Heavy Duty GT

Maintenance

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Maintenance Considerations

- Maintenance costs and equipment's availability are two of the most important parameters for the productivity and profit of a production Plant.
- Gas turbine influence on the above parameters is very significant, and therefore it is necessary to issue a maintenance program based on the following milestones :

PRODUCTION PLANT SPECIFIC CHARACTERISTICS AND PRIORITIES AVERAGE PERSONNEL TRADE SKILL RECOMMENDATIONS FROM GAS TURBINE OEM, BASED ON THE FOLLOWING RULES:

1. - Frequency and type of scheduied inspections
2. - Spare parts planning
3. - Control of gas turbine operation and lite affecting factors

Maintenance Planning

The major scope of maintenance planning is to reduce the Plant out of production time to the minimum. To reach good results, the following factors should be taken in to consideration :

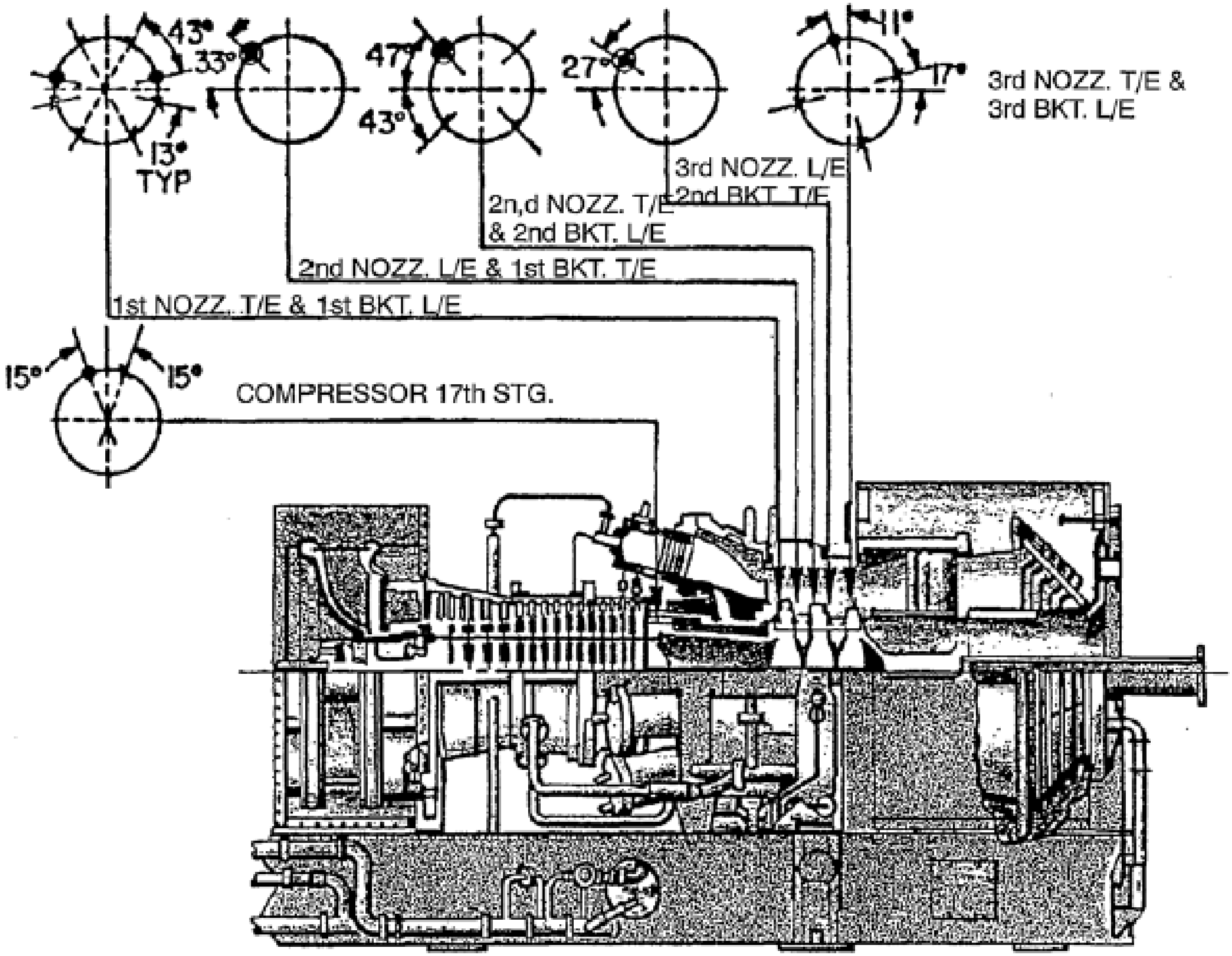
- PECULIAR CHARACTERISTICS OF THE PRODUCTION PLANT
- AMBIENT CONDITIONS
- TYPE OF SERVICE (CONTINUOUS, INTERMITTENT, PEAK LOAD, ETC.)
- TYPE OF FUEL
- LOSS OF PRODUCTION COSTS DUE TO THE TURBINE SHUT-DOWN TIME FOR INSPECTION/OVERHAULING
- MAN POWER LOCAL CAPABILITIES
- OEM MAINTENANCE RECOMMENDATIONS

Construction Features and Maintenance Flexibility

To facilitate turbine maintenance practices, the following major construction features are designed into the majority of the heavy duty gas turbine engines :

- HORIZONTALLY SPLIT CASINGS FOR EASY ACCESS TO THE INTERNAL PARTS
- STATOR BLADES CAN BE SLID ON THE CASING GROOVE WITHOUT ROTOR REMOVAL.
- ALL TURBINE ROTOR BLADES ARE NORMALLY MOMENT-WEIGHED AND DISTRIBUTED CIRCUMFERENTIALLY ON THE TURBINE WHEEL BY COMPUTER CHARTING PROGRAM, SO THAT NO SITE BALANCE IS GENERALLY REQUIRED IN CASE OF BLADE SUBSTITUTION.
- ALL BEARING HOUSING AND LINERS ARE SPLIT ON THE HORIZONTAL CENTERLINE SO THAT THEY MAY BE INSPECTED AND REPLACED, WHEN NECESSARY.
- BORESCOPE INSPECTION CAPABILITY.

Boroscope inspection ports



Boroscope inspection programming

The borescope inspection can be performed during a combustion inspection, or during a planned or unplanned shutdown.

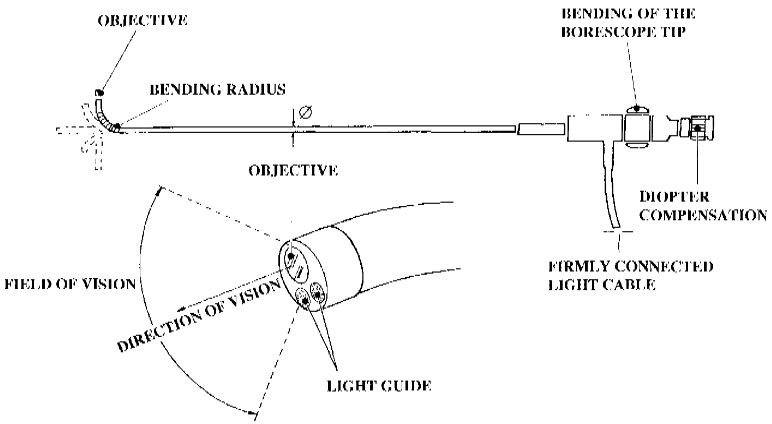
A planned borescope inspection program results in opening a turbine unit only when necessary to repair or replace parts. It should be recognized that inspection intervals are based on average unