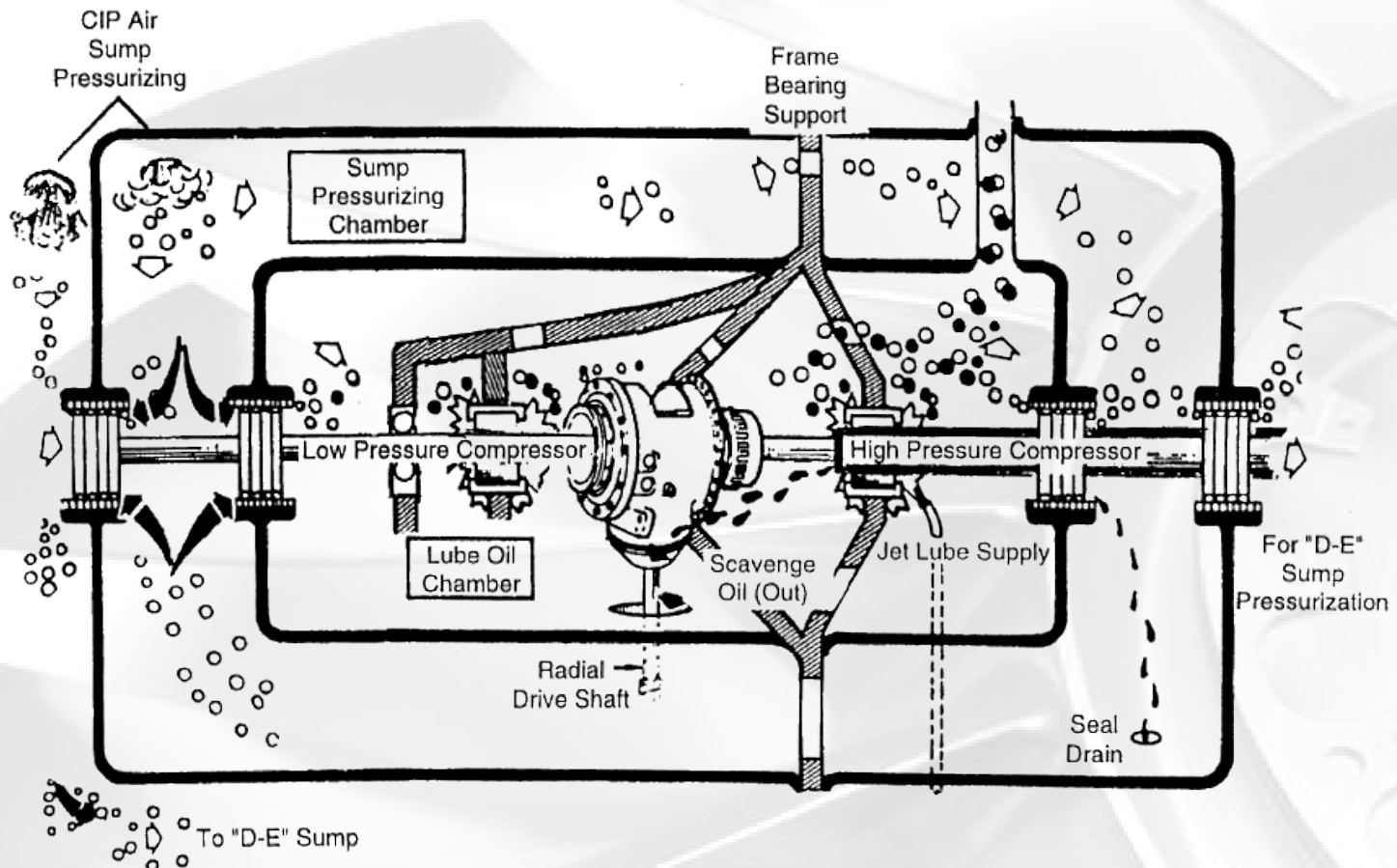
The A-sump contains bearings No.1B and 2R for forward LP shaft support, the IGB and Bearing No.3R for forward HP shaft support.

- Sump pressurization: LPC discharge air
- Oil supply: separate oil jets for each bearing and IGB splines
- Oil Scavenge: through TGB to L+S pump
- Seal drain: drains through TGB to scavenge
- Seal vent: back into LPC spool
- Sump vent: to package air oil separation



4. Major components of the LM6000

A-Sump Philosophy

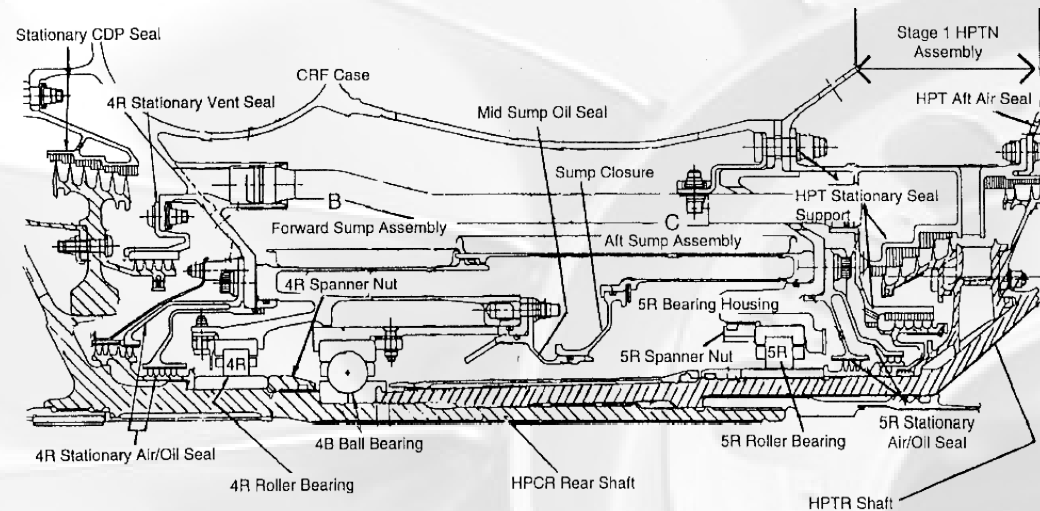


4. Major components of the LM6000

B-C-Sump Philosophy

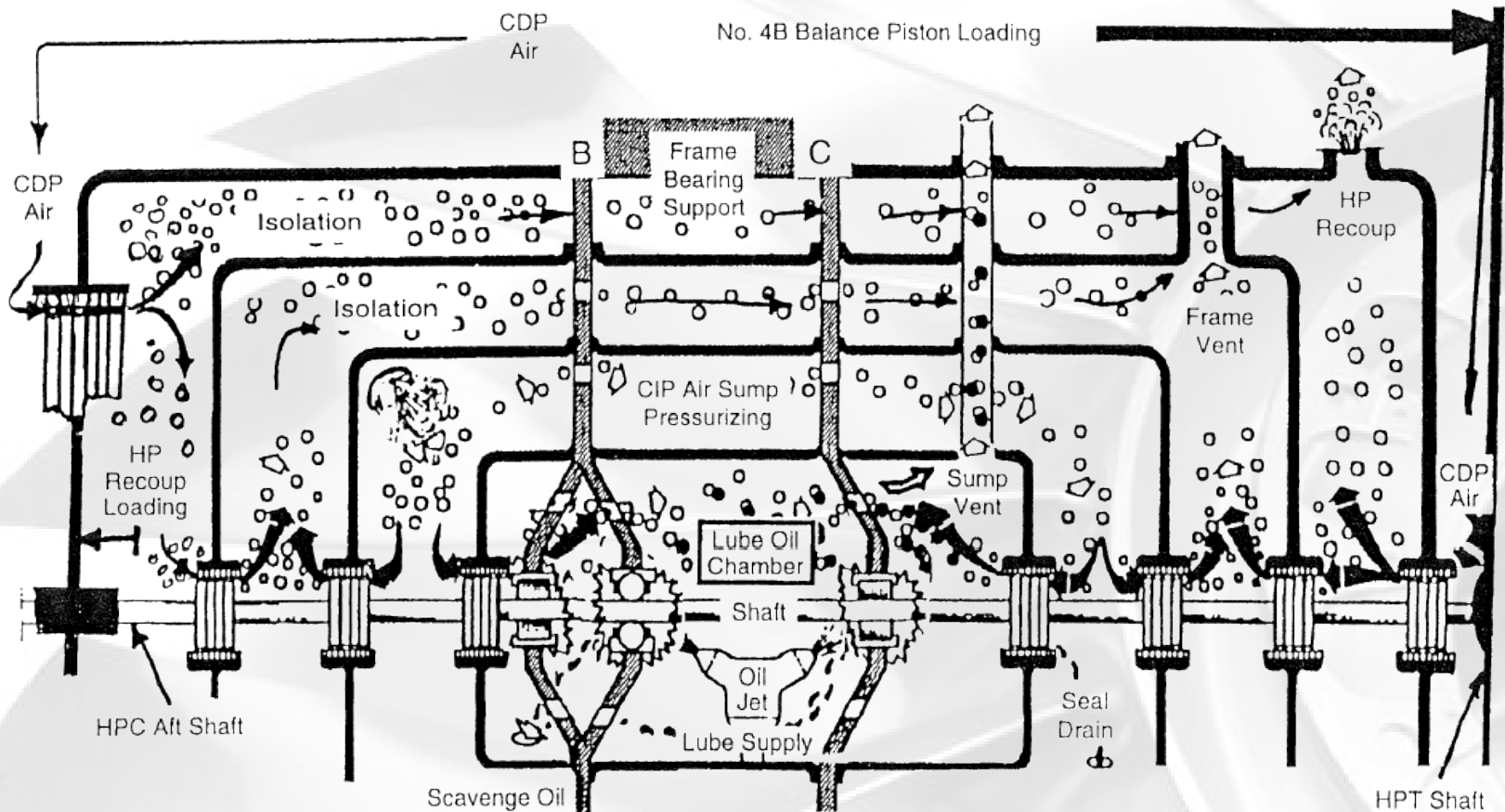
The B-C-sump contains bearings No.4R and 4B for mid section HP shaft support and bearing No.5R for rear HP shaft support.

- Sump pressurization: LPC discharge air (externally piped)
- Oil supply: separate oil jets for each bearing
- Oil Scavenge: 2 separate oil pipes to L+S pump for B and C scavenge
- Seal drain: drain pipe to drain tank
- Seal vent: into enclosure ambient
- Sump vent: to package air oil separation



4. Major components of the LM6000

B-C-Sump Philosophy

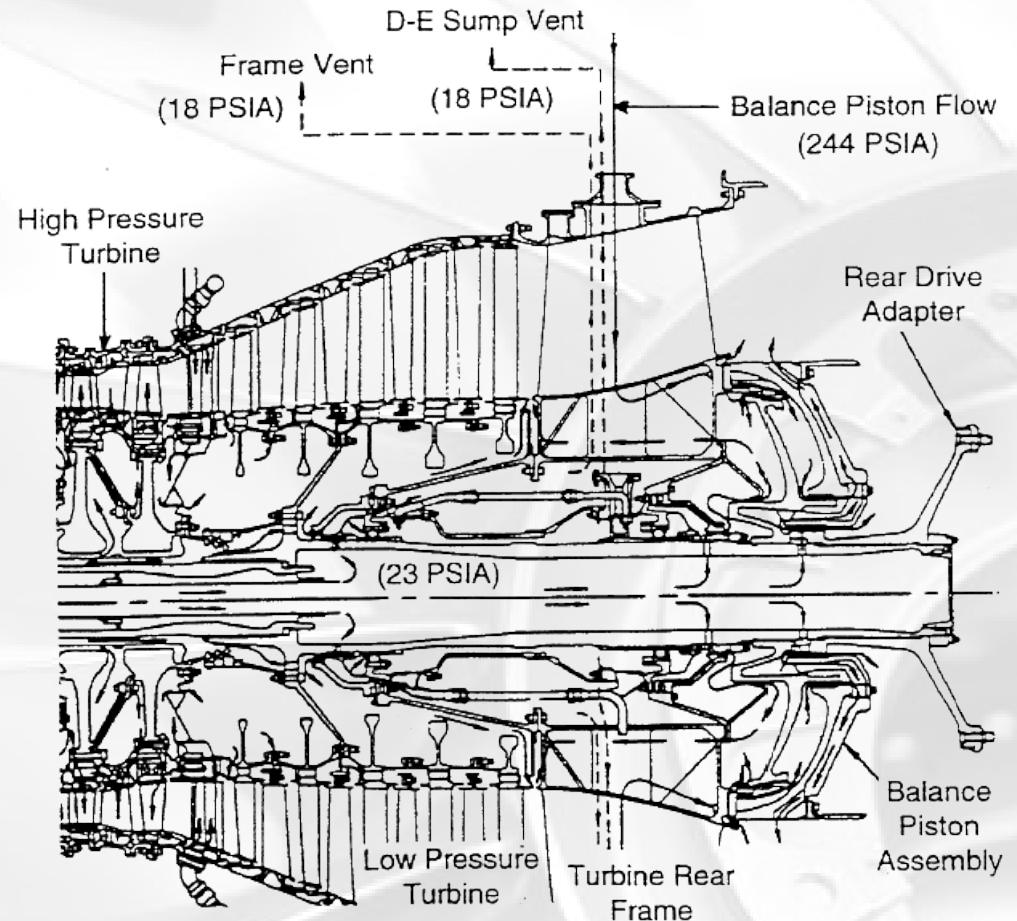


4. Major components of the LM6000

D-E-Sump Philosophy

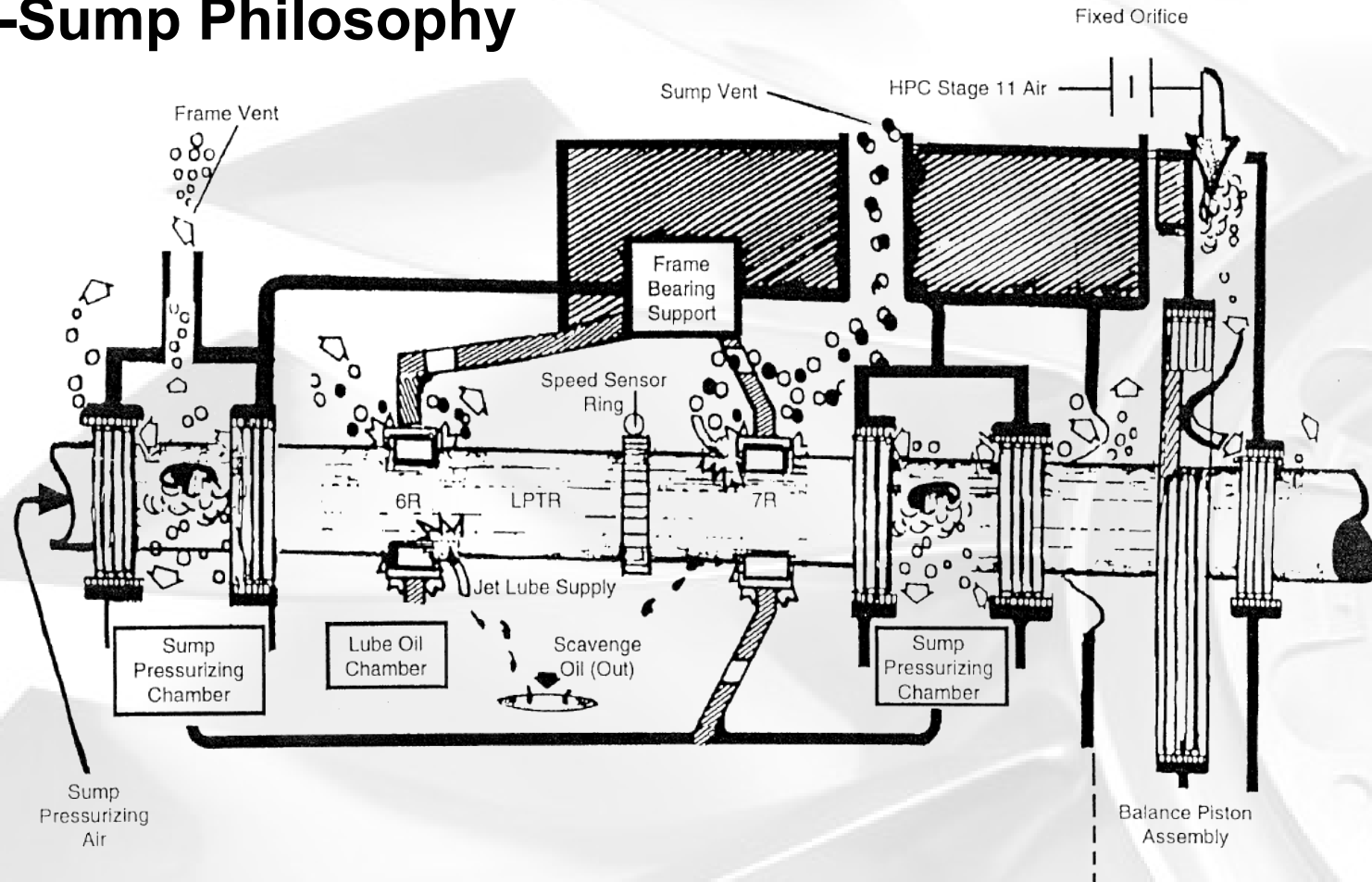
The D-E-sump contains bearings No.6R and 7R for rear LP shaft support.

- Sump pressurization: LPC discharge air (internally through mid shaft)
- Oil supply: separate oil jets for each bearing
- Oil Scavenge: 2 separate oil pipes to L+S pump for D and E scavenge
- Seal drain: drain pipe to drain tank
- Seal vent: into enclosure ambient
- Sump vent: to package air oil separation



4. Major components of the LM6000

D-E-Sump Philosophy



TECHNICAL TRAINING

Table of contents

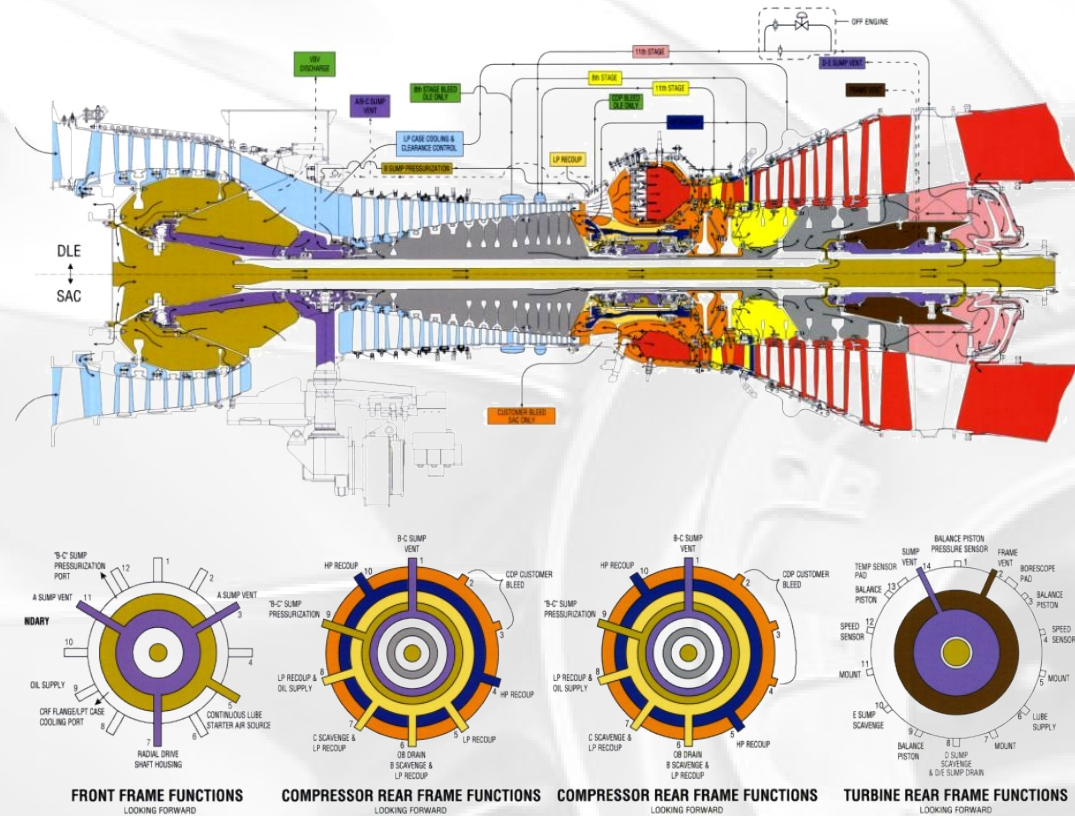
1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
4. Major components of the LM6000
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB; TGB; IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
5. Parasitic Air Flow
6. Auxiliary equipment and system
 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

5. Parasitic Airflow

Parasitic Airflow

GT airflows extracted from primary or secondary flow for internal cooling and pressurization is considered parasitic upon the GT's power output. These flows provide sump pressurization, localized cooling, thrust chamber pressurization and passive clearance control.

Portion of the parasitic airflow will re-enter the GT primary or secondary flow. Some flow will be ventilated directly to ambient.

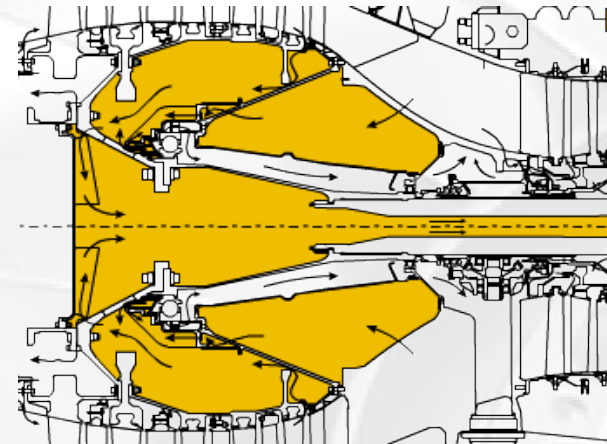


5. Parasitic Airflow

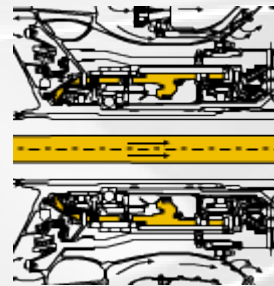
LPC Discharge (CIP) Airflow / Sump Pressurization

LPC discharge or Compressor Inlet Pressure (CIP) air is extracted:

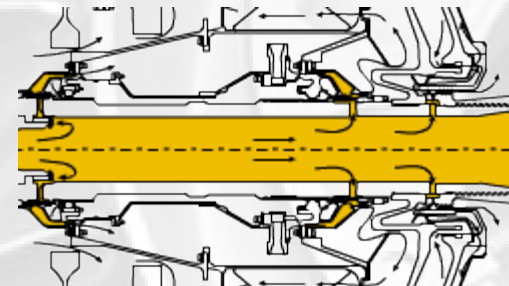
- through the gap between the LPC spool and the stg. 4 stator for pressurization of the D-E-sump via the midshaft (accelerated by the
- through CFF inner holes for pressurization of the A-sump
- through CFF external ports for pressurization of B-C-sump via external piping



LPC discharge extraction and A-Sump



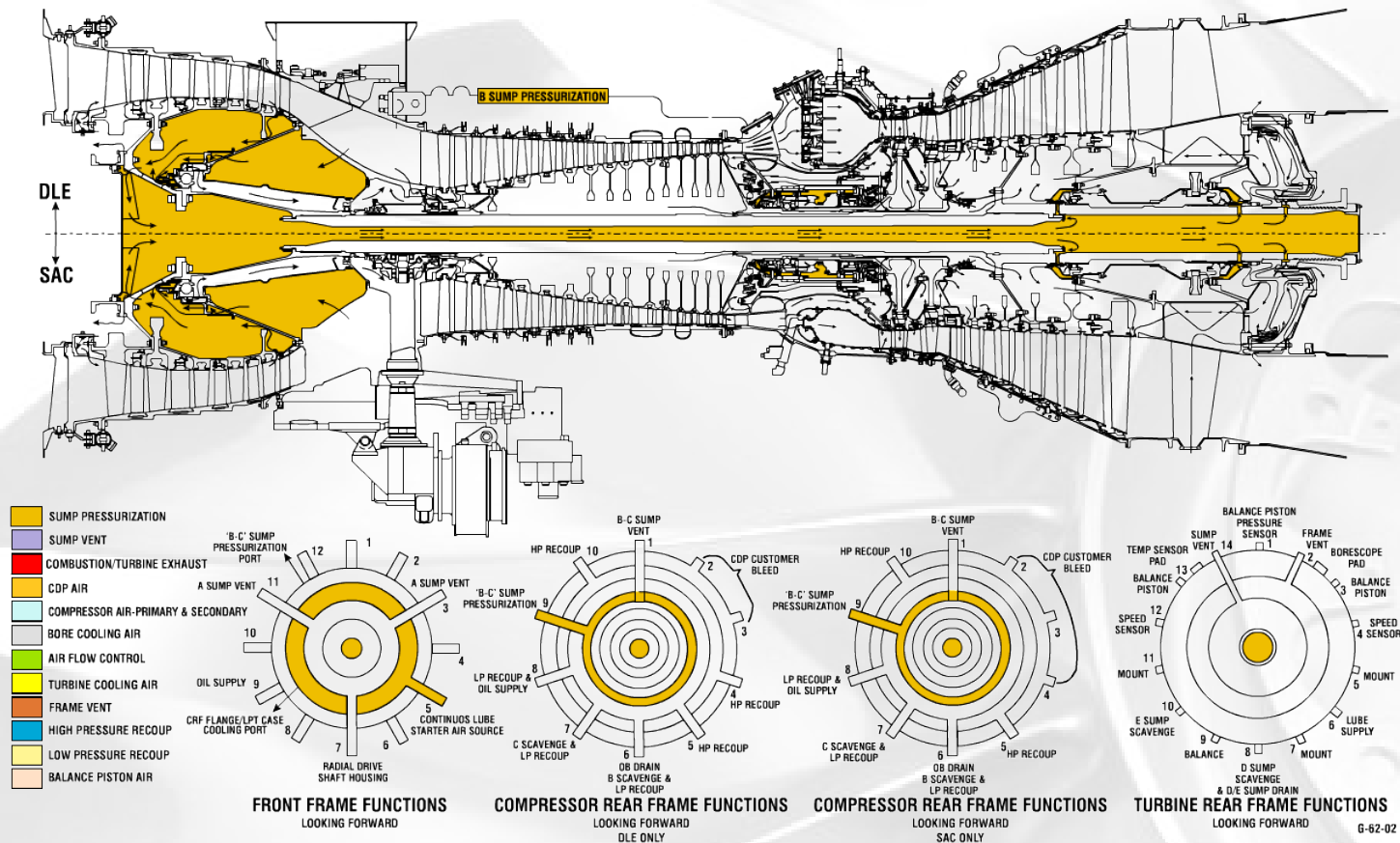
B-C-Sump



D-E-Sump

5. Parasitic Airflow

LPC Discharge (CIP) Airflow / Sump Pressurization

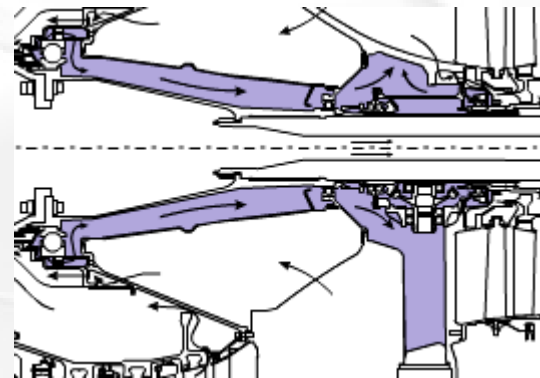


5. Parasitic Airflow

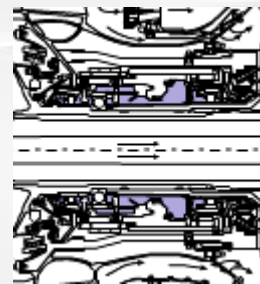
Sump Vent

Sump vent air is an air/oil vapor routed externally off- engine to a customer supplied air/oil separator for maximum oil reclamation.

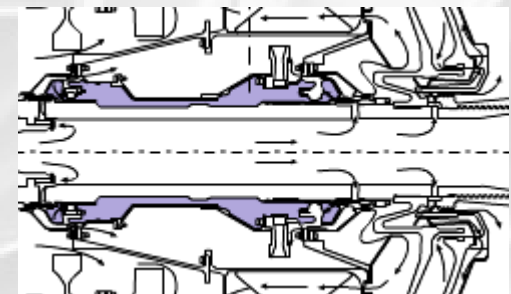
A- and B-C-sumps are manifolded together and then routed off-engine while D-E-sump vent air routes to air/oil separator via independent piping.



A-Sump



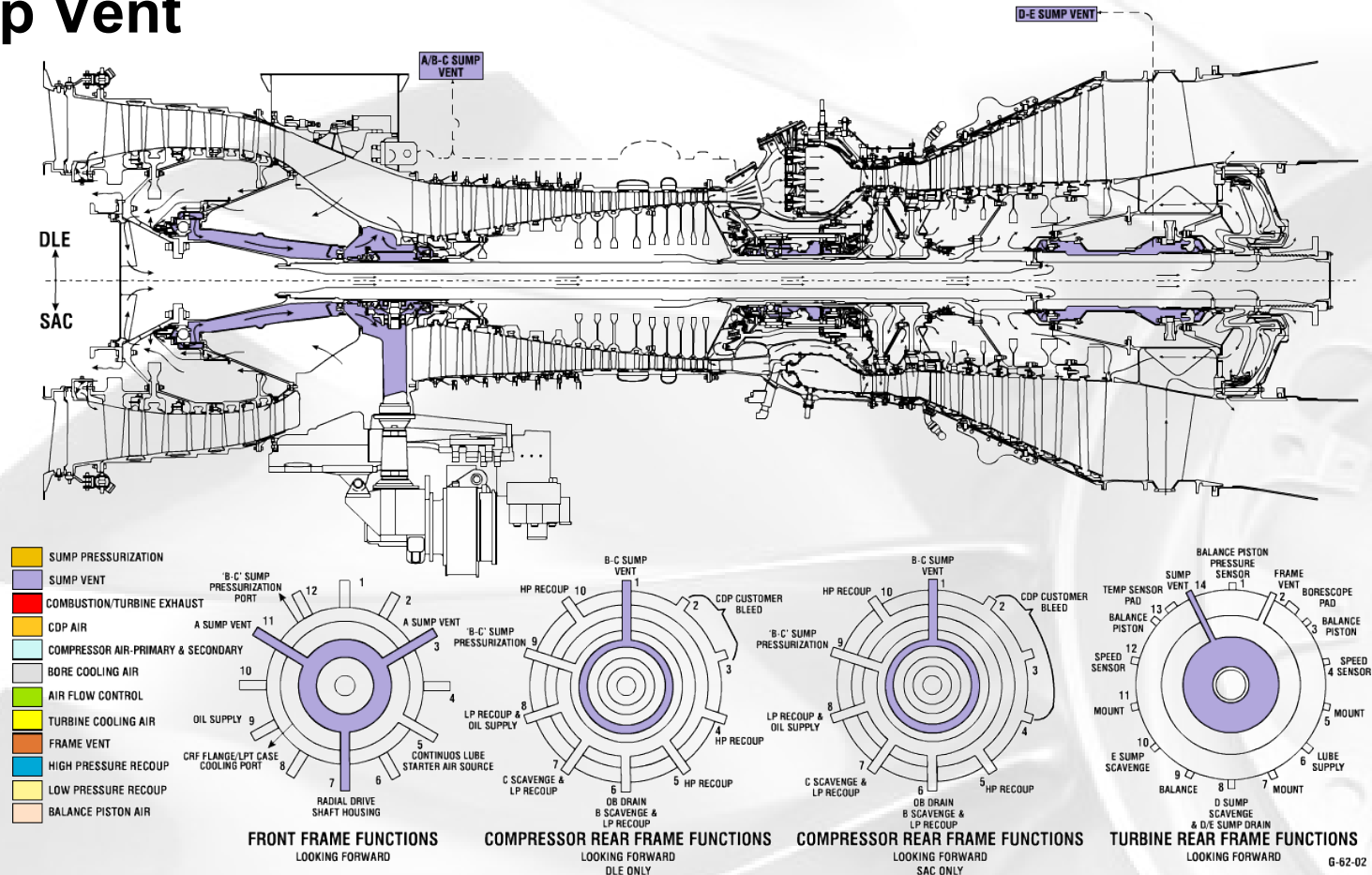
B-C-Sump



D-E-Sump

5. Parasitic Airflow

Sump Vent



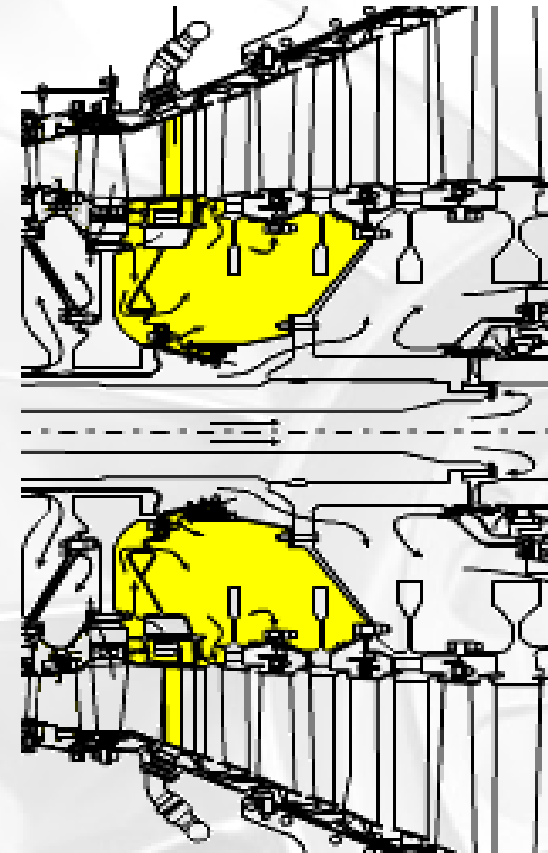
5. Parasitic Airflow

8th Stage Bleed Air

HPC stage 8 bleed air is routed externally aft to cool the leading edge of the stage 1 LPT nozzle vanes. Exiting the vanes the flow cools the balance seal bolted to the inner platform of the nozzle and then vents off through the rear LPT spool into the primary flow.

At DLE models stg. 8 bleed is also used for combustion control regulated by a control valve.

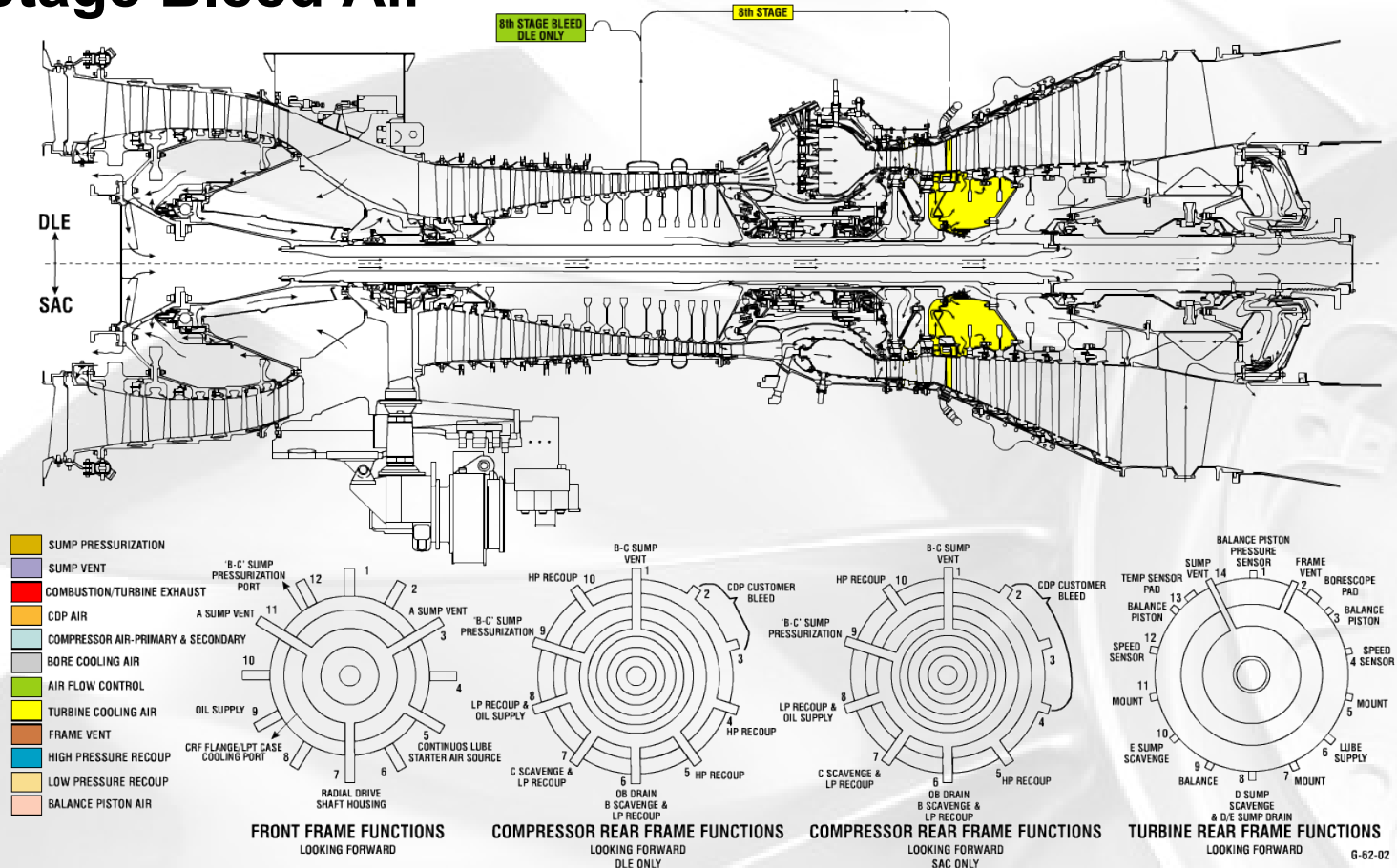
At SAC models stg. 8 bleed can be used at customers option.



LPT Nozzle 1
leading edge cooling

5. Parasitic Airflow

8th Stage Bleed Air



5. Parasitic Airflow

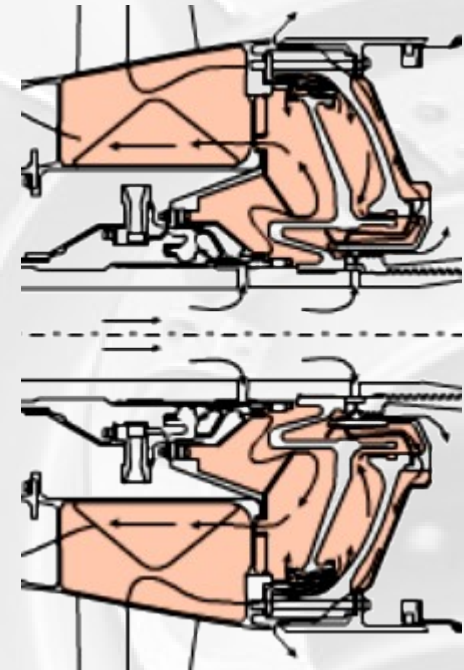
11th Stage Bleed Air

HPC stage 11 bleed air is routed externally aft to cool the HPT stage 2 nozzle vanes. 4 external tubes carry the air to the HPT stator case. Exiting the vanes the flow vents off into the primary flow.

Stage 11 bleed air is also routed externally to the TRF into the thrust balance cavity formed by a balance piston disk and the stationary balance piston seal. The high pressure air pushes the balance piston disk forward controlling the axial thrust on the No.1B bearing. The thrust balance pressure can be adjusted by either orifices or a control valve.



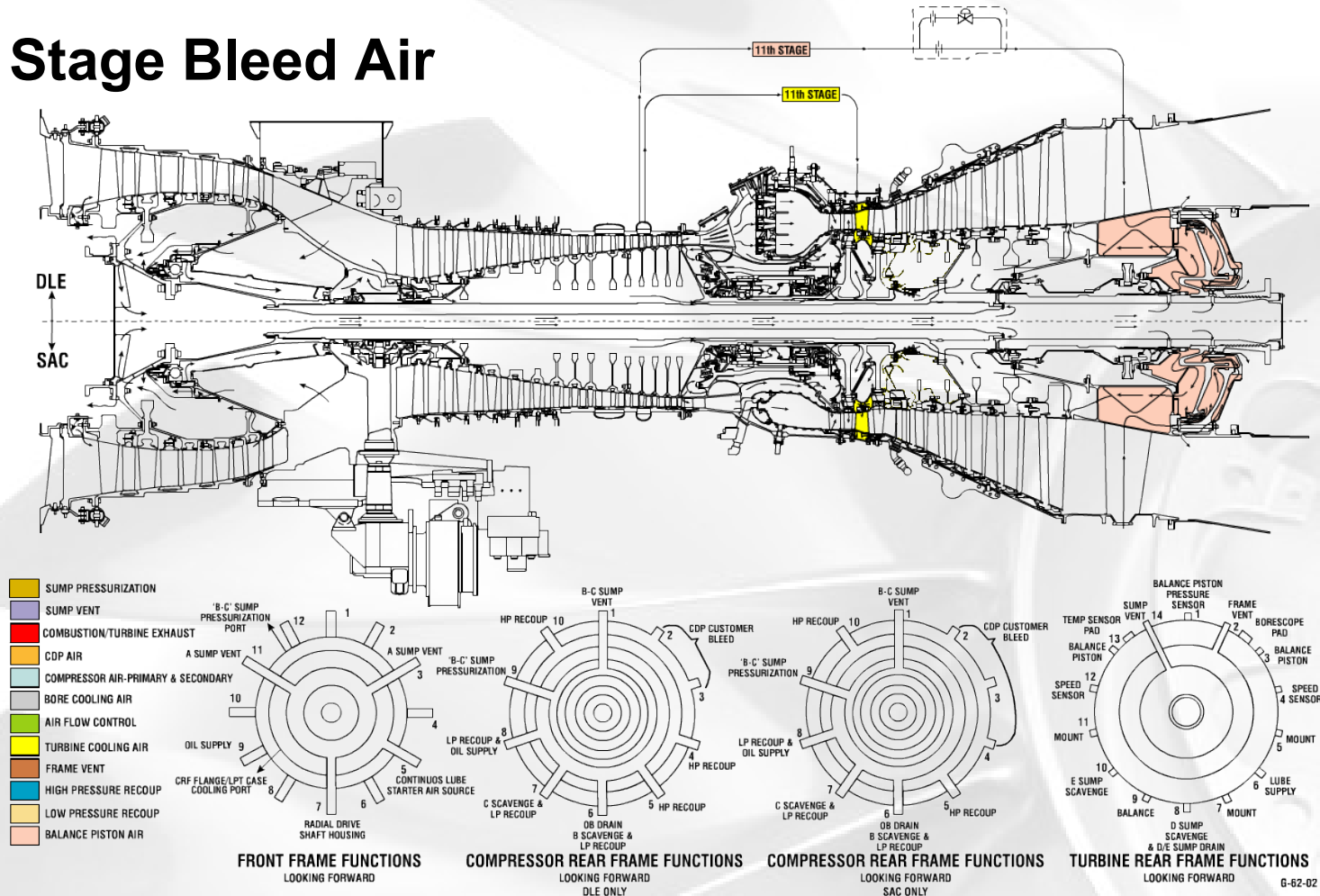
HPT Nozzle 2 cooling



No.1B Thrust Balance

5. Parasitic Airflow

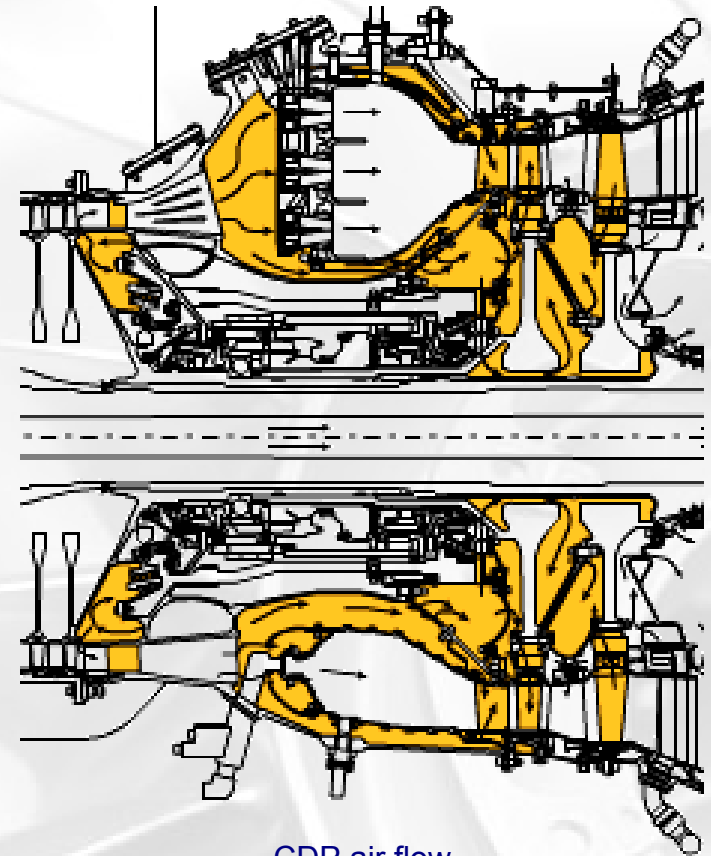
11th Stage Bleed Air



5. Parasitic Airflow

CDP Air

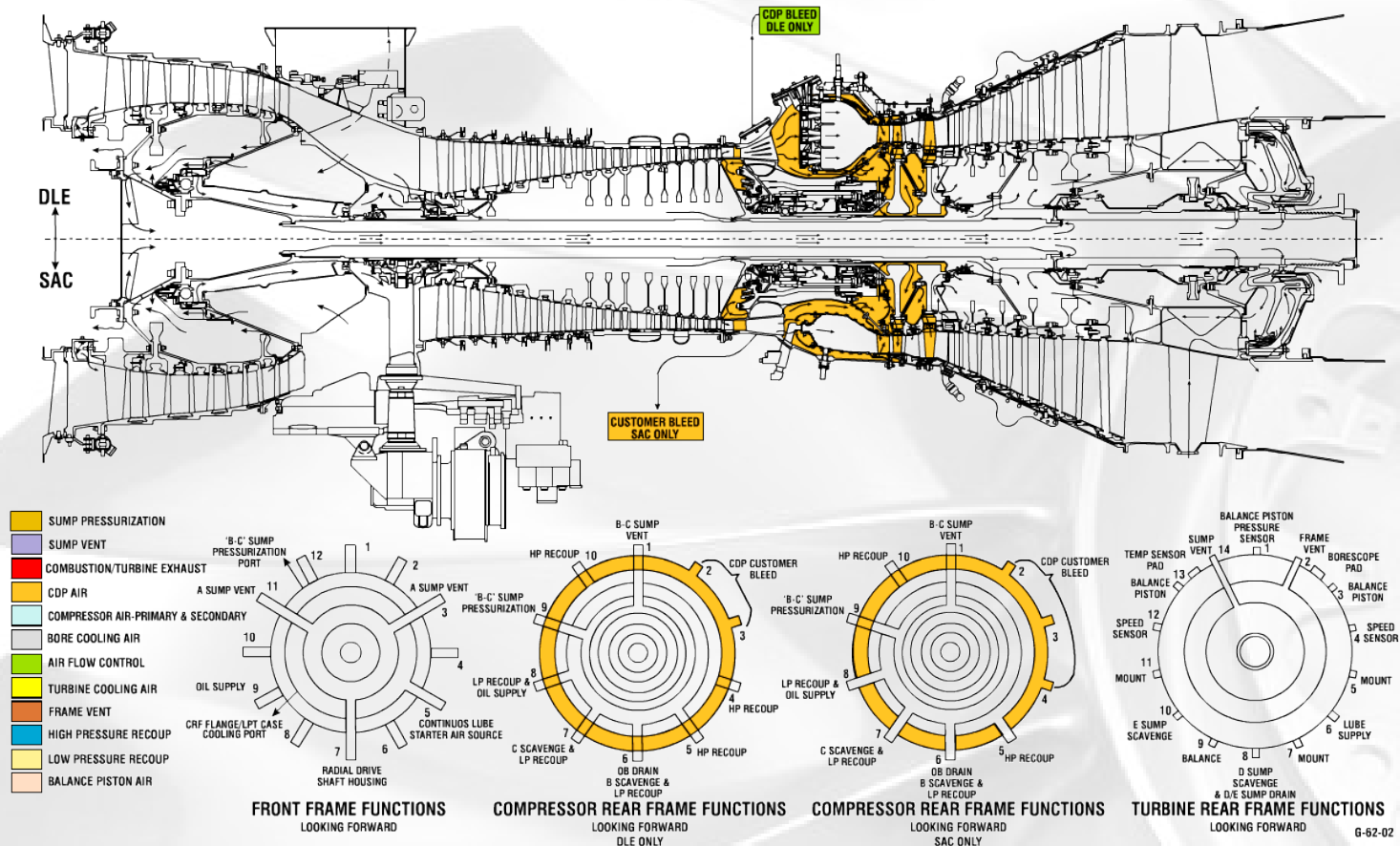
Compressor Discharge Pressure (CDP) air is used for HPT rotor cooling, HPT Nozzle Stg. 1 cooling, No.4B thrust balance and B-C sump venting. CDP air leaks through the gap between HPC rotor spool and stg. 14 stator into the forward pressure chamber. CDP inner combustor is routed through HPTN1 support holes to the HPT rotor and balance chamber, outer CDP air is used for rear HPTN1 cooling. At DLE models CDP bleed is regulated and used for combustion control. At dual fuel models CDP can be used at customers option (e.g. gas manifold purging).



CDP air flow

5. Parasitic Airflow

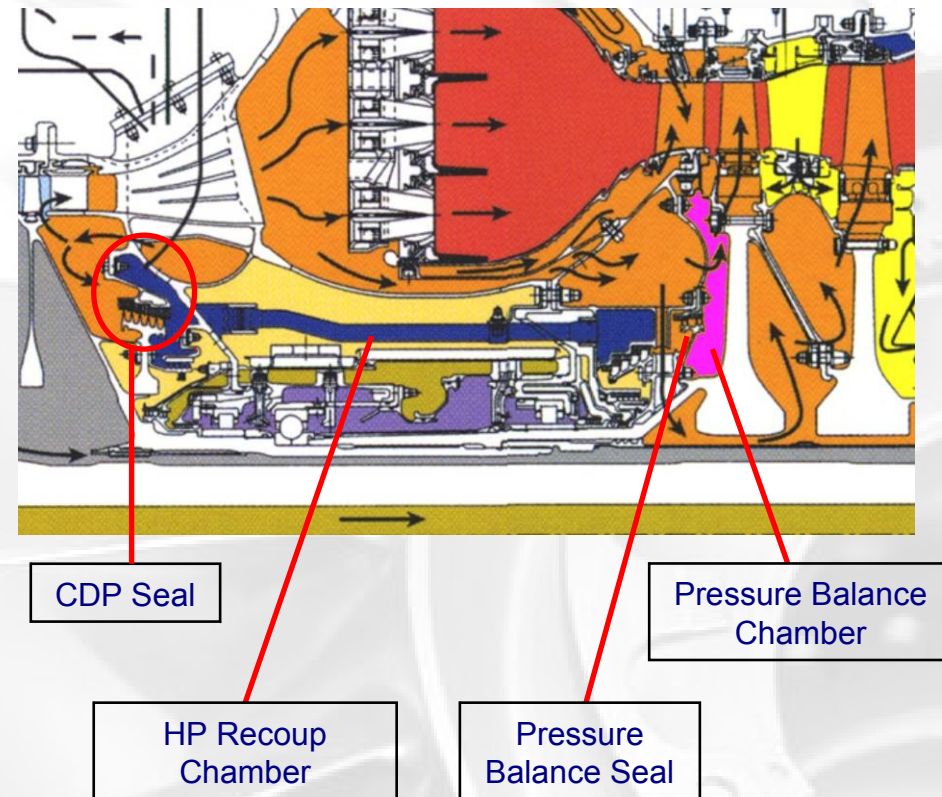
CDP Air



5. Parasitic Airflow

No.4B bearing thrust balance

The CDP air pressurizing the HPT rotor cavity is also leaking aft across the pressure balance seal into the HPT thrust balance chamber. Airflow into the chamber is higher than the airflow escaping through stg.1 rotor blade wing seal. This causes a pressure built up within the chamber and loading the HPT rotor aft, assisting No.4B absorbing the thrust load forward. An increasing HP Recoup pressure due to higher seal leakages would bring a forward load onto the HPCR via the CDP seal. This forward load cancels a part of the thrust balance increasing the axial load to No.4B.

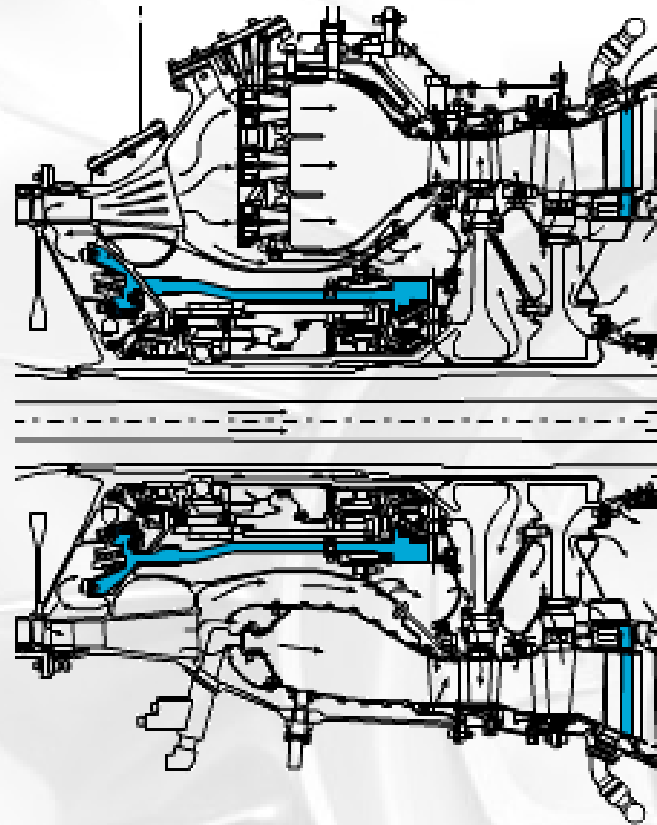


5. Parasitic Airflow

HP Recoup

The HP recoup airflow develops from CDP air leaking through the front CDP seal and rear balance piston seal. The HP recoup air is routed externally for LPT Stage 1 Nozzle vane trailing edge cooling and then vented into the primary flow. A part of the HP recoup air leaks through seals into the LP recoup air chamber and is then vented off into the GT enclosure.

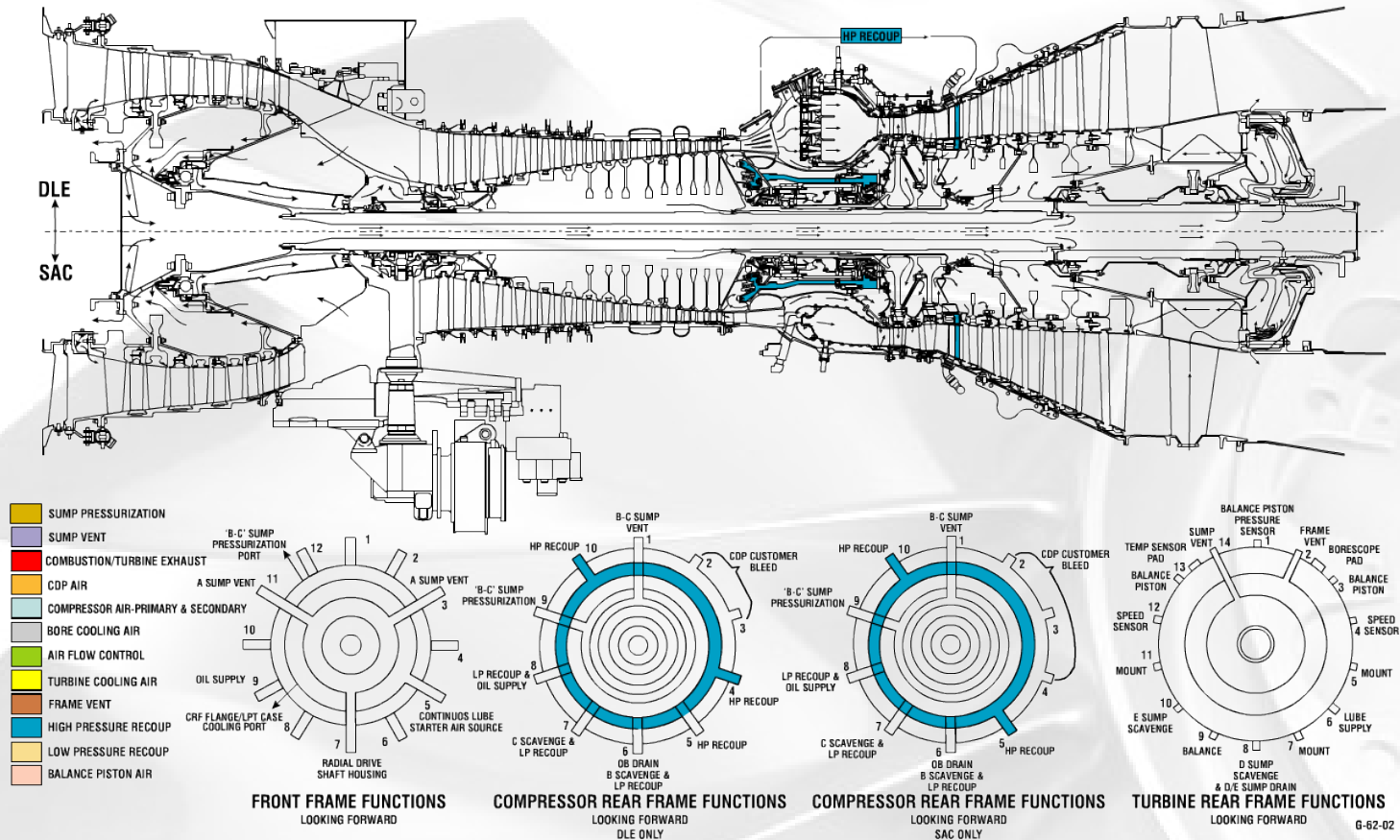
The HP recoup air pressure is also influencing the No.4B bearing thrust balance.



HP Recoup and LPT Nozzle
1 trailing edge cooling

5. Parasitic Airflow

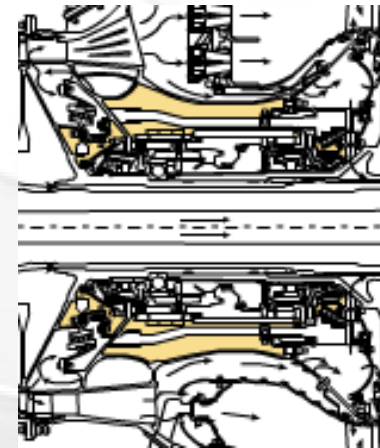
HP Recoup



5. Parasitic Airflow

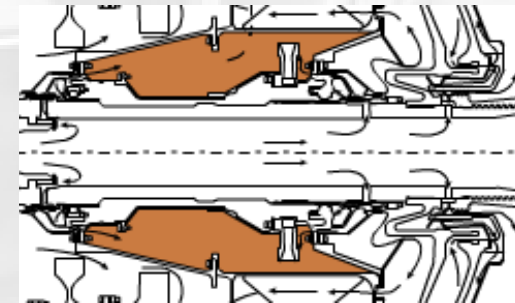
Frame Vent and LP Recoup

The B-C-sump LP recoup airflow develops from leaking HP Recoup air and sump pressurization air. The LP recoup air is vented off into the GT enclosure.



B-C-sump LP Recoup frame vent

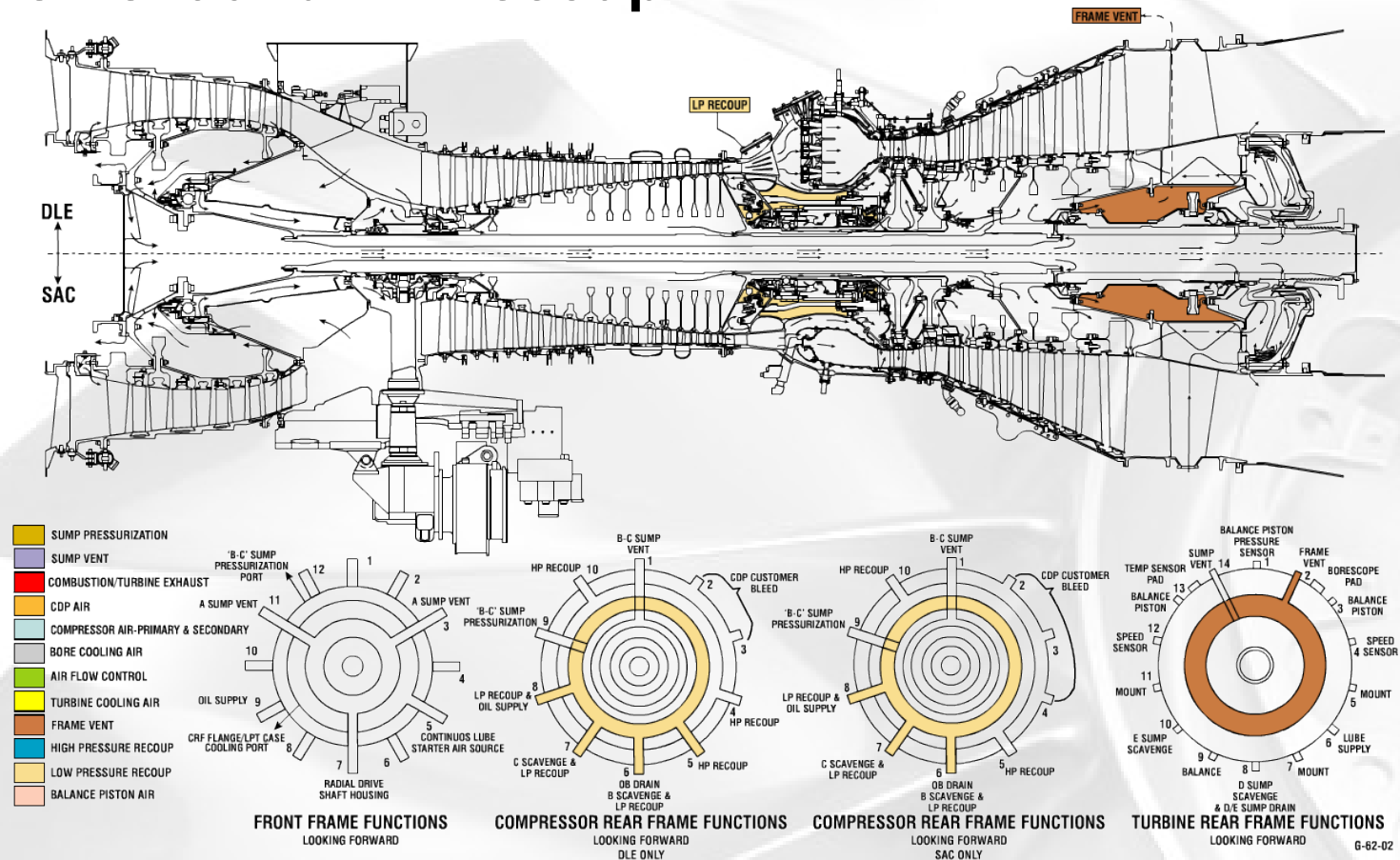
The D-E-sump frame vent airflow develops from leaking sump pressurization air. The frame vent is vented off into the GT enclosure.



D-E-sump frame vent

5. Parasitic Airflow

Frame Vent and LP Recoup

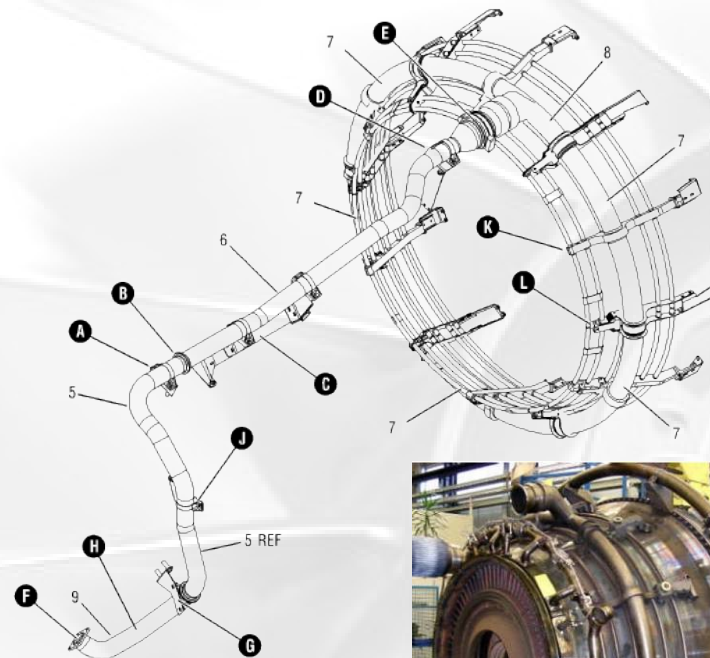


5. Parasitic Airflow

LPT case cooling and Passive Clearance Control (PCC)

LPC discharge air is extracted at the front frame and routed through external tubing to the LPT cooling manifold tubing that surrounds the LPT case. There the air is discharged through small holes to cool the skin temperature of the LPT stator case. The cooling air reduces the case thermal growth and decreasing the LPT blade clearance resulting in increased turbine efficiency.

The system is called Passive Clearance Control (PCC) as the airflow is not controlled by an additional valve. Valve controlled Active Clearance Control (ACC) is used at the Turbofan CF6-80.

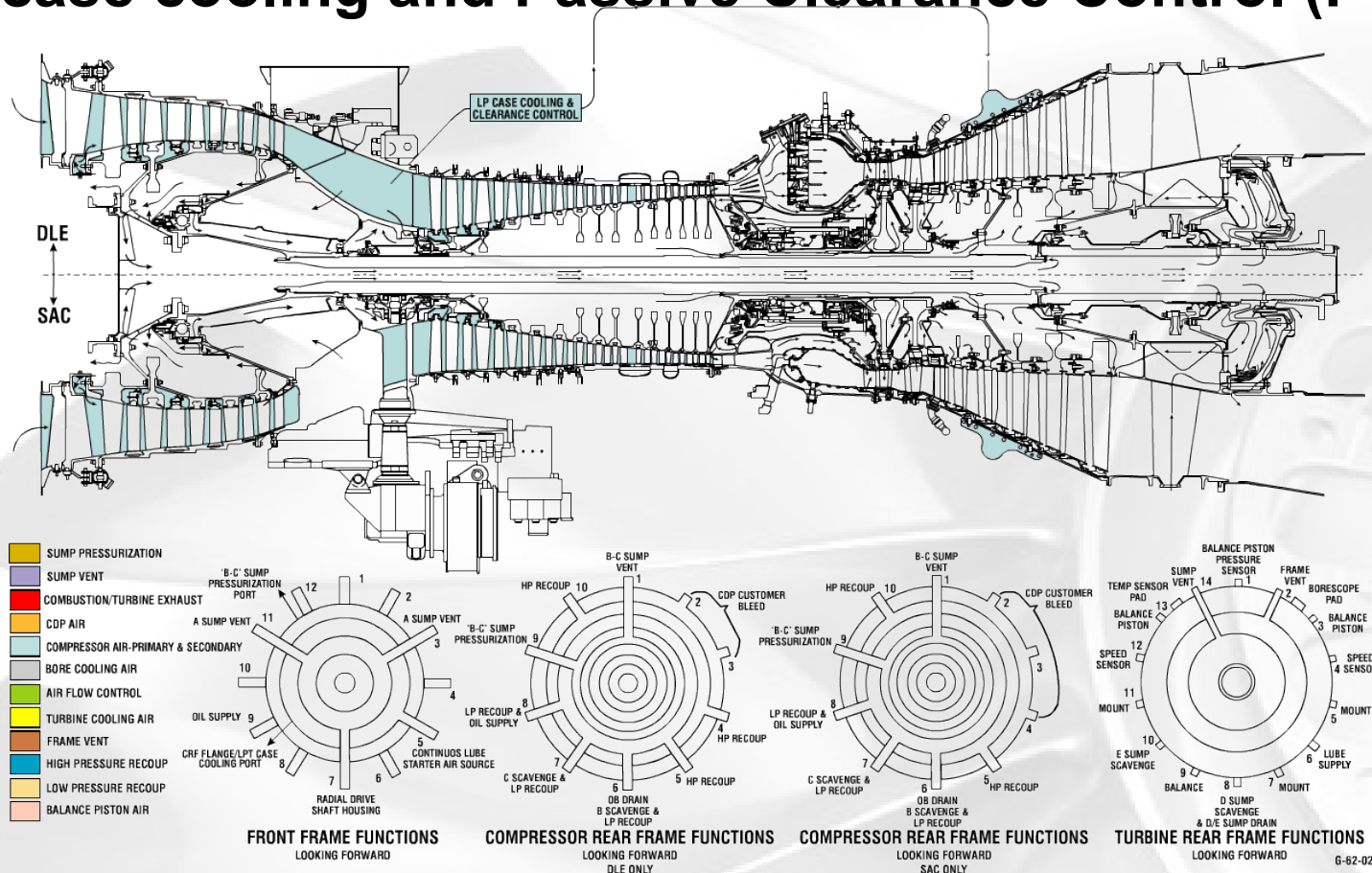


LPT cooling PCC-kit



5. Parasitic Airflow

LPT case cooling and Passive Clearance Control (PCC)



TECHNICAL TRAINING

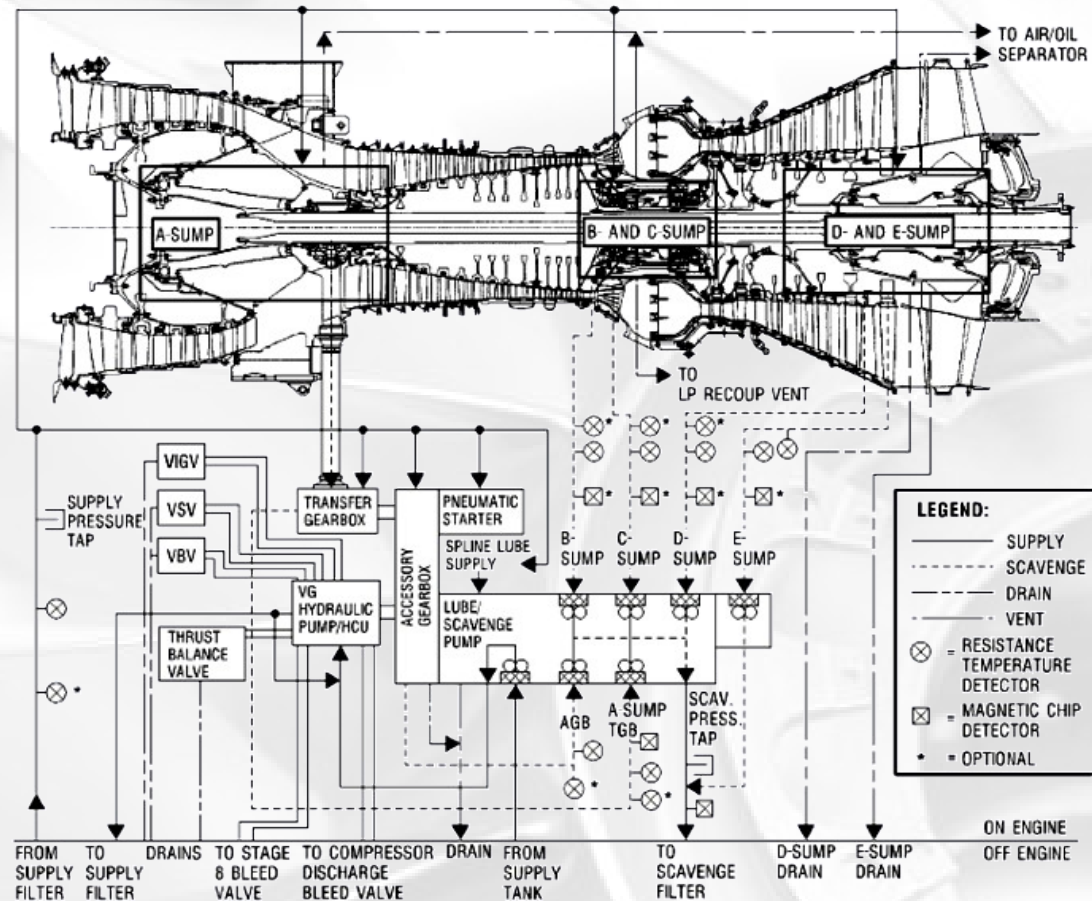
Table of contents

1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
4. Major components of the LM6000
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB; TGB; IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
5. Parasitic Air Flow
6. Auxiliary equipment and system
 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

6. Auxiliary Equipment and Systems

Lubrication System

The GT lubrication system consists of an AGB driven lube oil supply and scavenge pump. The lube oil is used to lubricate and cool all engine bearings, seals, sumps and the GT gearboxes. The lube oil is also used to operate the Variable Geometry (VG) system and/or additionally mounted hydraulic pumps for control valve operation. The lube oil system includes oil and vent piping, temperature sensors and chip detectors.



6. Auxiliary Equipment and Systems

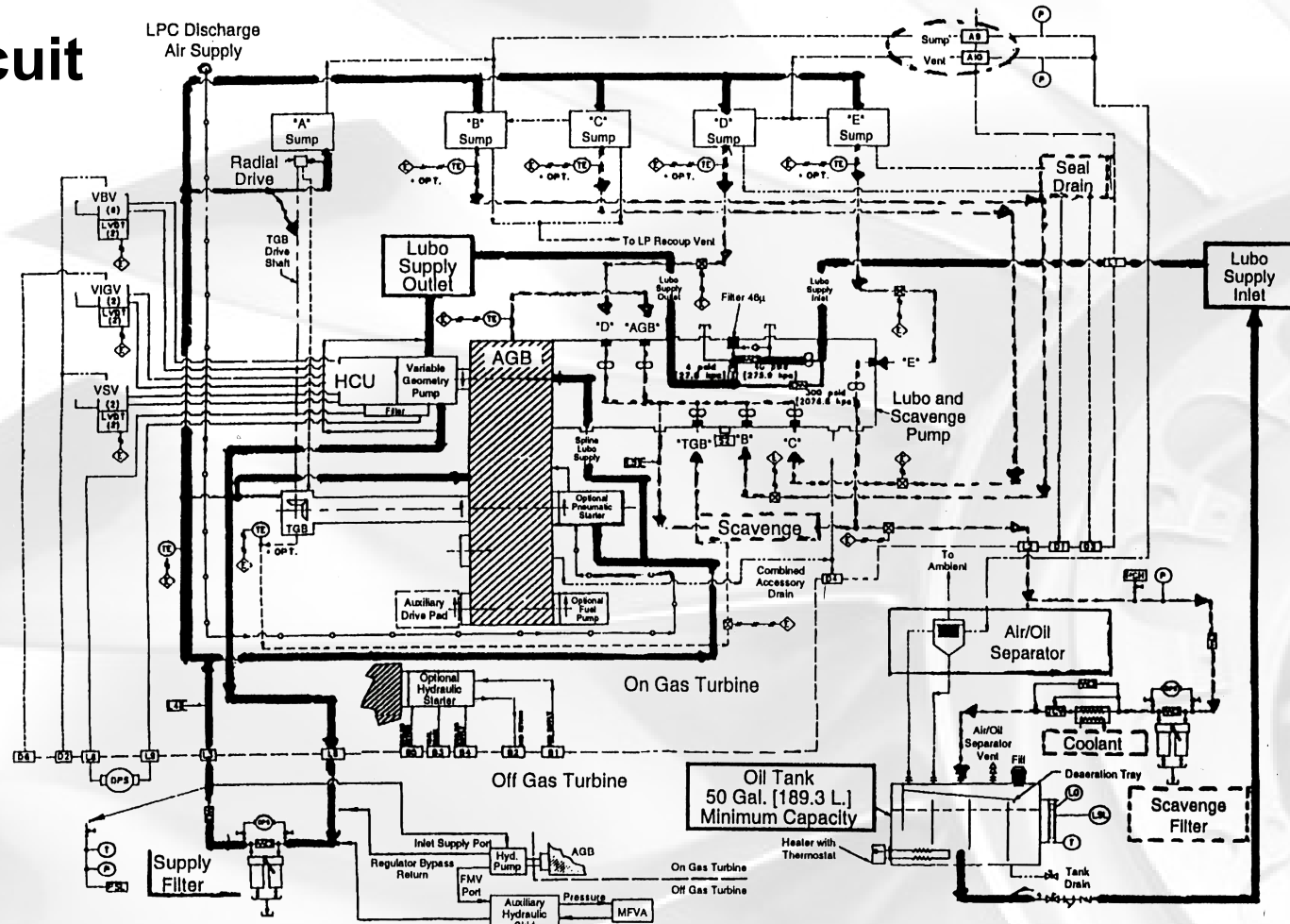
Lube Circuit

The L+S pump primes lube oil from tank via a suction line into lube supply inlet port L1. A gear pump then pressurizes and supplies the oil through lube oil discharge port L2. A portion of the oil is bypassed to fill and pressurize the GT hydraulic system. The main portion of the oil is pumped through the oil inlet filters into the GT lube oil supply manifold where it is separated to the different sumps and gearboxes. The oil is scavenged off the dry sumps by suction of the separate gear pump elements of the L+S pump.

In the pump the scavenge oil is merged together and pumped through the scavenge filter and oil cooler back into the tank. Lube oil supply and scavenge pressures are measured either at L+S pump pressure taps or at package lube oil lines. Lube oil supply and scavenge temperatures are measured by L+S pump installed RTD's. Optional each sump screen contains an electrical/magnetic chip detector.

6. Auxiliary Equipment and Systems

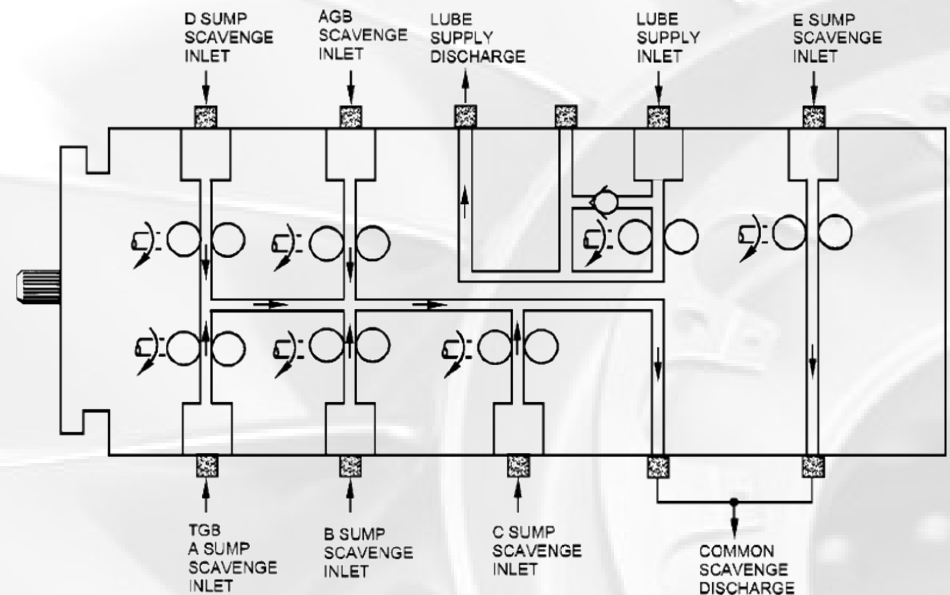
Lube Circuit



6. Auxiliary Equipment and Systems

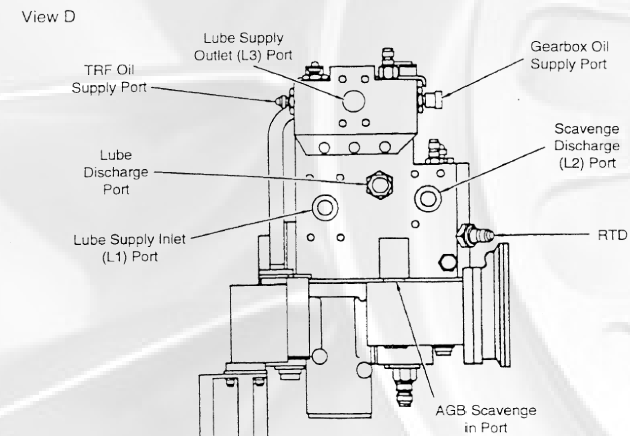
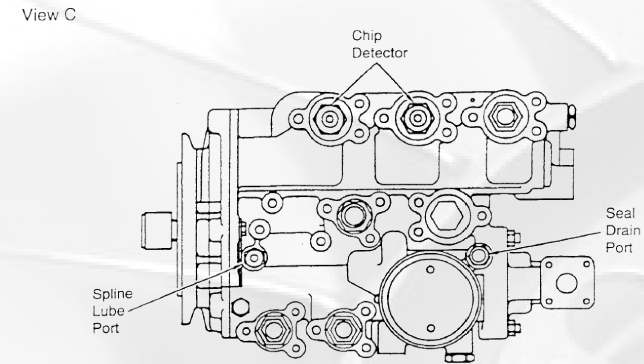
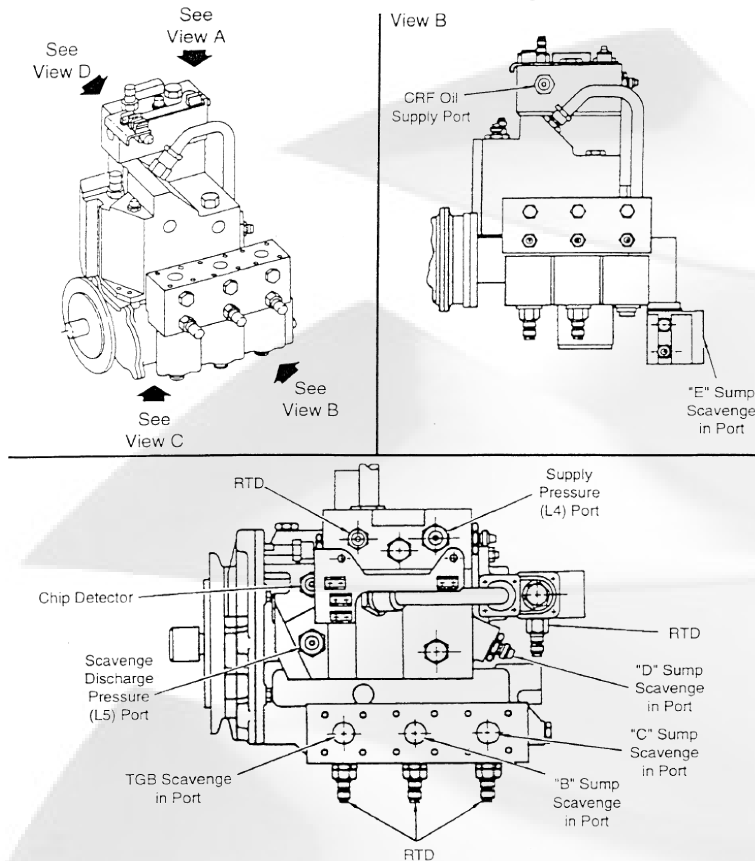
Lube and Scavenge Pump

The L+S pump is a 7 element (1 supply and 6 scavenge) positive displacement pump. At each port / element of the pump are inlet screens. The screens are non-bypassing and able to trap particles bigger than 0.03 inch / 0.76 mm. The pump also contains a relief valve with 300 psid / 20.7 barg cracking pressure (full bypass flow at 400 psid / 27.6 barg) for supply pressure limiting. The pump provides a total oil flow from tank to GT of approximately 17 gpm / 64.4 l/min. The scavenge elements are not equipped with relief valves, the maximum scavenge pressure is 180 psig / 12.4 barg with a flow of 17 gpm / 64.4 l/min.



6. Auxiliary Equipment and Systems

Lube and Scavenge Pump



TECHNICAL TRAINING

Table of contents

1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
4. Major components of the LM6000
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB; TGB; IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
5. Parasitic Air Flow
6. **Auxiliary equipment and system**
 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

6. Auxiliary Equipment and Systems

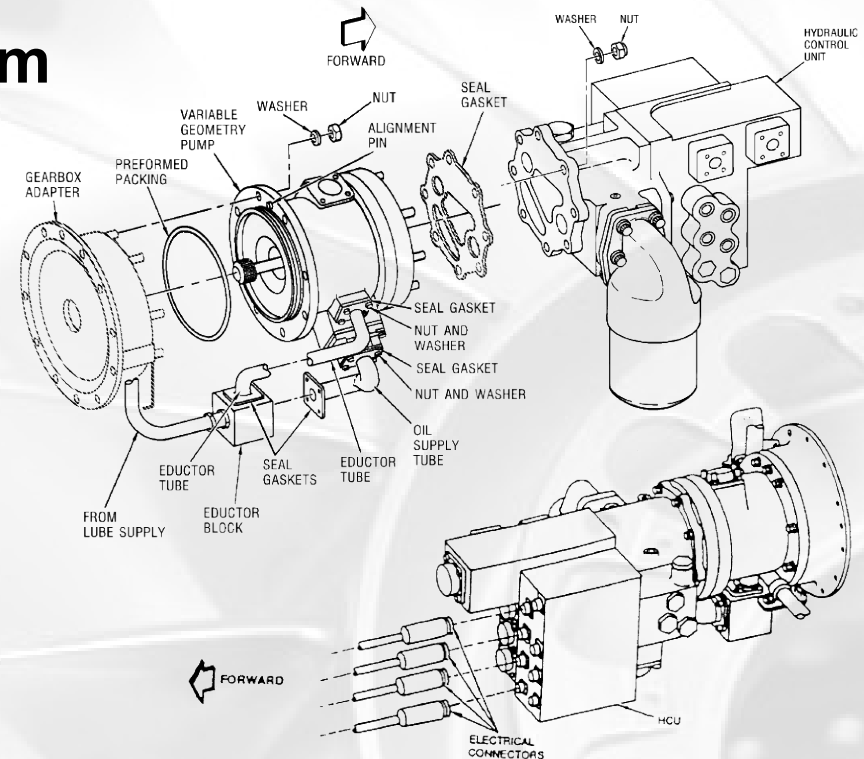
Variable Geometry (VG) System

The VG system consists of the VG hydraulic pump, the Hydraulic Control Unit (HCU), 2 VIGV, 6 VBV and 2 VSV actuators.

The VG hydraulic pump is a fixed displacement pump providing hydraulic pressure up to 1,400 psig / 96.5 barg. The oil is pumped internally into the HCU. The HCU houses torque motor positioned hydraulic servos for porting fluid at regulated pressure, which is max. 1,200 psig / 82.7 barg for VBV and 750 psig / 51.7 barg for VIGV and VSV.

Positioning of the VG system is scheduled by GT control system electrical inputs to the HCU servos.

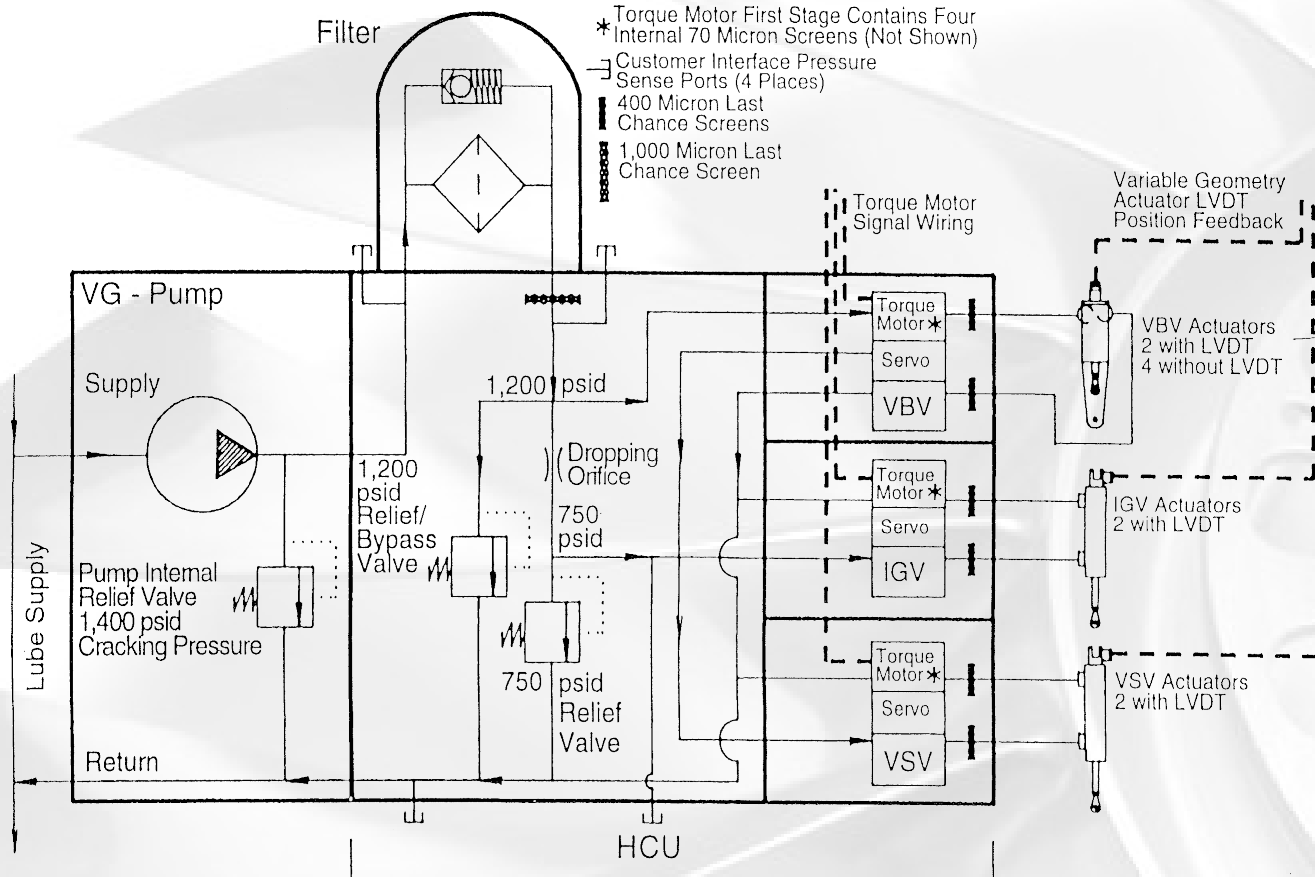
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The required position feedback is given by the actuator internal LVDT's of both VIGV-, both VSV- and two of the six VBV-actuators.

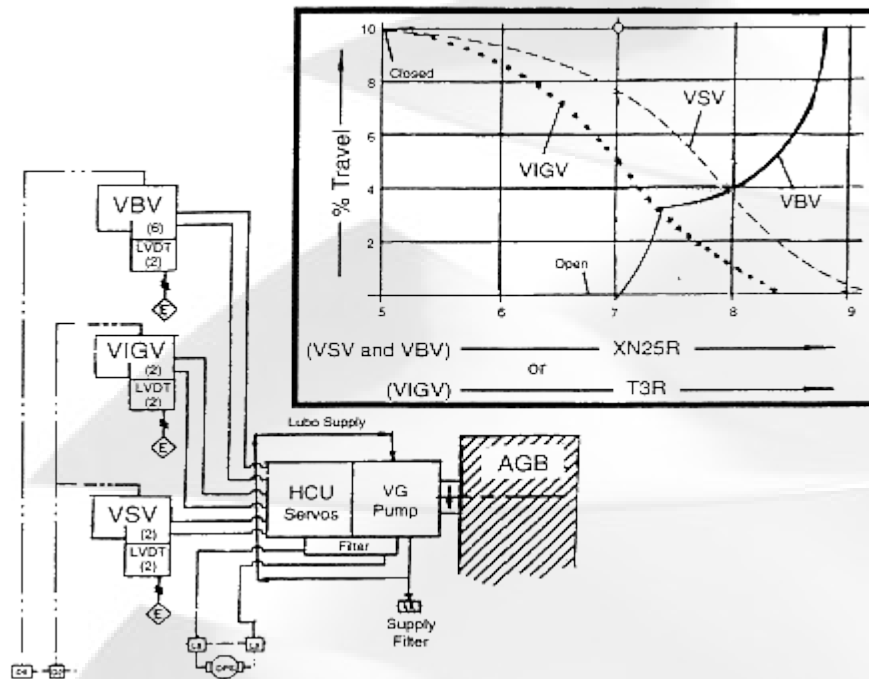
6. Auxiliary Equipment and Systems

Variable Geometry (VG) System

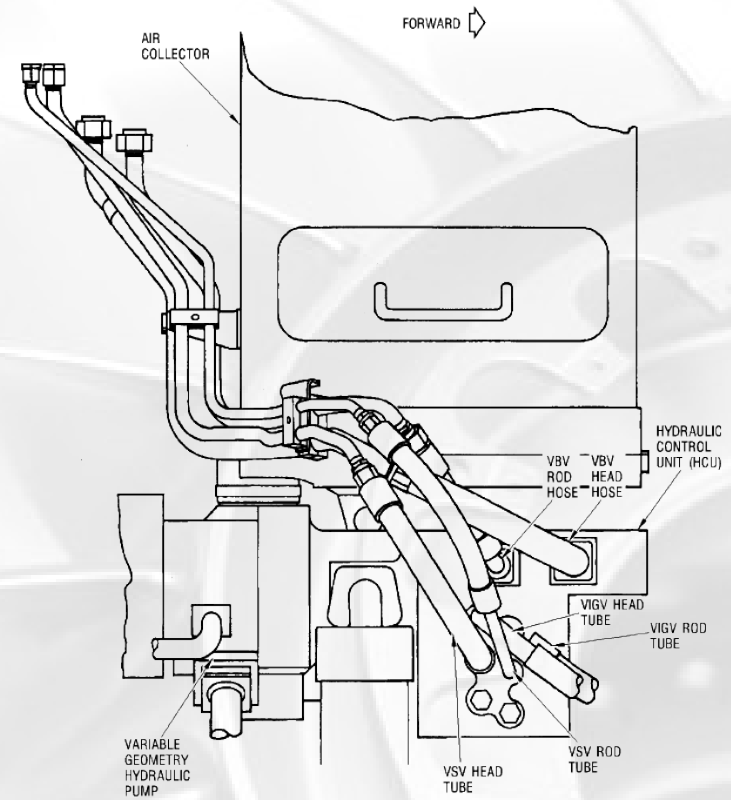


6. Auxiliary Equipment and Systems

Variable Geometry (VG) System



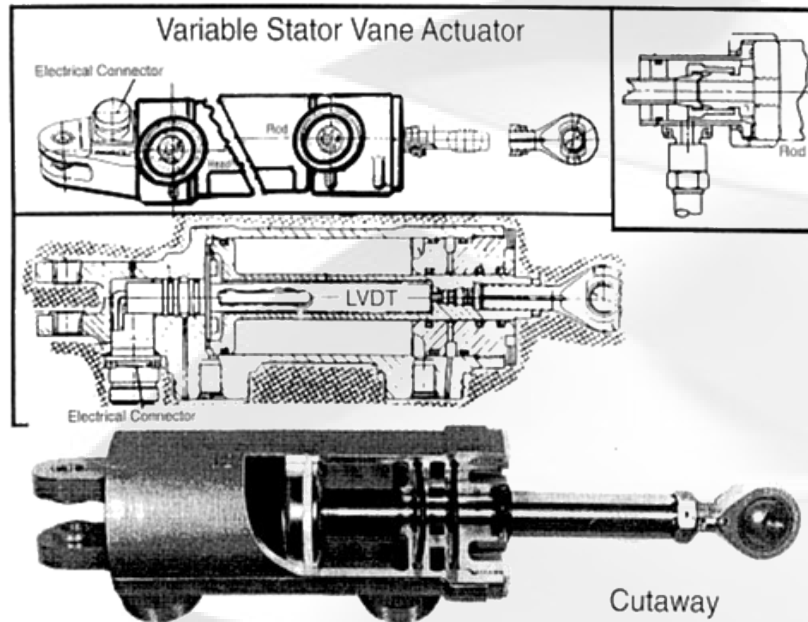
VG system control schedules



HCU hydraulic line connections

6. Auxiliary Equipment and Systems

Variable Geometry (VG) System



VIGV



VBV



VSV



VSV-actuators

TECHNICAL TRAINING

Table of contents

1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
4. Major components of the LM6000
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB; TGB; IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
5. Parasitic Air Flow
6. Auxiliary equipment and system
 - a. Lubrication System
 - b. Variable Geometry System
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6. Auxiliary Equipment and Systems

Fuel Systems

All fuel systems contain 30 Fuel Nozzles (SAC) or Premixers (DLE).

SAC gas and steam manifolds and all DLE fuel manifolds are not supported by the gas turbine but installed in the GT enclosure. Fuel Nozzles/Premixers and manifolds are connected via flexible hoses. This configuration provides the fuel system weight being uncoupled from the GT. SAC models water and liquid fuel manifolds are GT-mounted and connected to the Fuel Nozzles via fixed tubes.

Whenever the GT has to be moved or shipped the manifolds require additional supports.



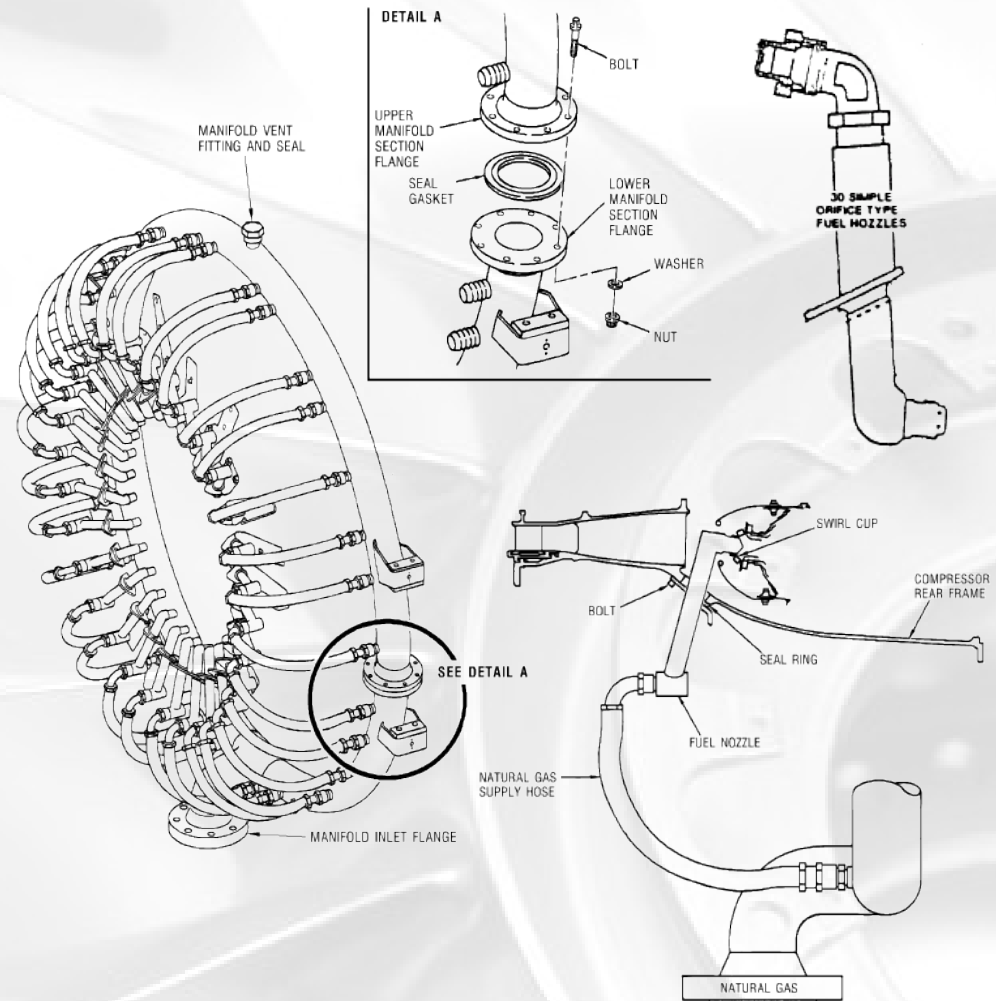
LM6000 PD with manifold
transport support

6. Auxiliary Equipment and Systems

SAC Gas Fuel

The natural gas / water system consists of 30 gas fuel nozzles, 30 gas fuel hoses and a gas manifold.

The manifold is a split ring type. The fuel nozzles are a simple orifice type and individually removable.

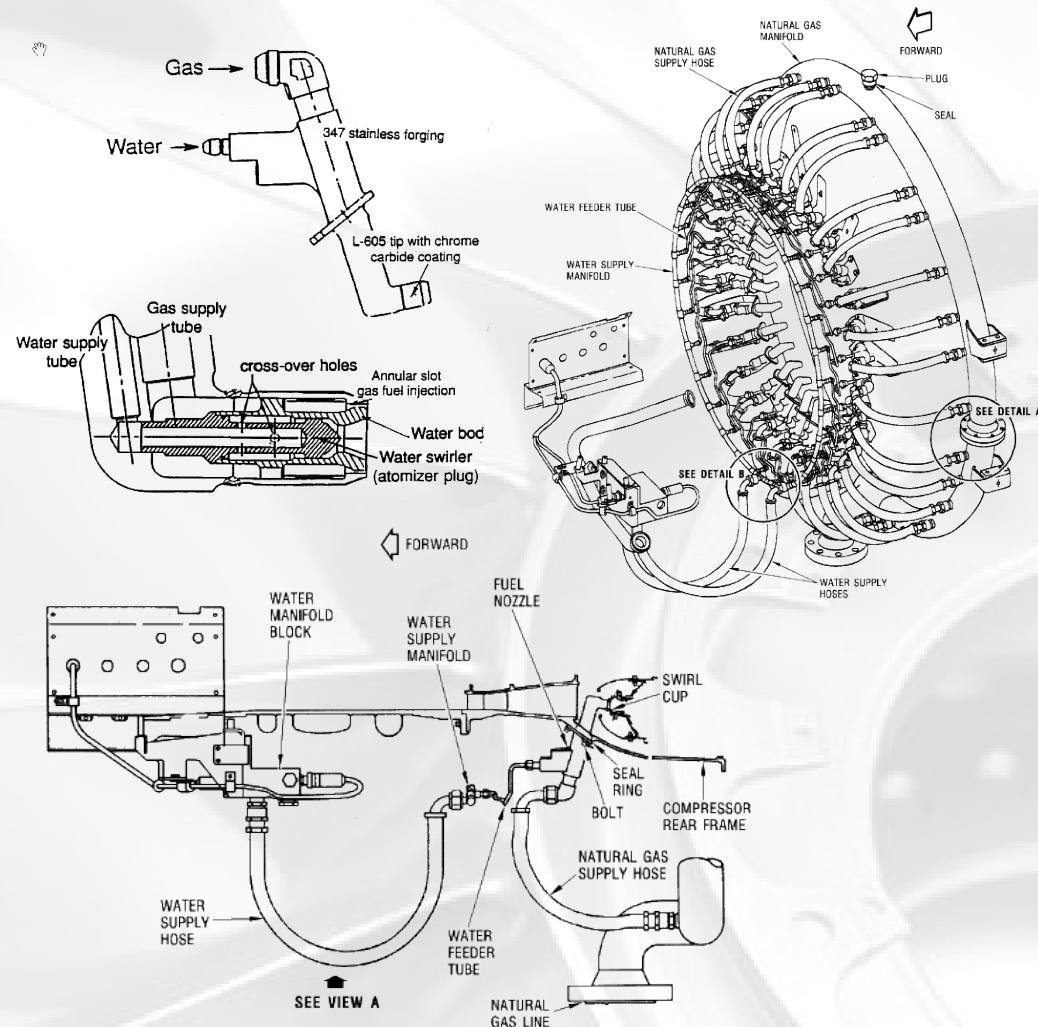


6. Auxiliary Equipment and Systems

SAC Gas Fuel with Water Injection

The natural gas / water system provides additional water injection through the fuel nozzles into the combustor to lower the flame temperature and with it the NOX emissions value. The water injection causes a lower T4.8 at the same gas fuel flow. This T4.8 margin and the higher mass flow result in a ca. 2-3MW higher maximum power output.

Additional to the gas system components a water manifold, 30 feeder tubes, and gas/water fuel nozzles are required.



6. Auxiliary Equipment and Systems

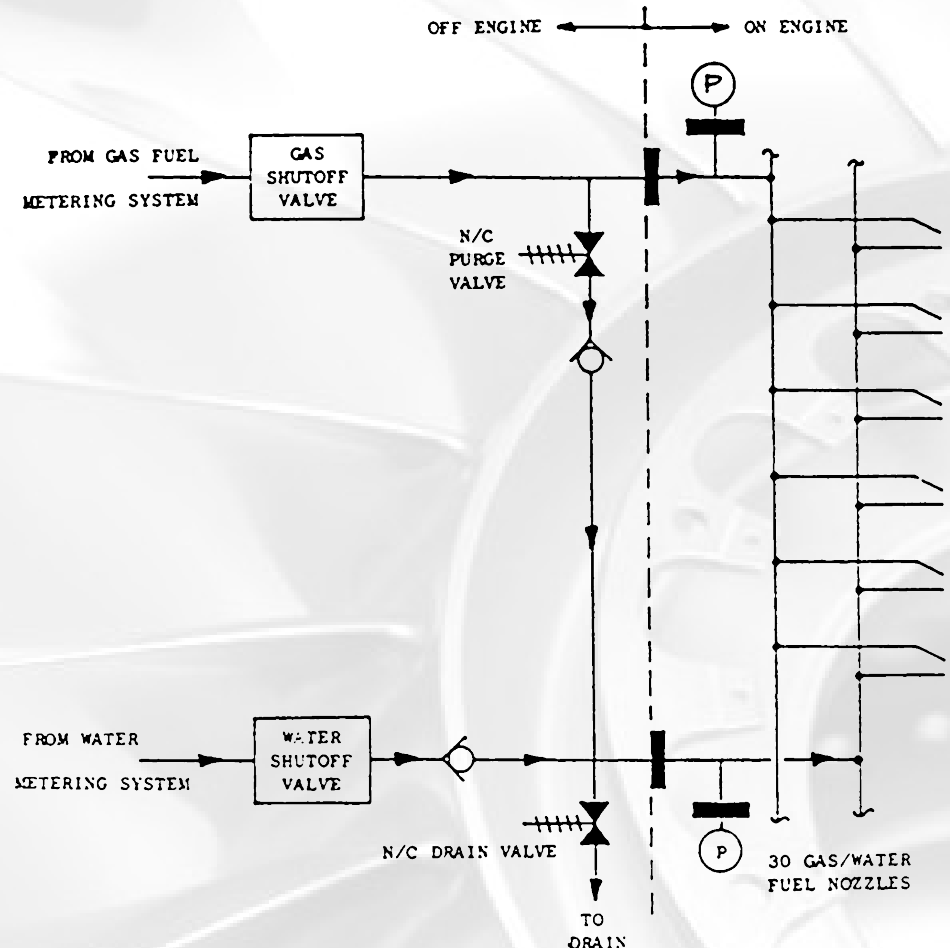
SAC Gas Fuel with Water Injection

Both the gas and water circuits contain metering and shutoff valves.

Water for NOX suppression will be injected from ca. 10 MW of load.

If no water is injected the water manifold will be purged with natural gas flowing back from the fuel nozzle tips.

The water system is secured from back flowing gas by non return and/or shutoff valves.

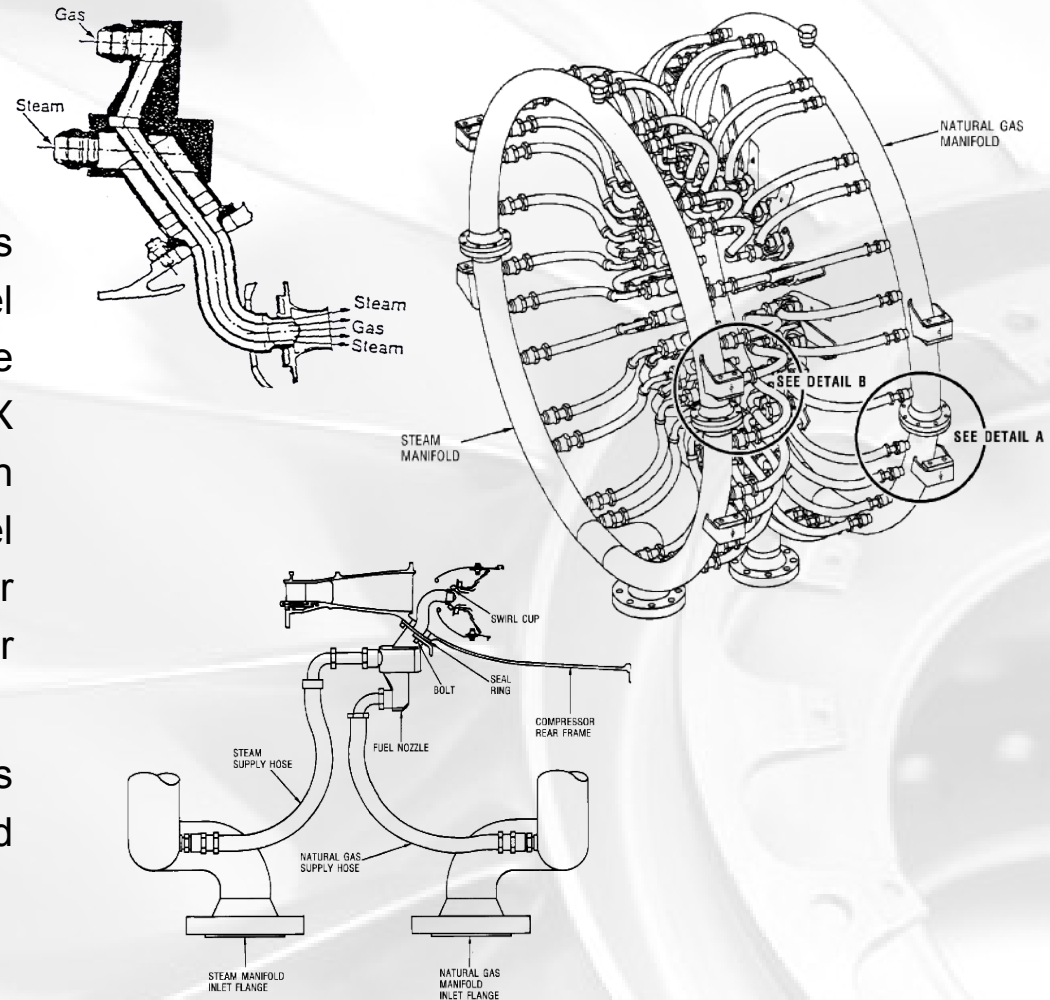


6. Auxiliary Equipment and Systems

SAC Gas Fuel with Steam Injection

The natural gas / steam system provides additional steam injection through the fuel nozzles into the combustor to lower the flame temperature and with it the NOX emissions value. The steam injection causes a lower T4.8 at the same gas fuel flow. This T4.8 margin and the higher mass flow result in a ca. 2-3MW higher maximum power output.

Additional to the gas system components a steam manifold, 30 flex hoses, and gas/steam fuel nozzles are required



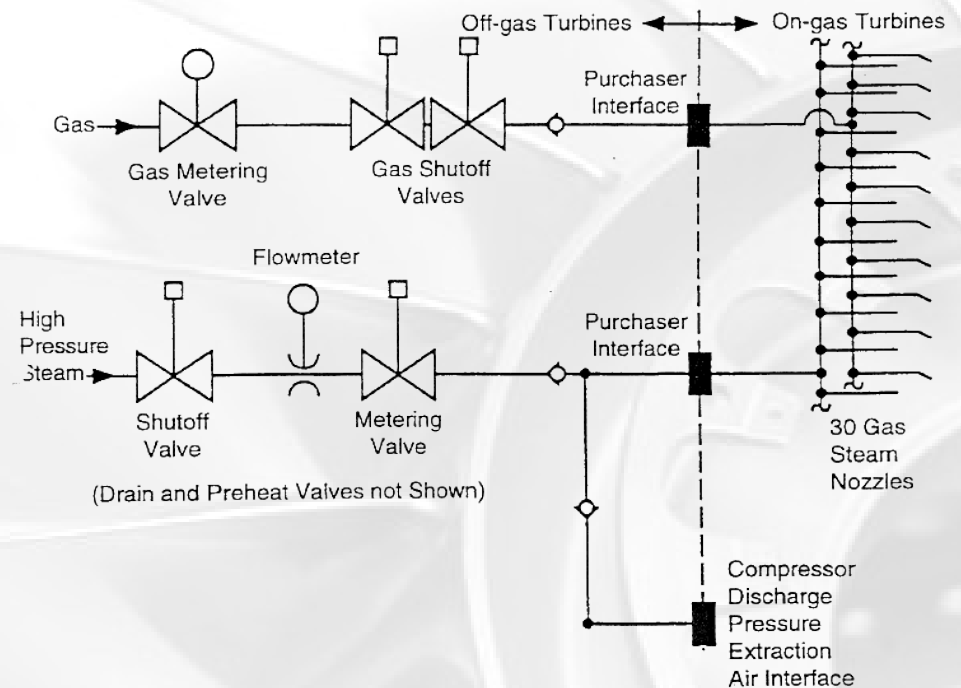
6. Auxiliary Equipment and Systems

SAC Gas Fuel with Steam Injection

Both the gas and steam circuits contain metering and shutoff valves.

Steam for NOX suppression will be injected from ca. 10 MW of load.

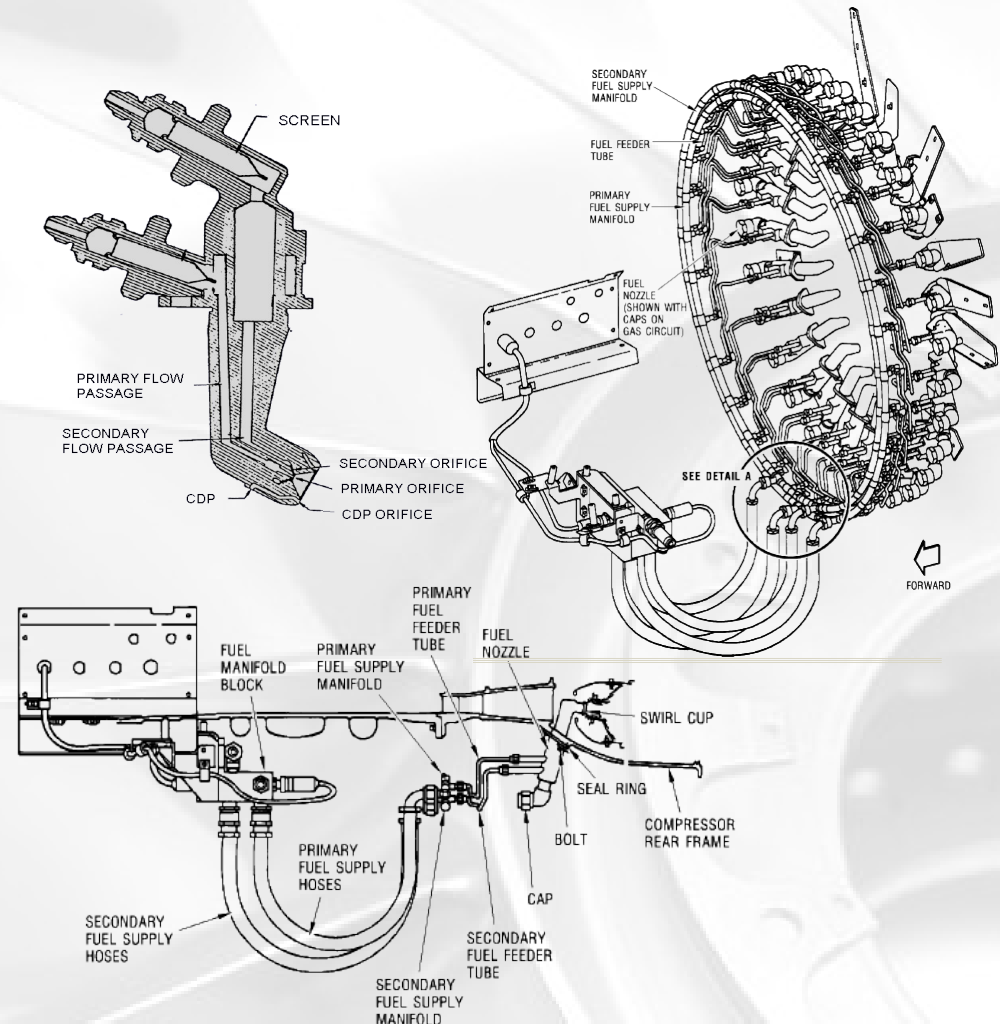
If no steam is injected the steam manifold will be purged with engine CDP air which is taken off the GT's CDP bleed ports at the CRF.



6. Auxiliary Equipment and Systems

SAC Liquid Fuel with or without Water Injection

The liquid fuel system is available either with or without NOX reduction water injection. The system consists of a primary and a secondary circuit, each with 1 manifold and 30 feeder tubes. The primary circuit has a lower flow capacity and supplies the fuel nozzles for the GT start. The secondary circuit provides full flow capacity for load operation. Water will be additionally injected through the secondary circuit. At positions 4 and 27 special fuel nozzles with higher primary flow are installed to provide sufficient UV-flame indication at start up.



6. Auxiliary Equipment and Systems

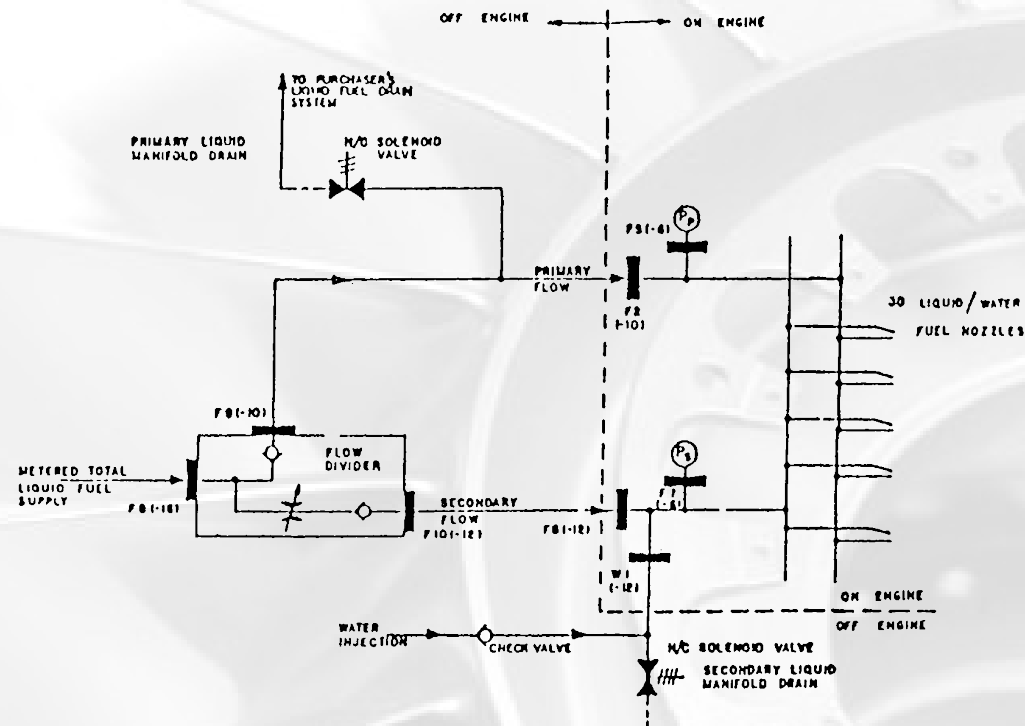
SAC Liquid Fuel with or without Water Injection

Both the liquid and water circuits contain metering and shutoff valves.

There is only one metering valves for both liquid fuel circuits. A flow divider valve always provides flow to the primary circuit but opens the secondary circuit only when a certain fuel pressure is reached.

Water for NOX suppression will be injected from ca. 10 MW of load.

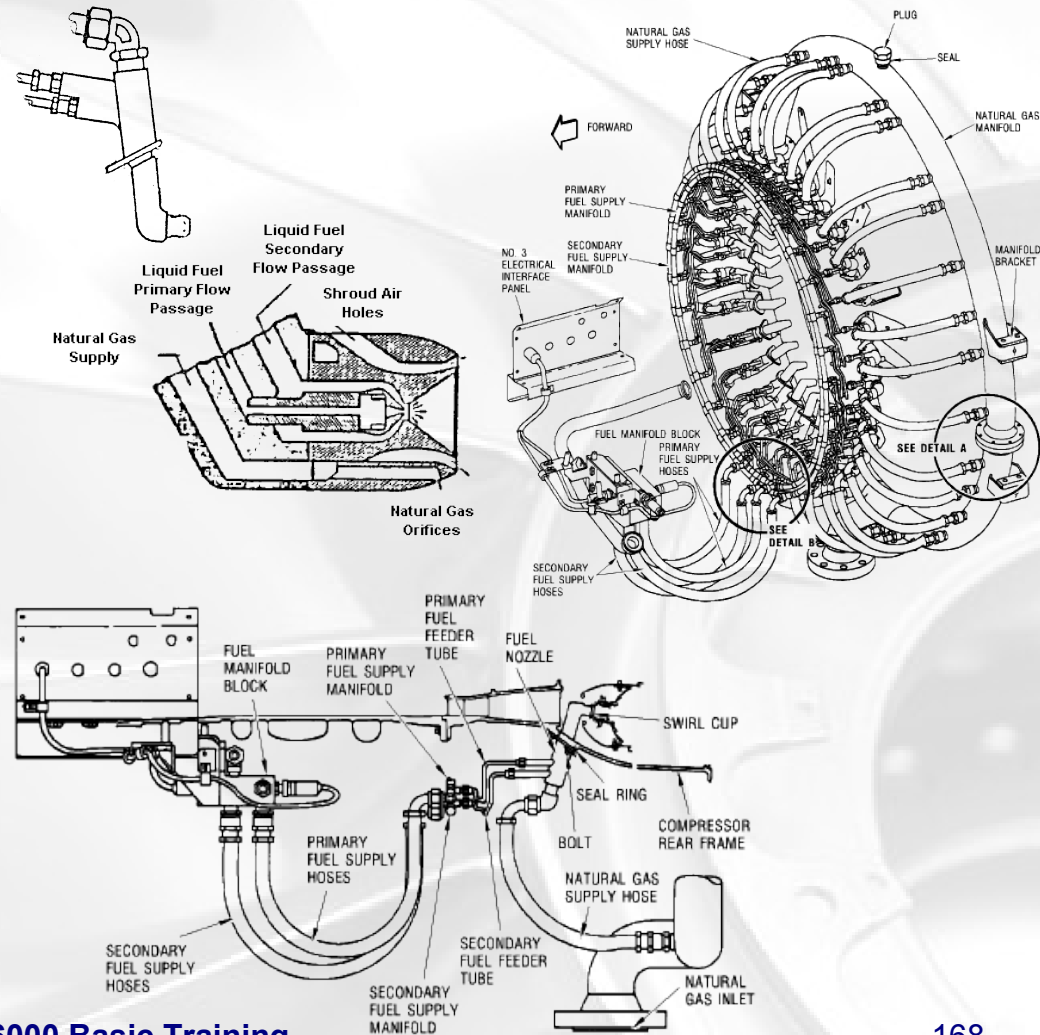
If no water is injected the water system is blocked by a non return valve from liquid fuel back flow.



6. Auxiliary Equipment and Systems

SAC Dual Fuel with or without Water Injection

The dual fuel system is available either with or without NOX reduction water injection. The system consists of both the gas fuel and liquid fuel system components and enables operation with different fuel types. The fuel can be changed during operation at all loads. Water for NOX reduction will be additionally injected through the secondary liquid circuit. At positions 4 and 27 special fuel nozzles with higher primary flow are installed to provide sufficient UV-flame indication at start up.

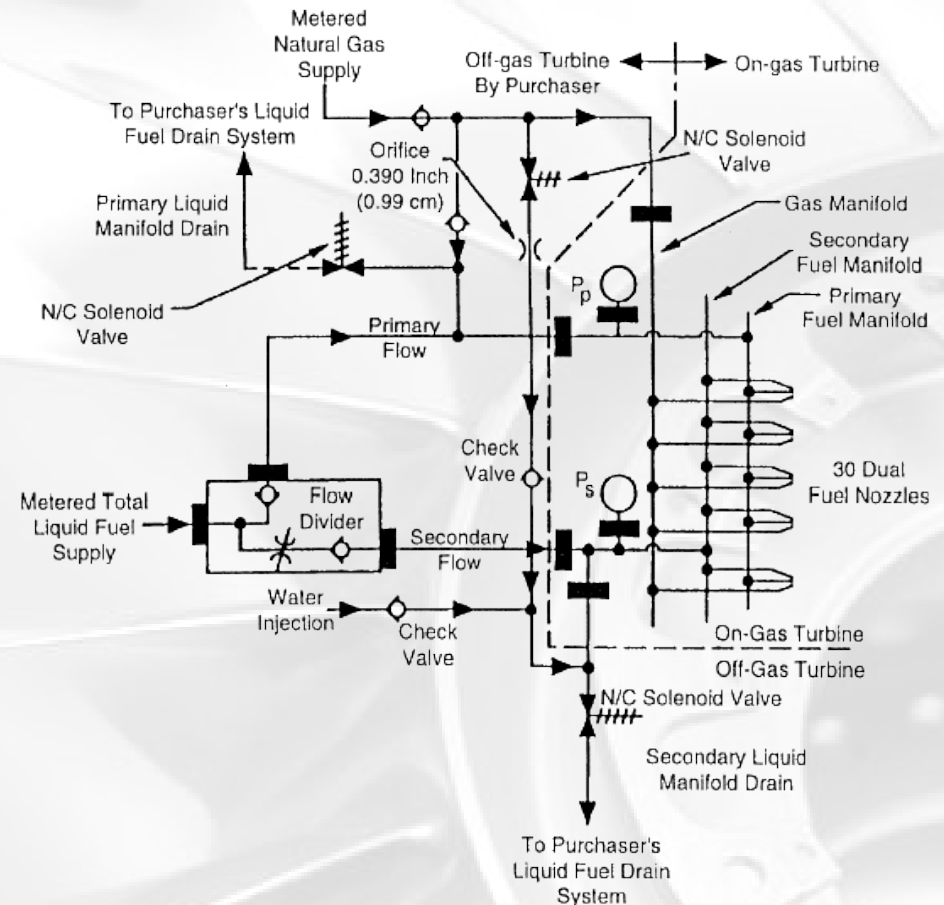


6. Auxiliary Equipment and Systems

SAC Dual Fuel with or without Water Injection

The dual fuel /water system is a mix of the gas and liquid fuel / water systems.

The liquid manifolds are purged with gas when not in use. Both liquid fuel and water systems are blocked by non-return or shutoff valves to prevent back flow of gas. If operation on liquid fuel the gas manifold will be purged with CDP air to prevent backflow of hot gases and to cool the fuel nozzle tips additionally to the shroud air flow.



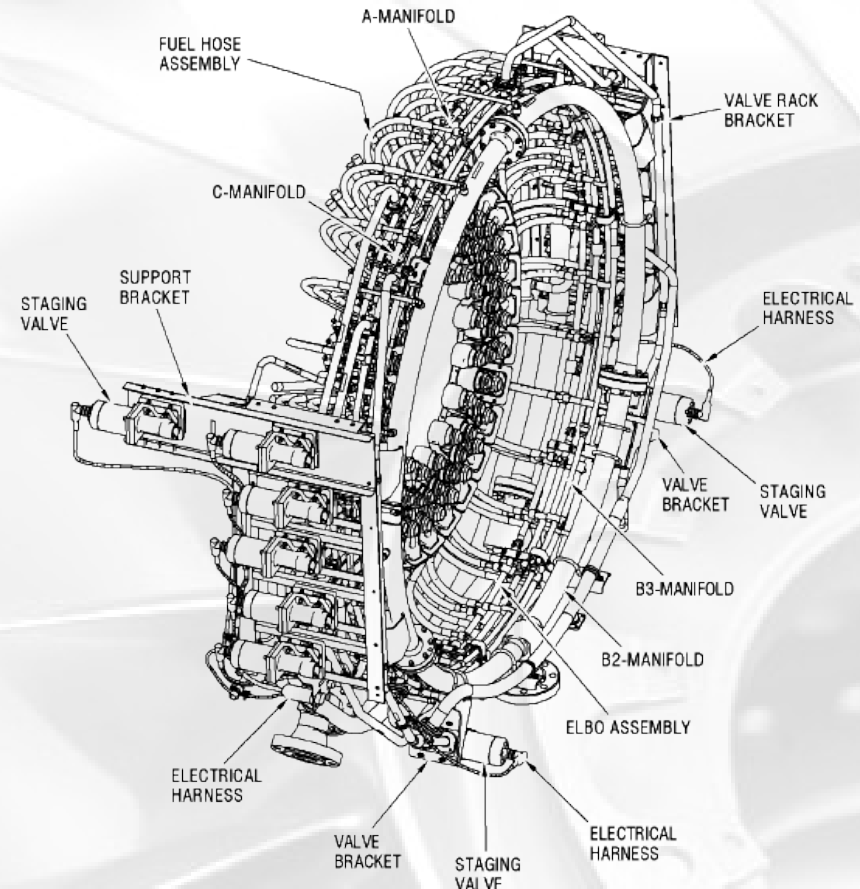
6. Auxiliary Equipment and Systems

DLE Gas Fuel

The DLE gas fuel system contains of 30 Premixers, 3 (PD) or 5 (PF) fuel manifolds, 11 (PD) or 13 (PF) staging valves and 30 fuel hose assemblies.

Each of the 3 or 5 manifolds is controlled by a separate fuel metering valve.

The staging valves open or shut manifold segments to enable the required burner modes and fuel flows depending on the load of the engine.



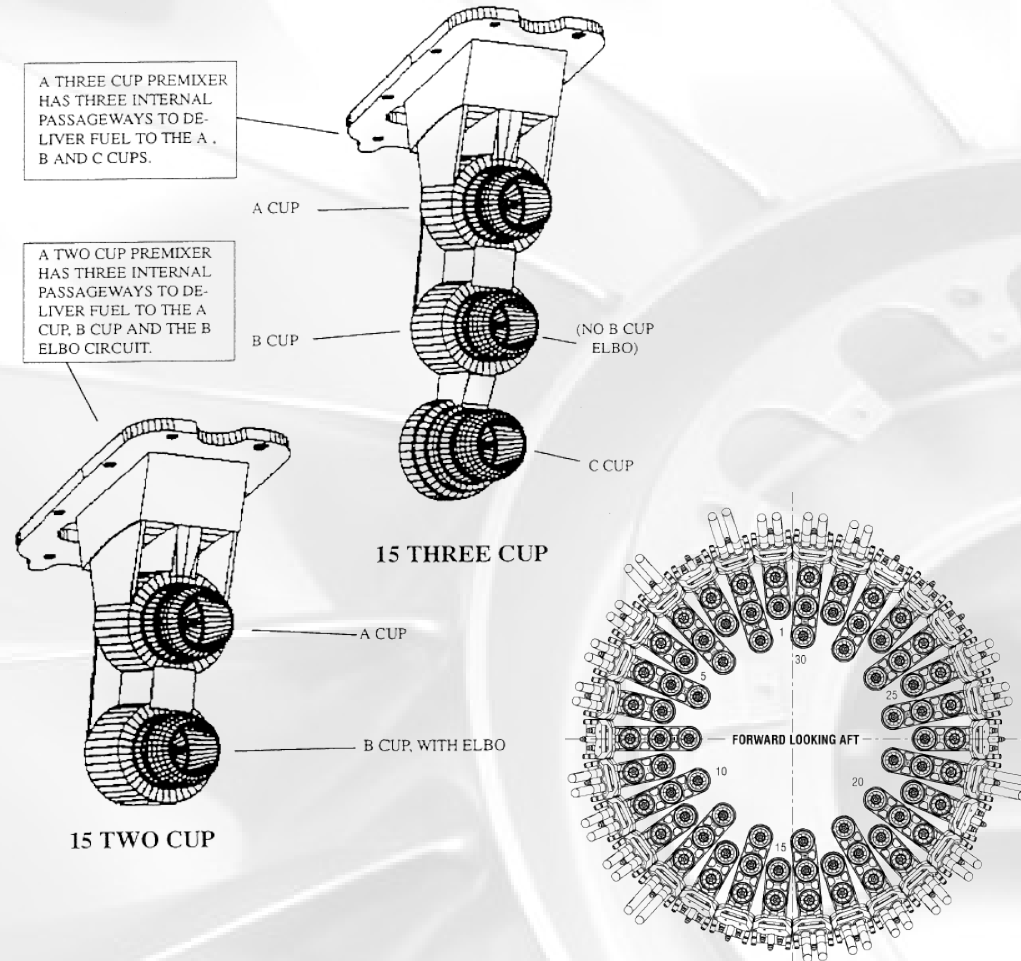
6. Auxiliary Equipment and Systems

DLE Gas Fuel Premixer

The DLE system contains 30 premixers, 15 2-cup and 15 3-cup. The three burner rings contain all together 75 burners, 30 for the outer A-ring, 30 for the pilot B-ring and 15 for the inner C-ring.

All premixers have got three fuel gas connections. The third connection for the 2-cup premixers supplies the B-cup elbo flow passage.

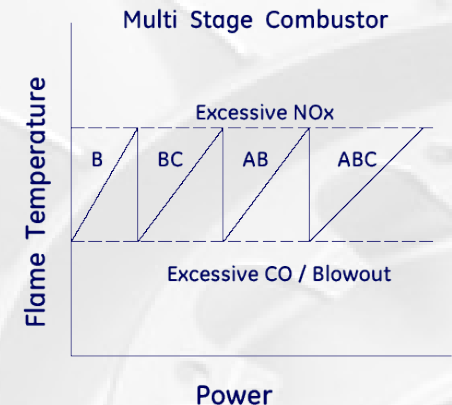
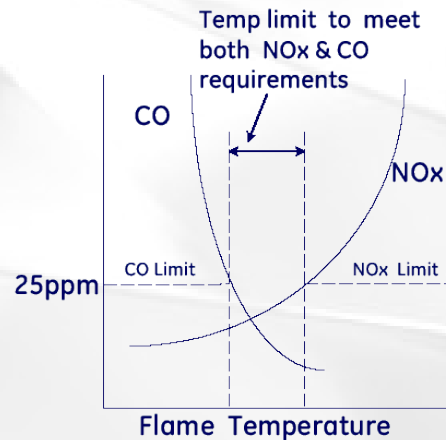
PREMIXERS:



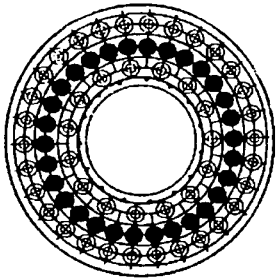
6. Auxiliary Equipment and Systems

DLE Gas Fuel Mapping

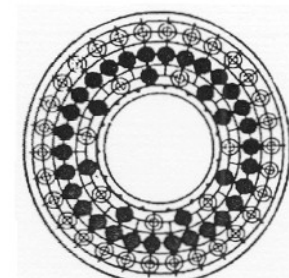
The DLE fuel system operates in different burner modes dependent on the GT load. These burner modes in conjunction with the bleed air system provide the correct fuel air mixture for a low NOX and CO creating flame temperature. The adjustment of these burner modes are called “combustor mapping”.



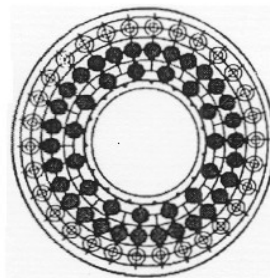
B (Pilot) Only Mode



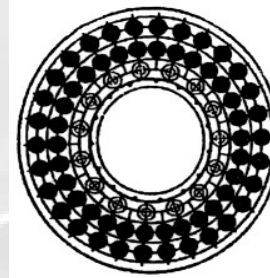
BC/2 (Pilot and Half Inner) Mode



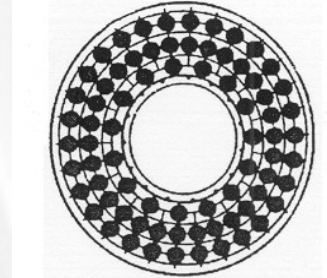
BC (Pilot and Inner) Mode



AB (Outer and Pilot) Mode



ABC (Outer, Pilot, and Inner) Mode



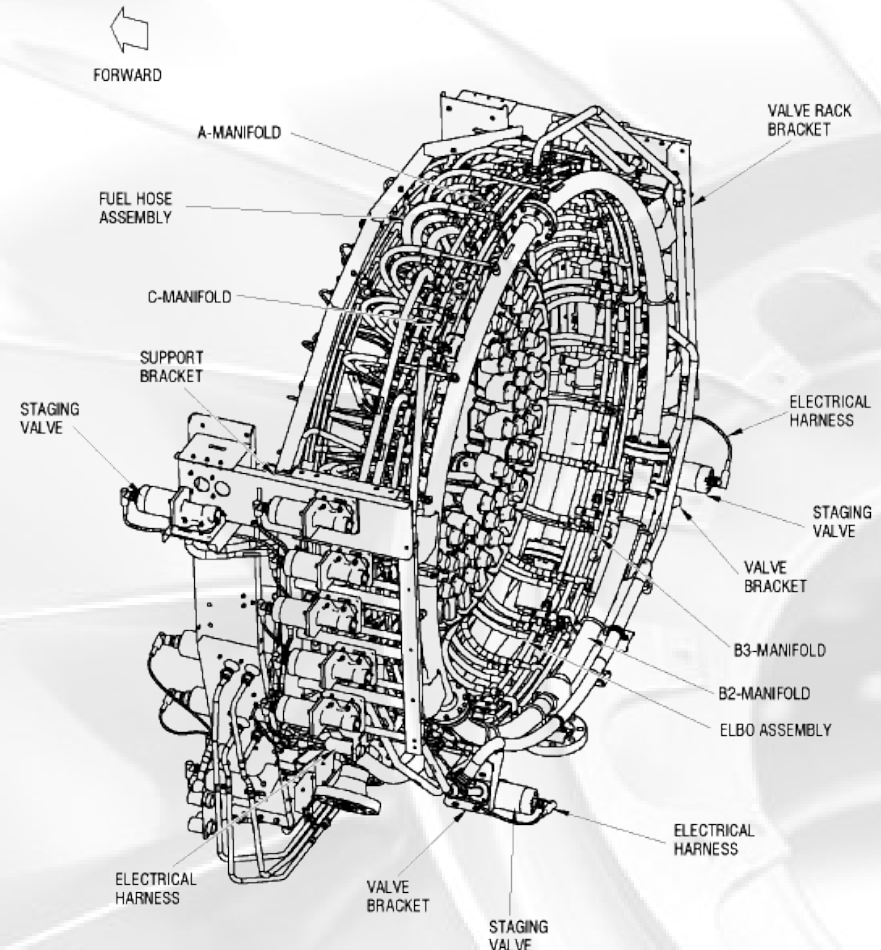
6. Auxiliary Equipment and Systems

DLE Dual Fuel

LM6000PD and PF can be supplied with a dual fuel system.

The dual fuel DLE system allow reduced NOX and CO emissions operating the GT with either gas or liquid fuel without additional injections.

The dual fuel DLE system contains additional liquid fuel lines, staging valves and dual fuel premixers.

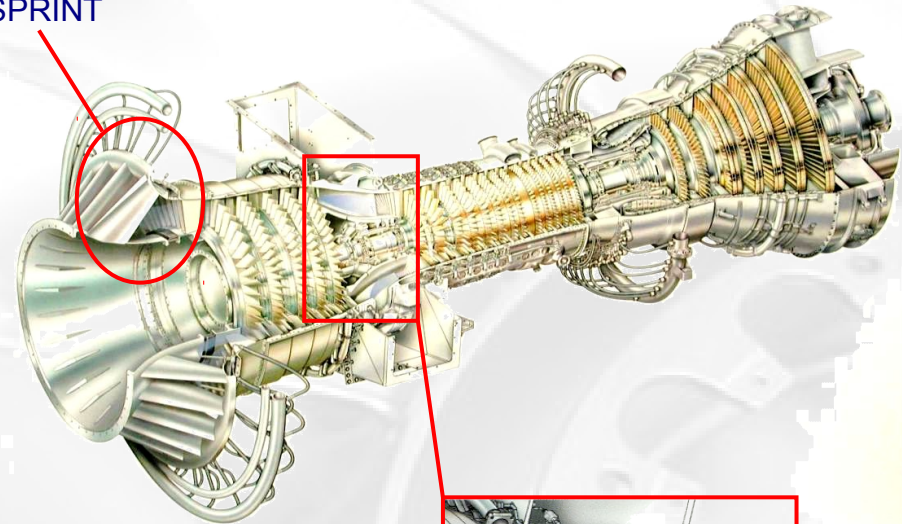


6. Auxiliary Equipment and Systems

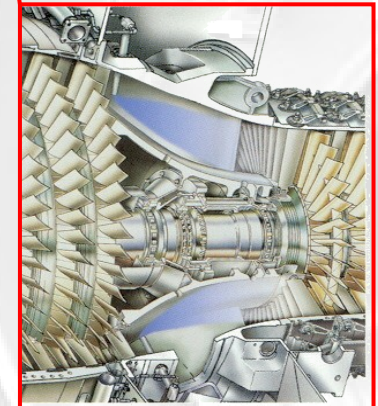
SPRINT System

SPRINT is optionally available for power enhancement for inlet temperatures above 30°F (1.1°C). SPRINT operates as an intercooler by injecting a fine mist into the compressor airflow and reduces the temperature of the air as it evaporates in the front compression system. Two SPRINT systems are used. HP SPRINT injects water mist into the HPC inlet via nozzles mounted in the CFF. LP SPRINT provides additional evaporative cooling during hot-day operation by injecting mist into the LPC via nozzles mounted in the inlet duct. LP SPRINT is disabled below 45°F (7.2°C) to prevent icing conditions.

LP SPRINT



HP SPRINT



TECHNICAL TRAINING

Table of contents

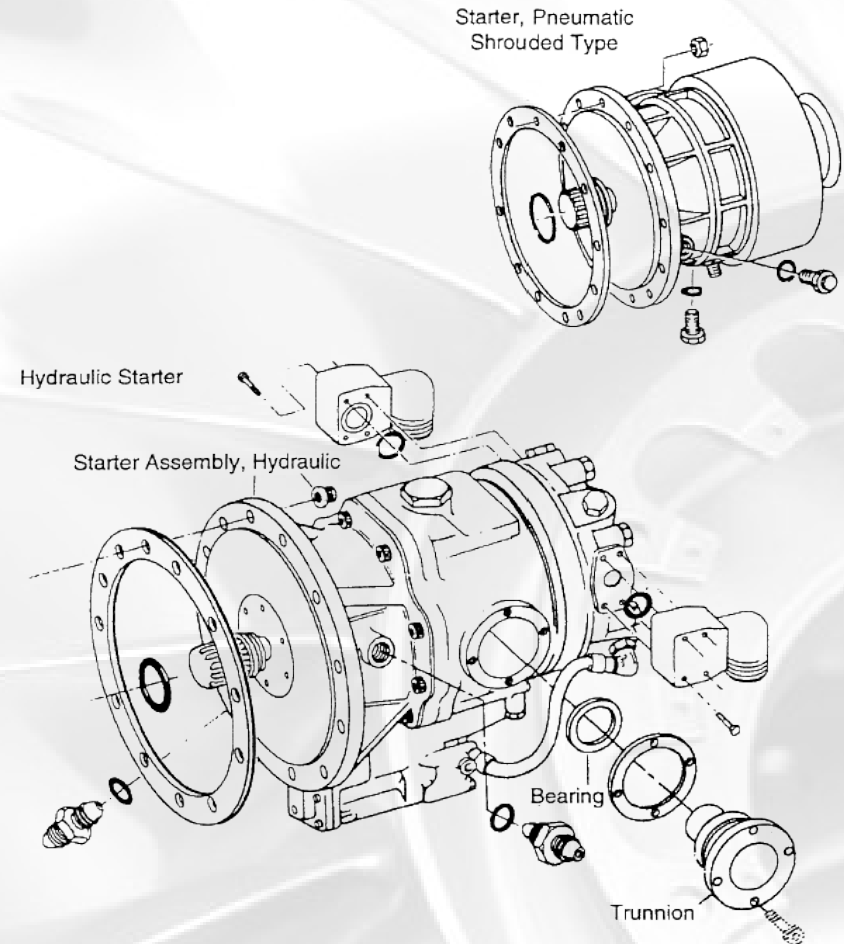
1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
4. Major components of the LM6000
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB; TGB; IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
5. Parasitic Air Flow
6. **Auxiliary equipment and system**
 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. **Starting System**
 - e. Instrumentation

6. Auxiliary Equipment and Systems

Starting System

The starting system provides speed to the GT HP-shaft to enable firing up the gas turbine. The starter motor is connected to the HP shaft via AGB, TGB, Radial Drive Shaft and IGB. The LP shaft will turn automatically as the air and gas flows increase during the start.

All types of starters contain of a clutch and the actual drive motor. The clutch provides the starter motor to disengage when it's speed is overrun by the GT speed. A part of the clutch stays turning during the GT's operation and requires continuous lubrication.

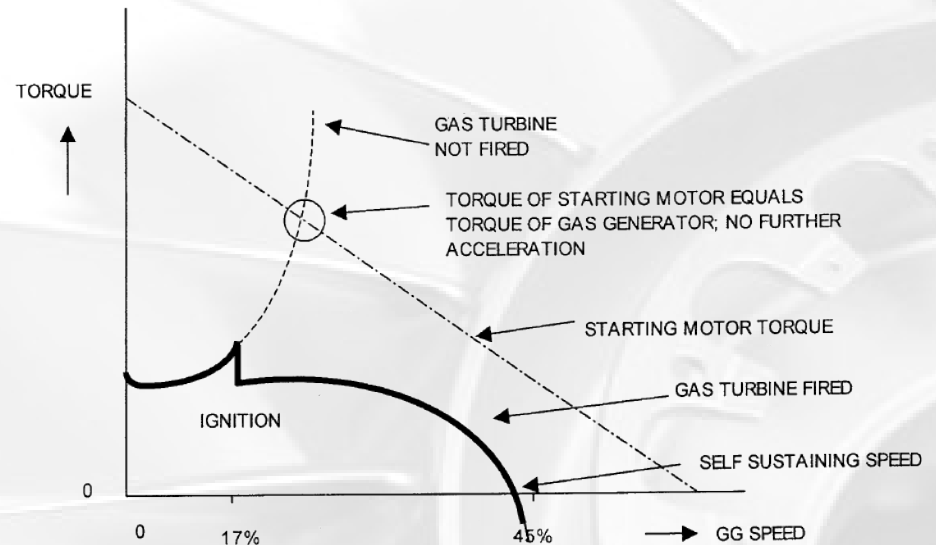


6. Auxiliary Equipment and Systems

Starting System

The starting system has the following tasks:

- Accelerate the HP rotor to ignition speed
- Help the HP rotor to accelerate to self-sustaining speed
- Disconnect from GT automatically
- Drive the HP rotor at low speed during water wash
- Drive the HP rotor during slow roll (cool down period) in the stop procedure



6. Auxiliary Equipment and Systems

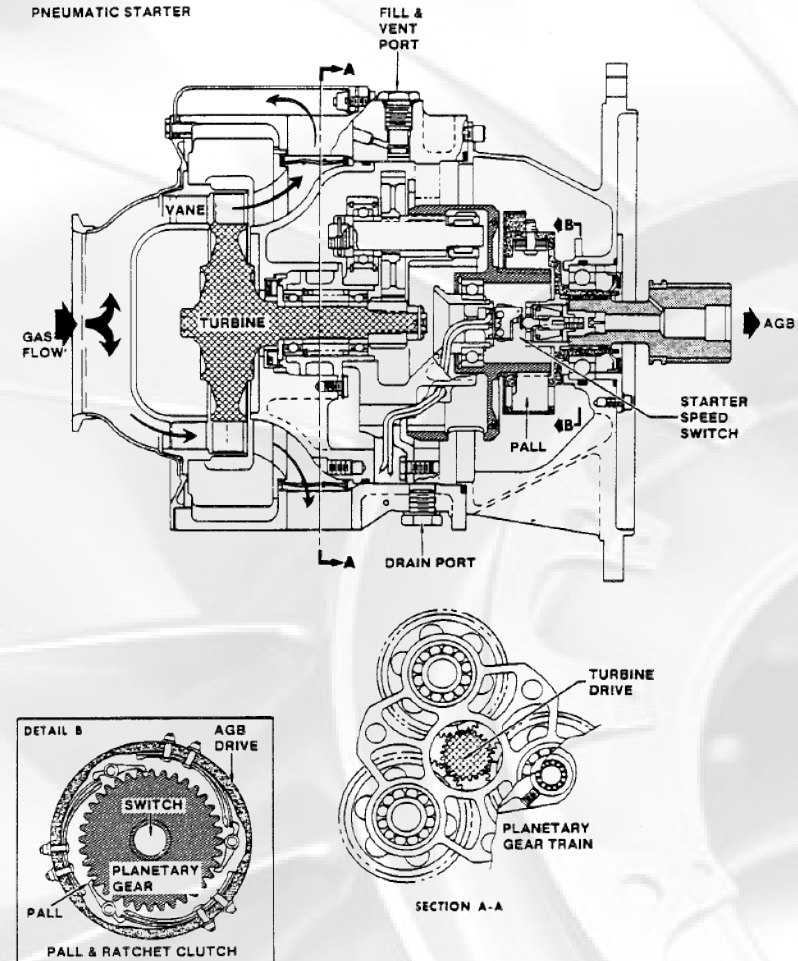
Pneumatic Starter

The pneumatic starter can be either supplied with compressed air or compressed natural gas.

The starter motor contains a single stage axial flow turbine which drives the drive shaft via a planetary reduction gear and a ratchet type over-running clutch.

The discharge air or gas is vented off through a shrouded exhaust.

The starter is connected to the GT supply and scavenge oil system.

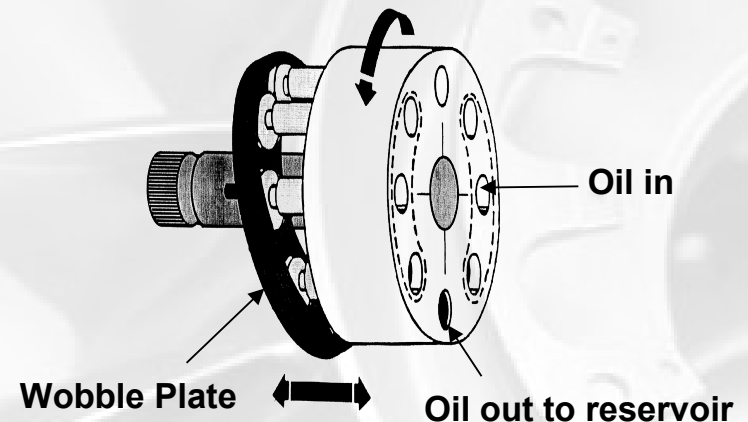
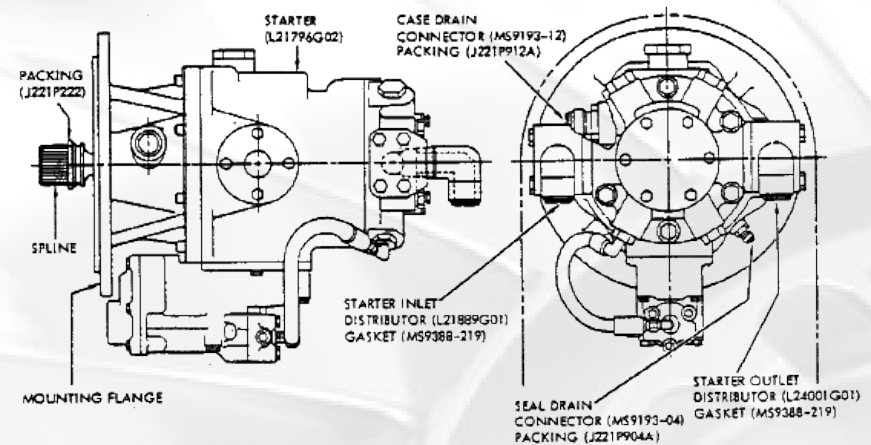


6. Auxiliary Equipment and Systems

Hydraulic Starter

The hydraulic starter consists of a variable displacement-type hydraulic motor with piston stroke controlled by a wobble plate. Displacement is controlled by varying the angle of the wobble plate by means of a pressure compensator. The starter is equipped with an overrunning clutch to disengage from GT when the HP shaft reaches 4,600 rpm.

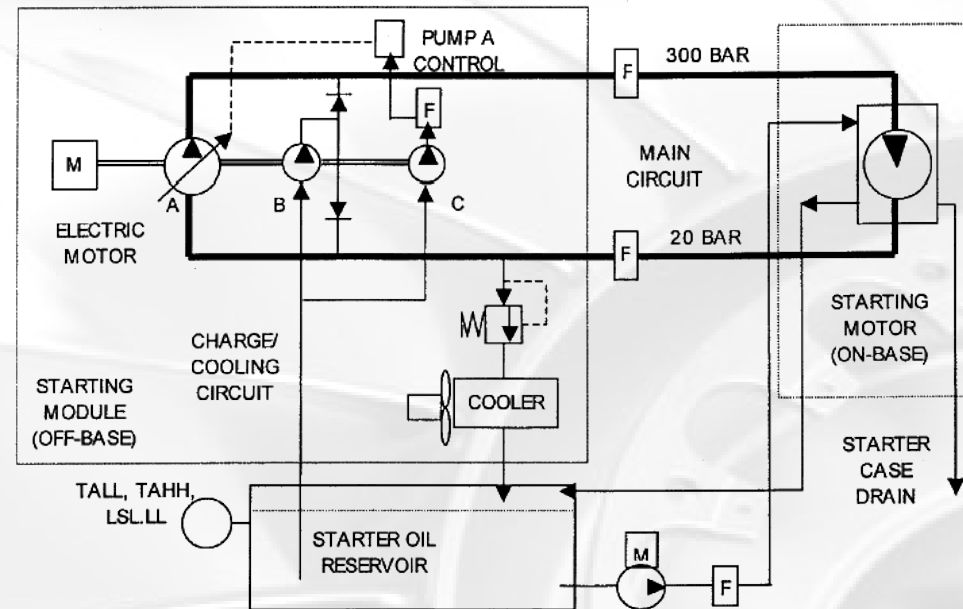
The maximum supply pressure is 365 bar at a flow of 208 l/min.



6. Auxiliary Equipment and Systems

Hydraulic Starting System

The hydraulic starting system consists of an off-engine starter module and an on-engine starter motor. An E-motor drives 3 pumps, a controllable main pump to supply oil to the starter motor, a boost pump to fill and continuously flush the hydraulic system and a pilot pump for main pump controller pressure. The boost pump charge oil flow from the tank into the HP system on the main pumps suction side and via a relief valve back into the reservoir. Oil from main loop will heat up and will be returned to the reservoir via an internal relief valve and an oil cooler.



A 4th pump is required for the starter clutch lubrication loop which is commonly operating with the same hydraulic oil (not shown in schematic).

6. Auxiliary Equipment and Systems

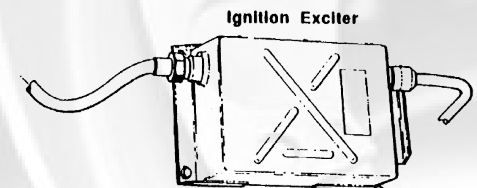
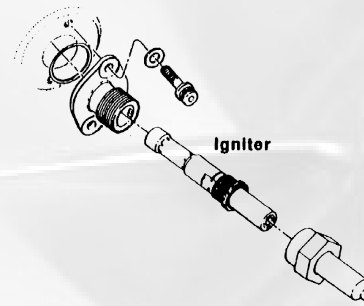
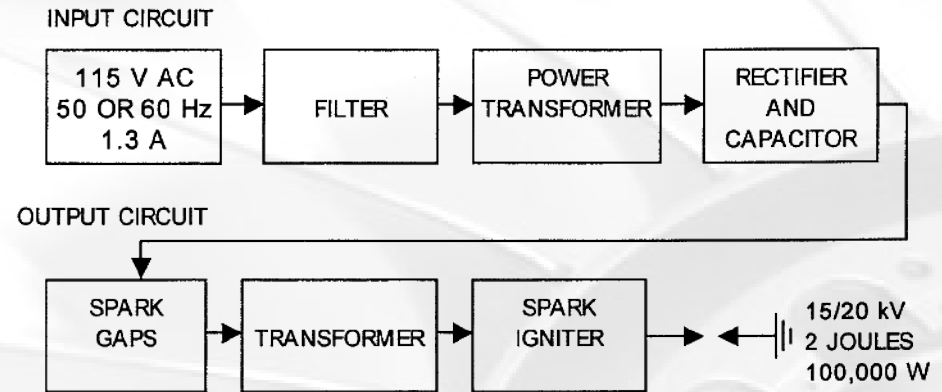
Ignition System

The ignition system consists of the ignition excitors, leads and spark igniters. The purpose is to ignite the fuel-air mixture within the combustor during the start cycle.

The excitors operate on 115 VAC 60Hz input and discharge two 20,000 VDC pulses per second through coaxial shielded leads to the igniters. A 24 VDC input version is also available.

The spark igniters are a gap firing type. The surface gap will ionize at 8,500 volts. The discharge energy is 2 joules.

The ignition system is energized parallel with energizing of the starter (1,200 - 4,700 rpm).



TECHNICAL TRAINING

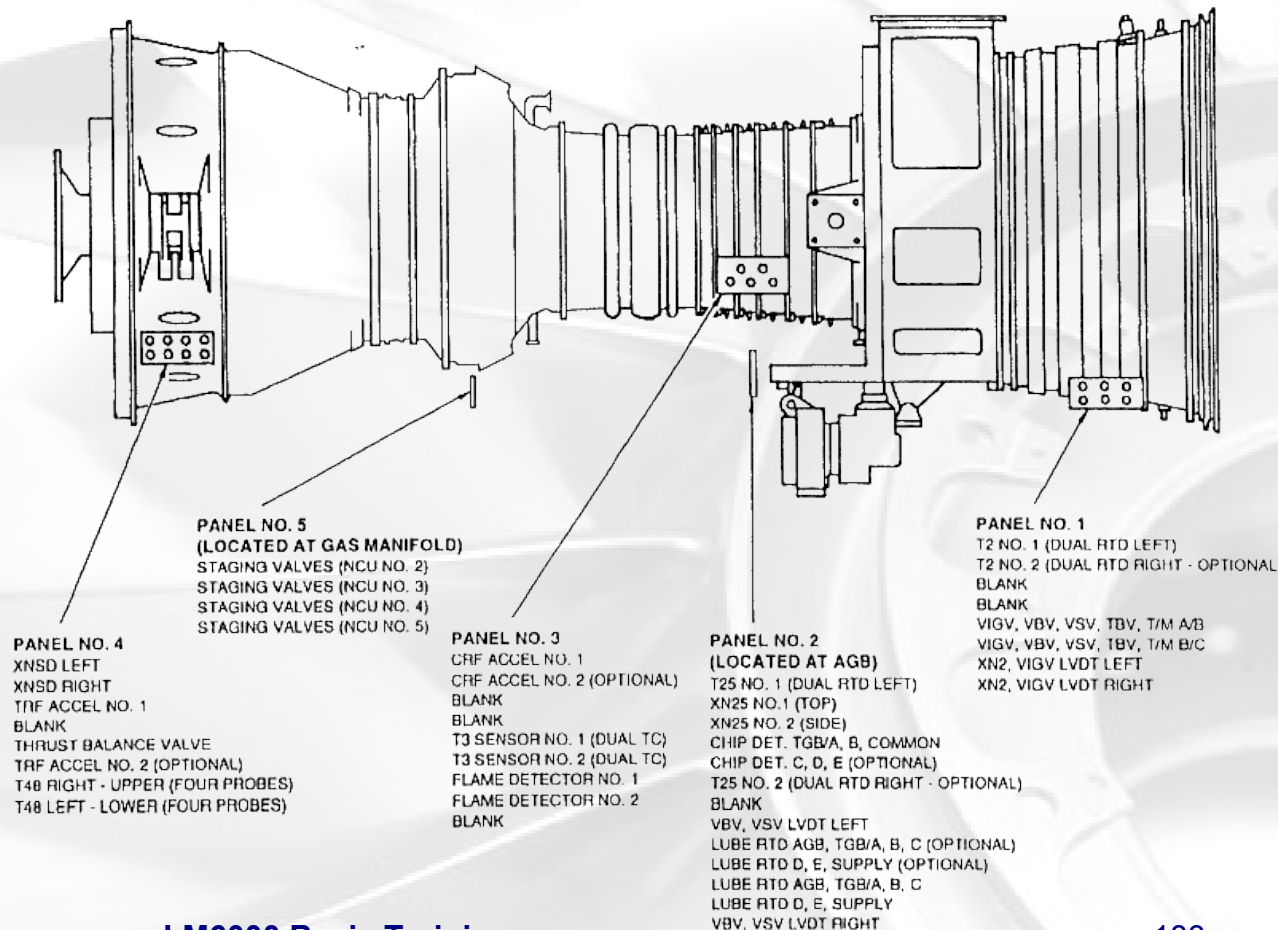
Table of contents

1. Abbreviations and acronyms
2. Gas turbine basics
3. Introduction to the LM6000
4. Major components of the LM6000
 - a. Low Pressure Compressor (LPC)
 - b. High Pressure Compressor (HPC)
 - c. Combustor
 - d. High Pressure Turbine (HPT)
 - e. Low Pressure Turbine (LPT)
 - f. Accessory Drive (AGB; TGB; IGB)
 - g. Engine Frames (CFF, CRF, TRF)
 - h. Bearings and Sumps
5. Parasitic Air Flow
6. Auxiliary equipment and system
 - a. Lubrication System
 - b. Variable Geometry System
 - c. Fuel, Water and Steam Systems
 - d. Starting System
 - e. Instrumentation

6. Auxiliary Equipment and Systems

Instrumentation interface

Five interface panels are provided at LM6000 GT's for connection of off-engine signal lines to the on-engine instrumentation.

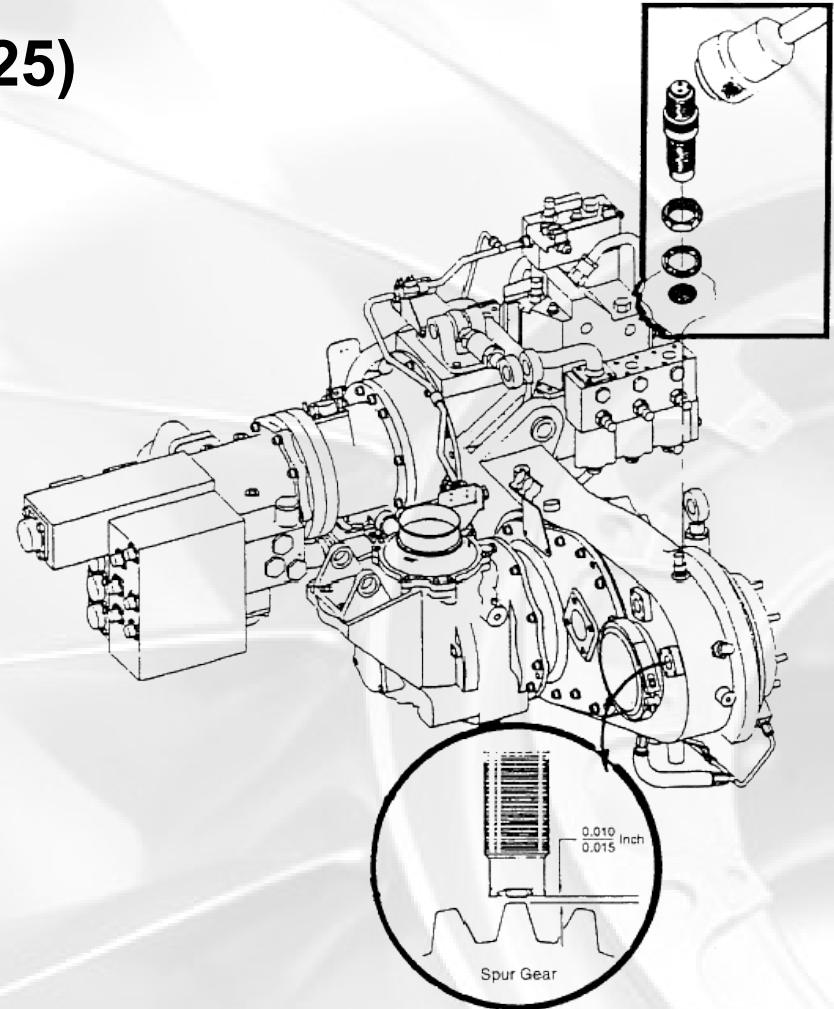


6. Auxiliary Equipment and Systems

HP Rotor Speed Sensors (XN25)

Two HP rotor speed sensors are located at the LH side of the AGB. These are magnetic reluctance type sensors, the speed signal is produced by sensing the passing gear teeth on an AGB spur gear.

The sensors require gap setting when installed. The gap is checked through inspection holes at the forward side of the AGB, adjusted by threading in or out and secured by a lock-wired jamnut. The threads have to be coated with RTV silicon to provide sealing of the AGB sump.



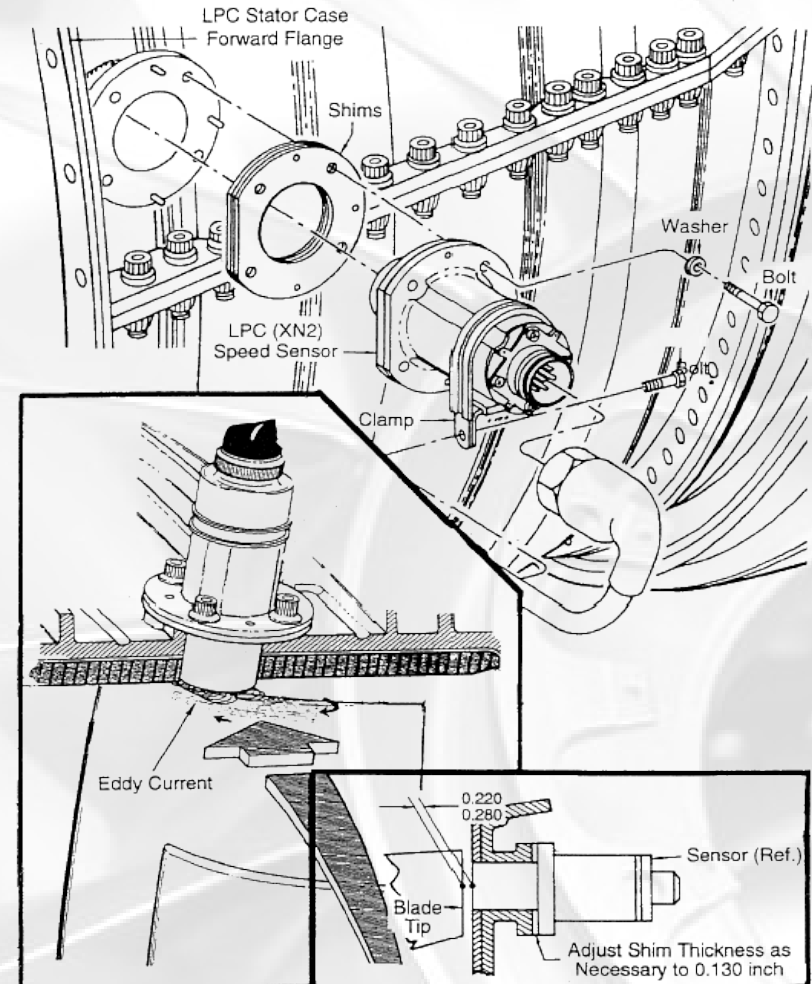
6. Auxiliary Equipment and Systems

LP Rotor Speed Sensors (XN2)

Two LP rotor speed sensors are located at both LPC stator case sides (3 and 9 o'clock). These are eddy current type sensors, the speed signal is produced by sensing the passing LPC stage 0 rotor blades.

The sensors require gap setting when installed. The gap is adjusted by peeling laminated shim packs. For adjustment the average stage 0 blade tip clearance has to be determined by measuring each blade gap.

XN2 sensors are not used anymore at newer LM6000 versions.



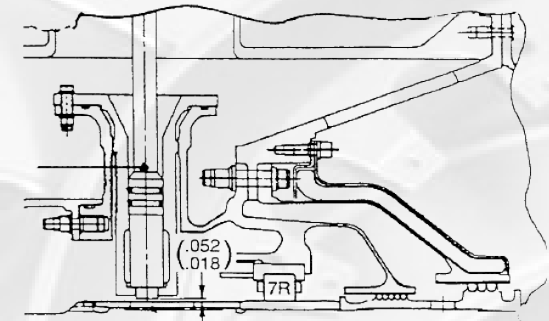
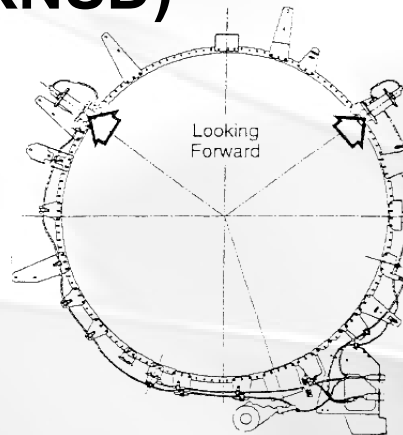
6. Auxiliary Equipment and Systems

LP Rotor Speed Sensors (XNSD)

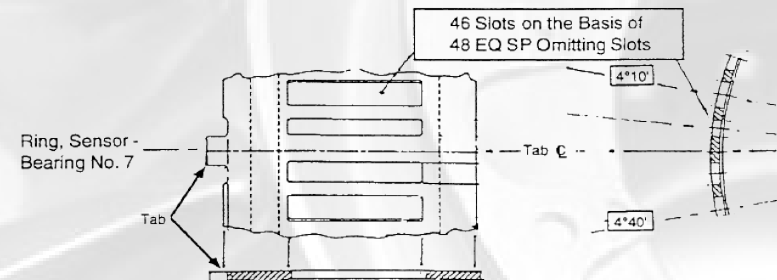
Two LP rotor speed sensors are located at the LPT TRF. These are magnetic reluctance type sensors, the speed signal is produced by sensing ring lands of a slotted ring installed in front of the No. 7R bearing inner race.

The sensors do not require gap setting.

As one of the 48 slotted ring lands is wider, it produces a stronger pulse which creates a 1/rev signal that can be used for LP rotor trim balancing.



Low Pressure Turbine Rotor
Speed Sensor (XNSD)



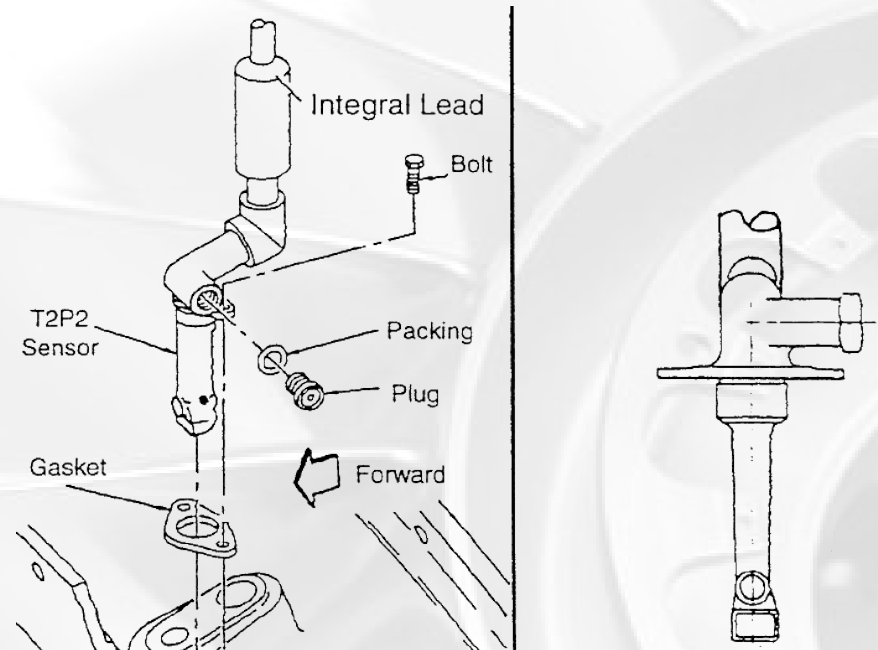
6. Auxiliary Equipment and Systems

Compressor Inlet Sensors (T2/P2 and T25/P25)

For LP and HP compressor inlet temperatures and pressures two combined P/T probes are used. The LPC-one is installed in VIGV housing the HPC-one in the CFF.

The P/T sensor probe contains a duplex RTD type temperature sensor with an integral lead and a pressure probe with a port to connect an off-engine pressure transmitter.

T2 and T25 temperatures are mainly required for speed corrections to control the VG system components

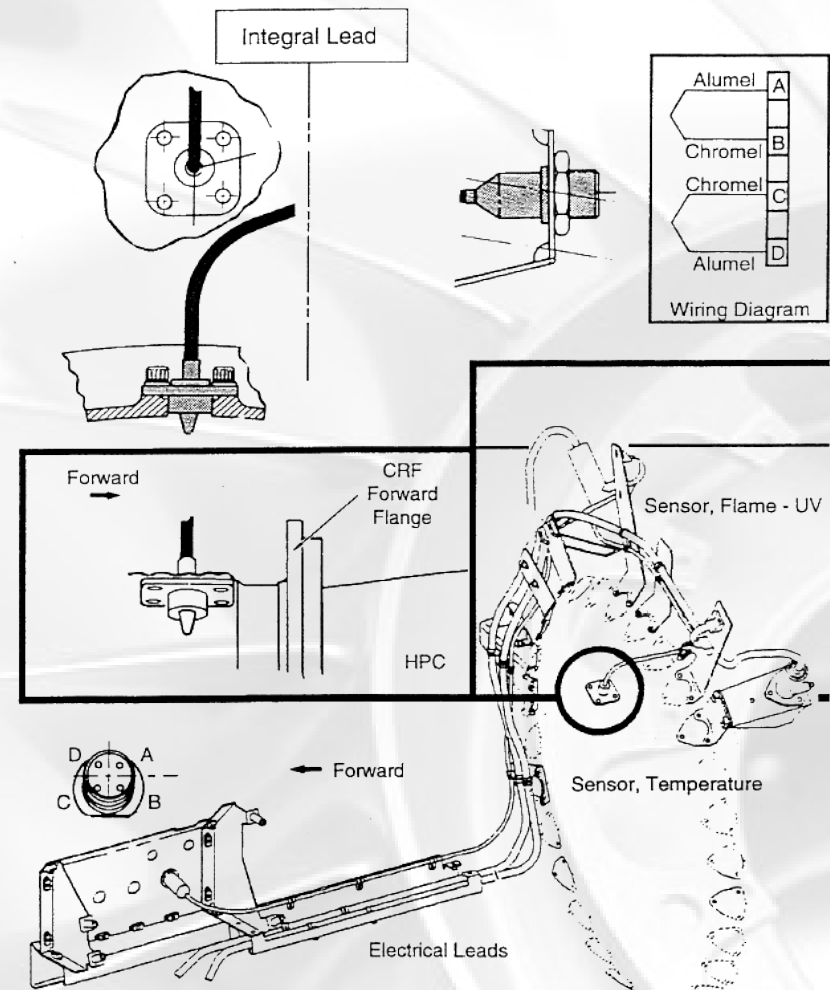


6. Auxiliary Equipment and Systems

Compressor Discharge Temperature (T3)

The compressor discharge temperature T3 sensor is a dual-element type K (chromel/alumel) thermocouple with an integrated lead. Each element has a separate read-out capability. DLE version use 2 sensors, SAC versions one sensor. All of them are installed at the CRF just behind the HPC-CRF flange.

The T3 sensor is required for power limitation and for flame temperature calculations at DLE versions.

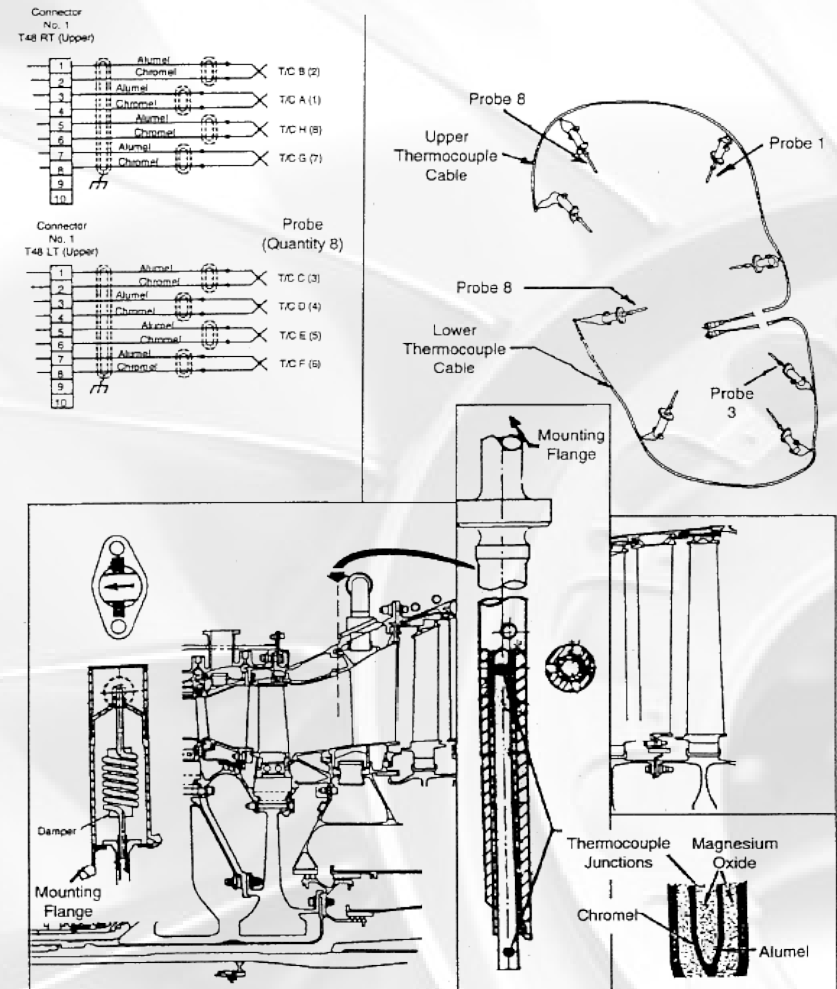


6. Auxiliary Equipment and Systems

LPT Inlet Temperature (T48)

There are eight dual-element type K (chromel/alumel) T48 thermocouples. There are 2 internal thermocouples in each sensor to sense the outer and inner temperature profile. These 2 thermocouples are connected in line to give an average temperature for each sensor. Two flexible harnesses, each connected to four sensors are routed to connectors on the TRF interface panel.

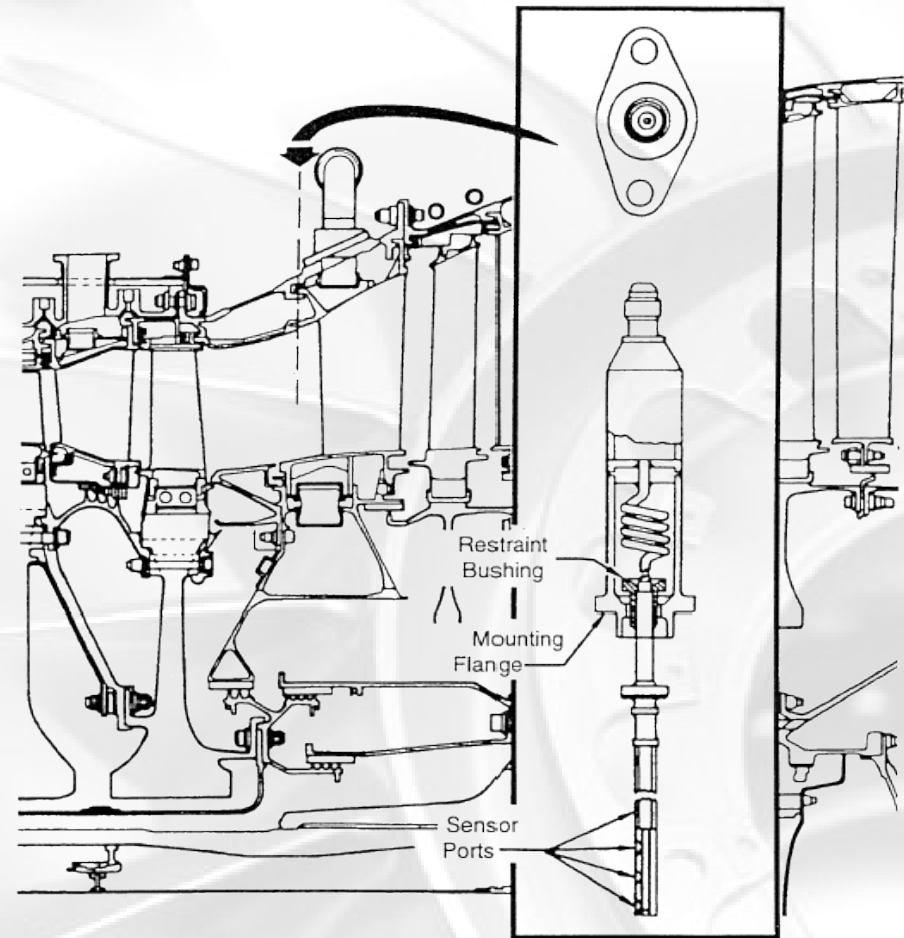
The 8 individual temperature readouts are also used to sense a temperature spread in the hot gas path.



6. Auxiliary Equipment and Systems

LPT Inlet Pressure (P48)

The LPT inlet pressure P48 is used for power calculation and comparisons. A probe to sense the total pressure is installed through the 9:30 o'clock position port at the forward LPT case in the same area where the T48 probes are located. The probe has four ports directed towards the engine inlet to enable pressure average sensing of the whole LPT inlet profile. The probe housing internal manifold is coiled to absorb vibration and thermal growth forces. Externally the probe has got a pressure tap to connect an off-engine transmitter or gage.

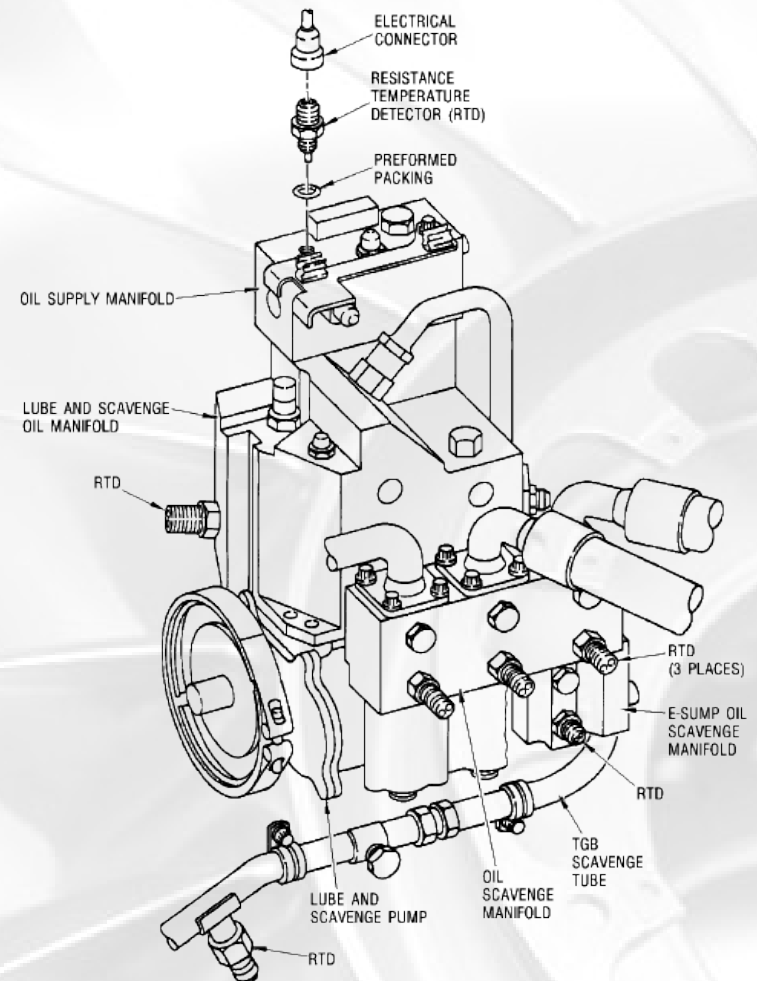


6. Auxiliary Equipment and Systems

Lube Oil Temperature Sensors

The standard lube system instrumentation consists of dual-element PT100 type RTD's. Seven RTD's are installed to measure the AGB, TGB-A, B, C, D and E sump scavenge temperatures as well as the supply oil temperature.

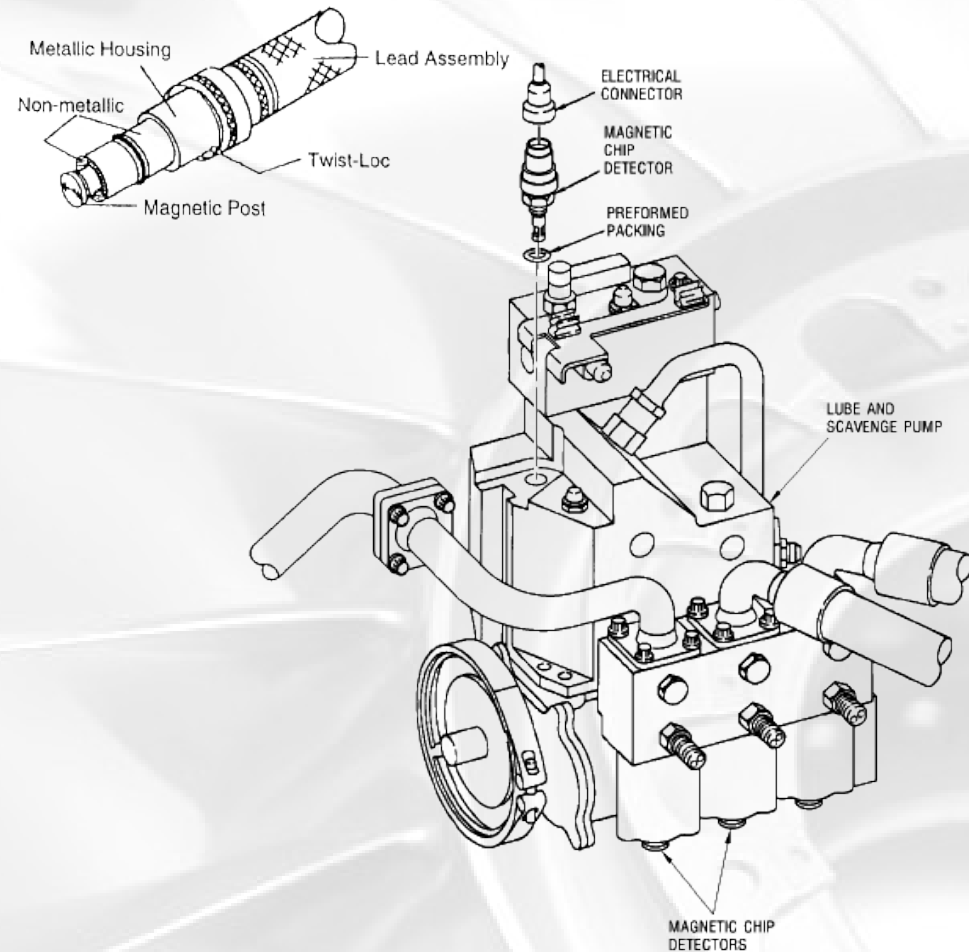
All RTD's are located at the Lube and Scavenge Pump manifolds.



6. Auxiliary Equipment and Systems

Lube Oil Chip Detectors

The standard lube system chip detection consists of electric/magnetic remote readout chip detectors for the thrust bearing containing sumps TGB/A (No.1B) and B sump (No. 4B) as well as in the common scavenge return line. Optional all remaining sump scavenge lines can also be equipped with chip detectors. All chip detectors are threaded into the L+S pump scavenge finger screens. The remote indication will be activated when the resistance across the detector is below 100 ohms. The detector input voltage is 24 VDC at 40 mAmps.

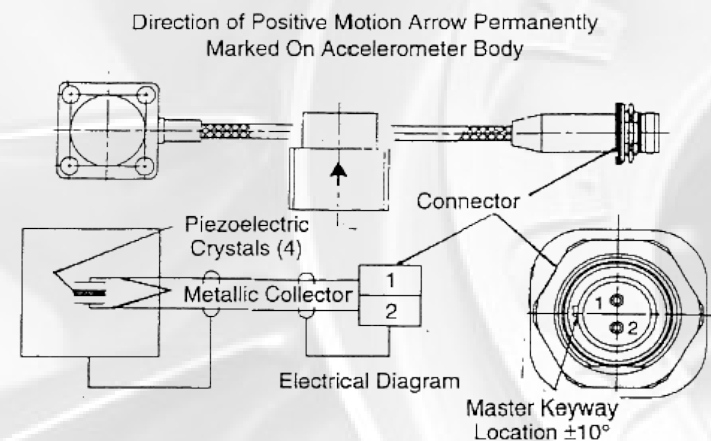
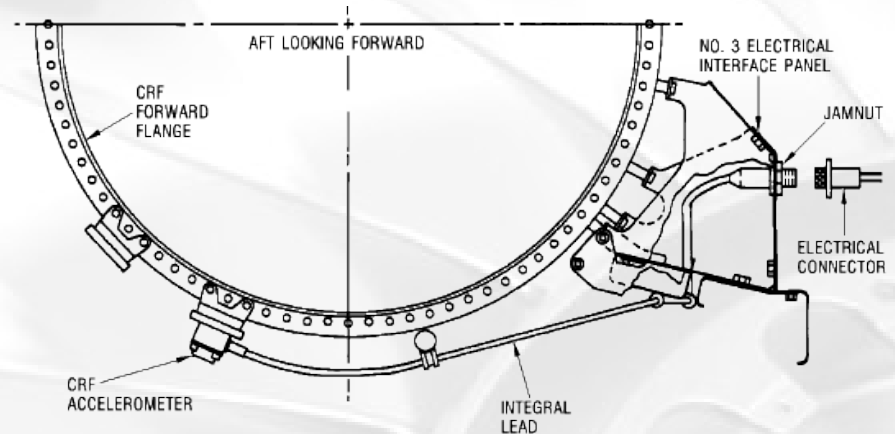


6. Auxiliary Equipment and Systems

Vibration Sensors

The gas turbine is equipped with two high temperature accelerometers to detect the GT vibrations. Each sensor monitors the vibration wideband frequency. The two signals will then be band filtered in the monitoring system for both the LP and HP shaft frequencies. This creates 4 vibration readings (LP forward and aft & HP forward and aft).

The accelerometers are 1-axis piezoelectric crystal type which produce a voltage output that measures the GT vibrations.

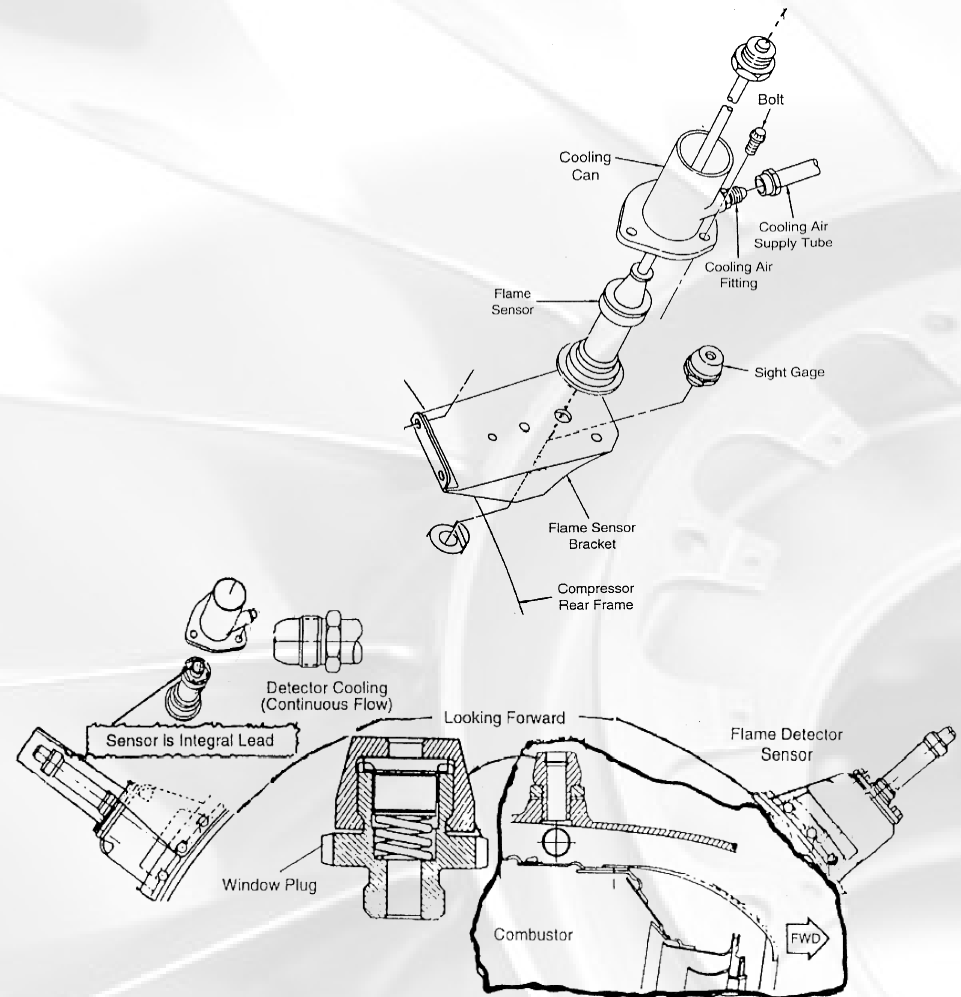


6. Auxiliary Equipment and Systems

UV Flame Detectors

Two UV-type flame detectors are provided with integral leads and air cooling jackets as standard equipment for fast indication of presence or loss of flame in the GT combustion system.

To sapphire viewing window assemblies (flame eyes) are installed in the CRF. The flame sensors are positioned radially from combustion section in line with the axis of symmetry of the flame eyes and detect the flame by sensing the UV-radiation. The sensors have got a cooling can to enable cooling with cooling air.



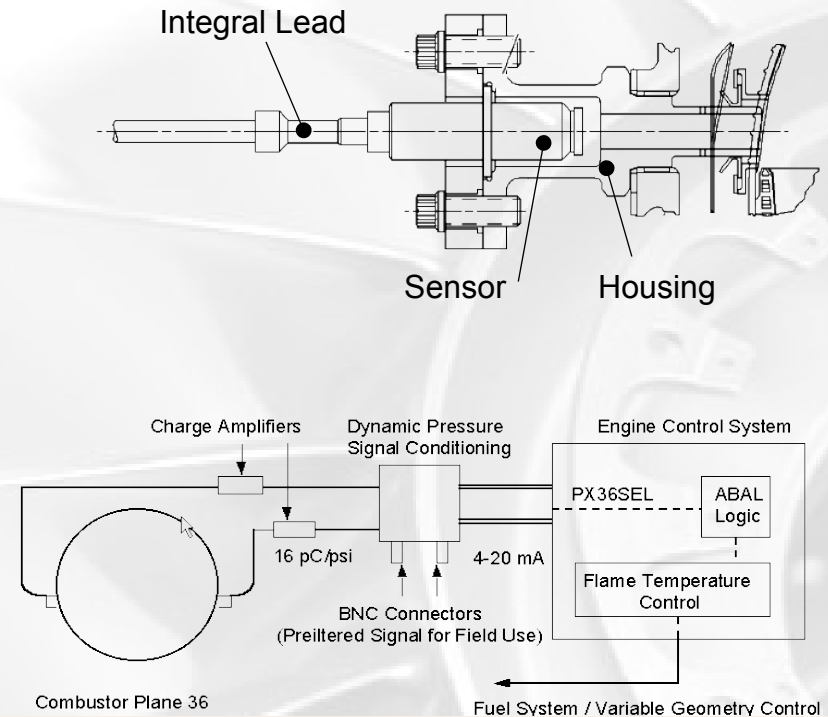
6. Auxiliary Equipment and Systems

Acoustic Sensors (PX36)

Two Acoustic sensors are installed at LM6000 DLE versions mounted at the CRF case. These sensors control and monitor the combustor dynamic pressure.

The acoustic sensors are piezo-electric charge devices similar to the vibration accelerometers.

Each sensor has an integral lead with connector.



6. Auxiliary Equipment and Systems

Gas Turbine Pressure Taps

The following taps are provided for off-engine pressure sensing devices:

- at GT lube oil supply line
- at GT lube oil scavenge line
- at CRF for CDP (PS3), 1 at SAC, 2 at DLE
- at each fuel manifold (gas and liquid)
- at CFF for HPC inlet static pressure (PS25)
- at thrust balance manifold for LP thrust balance

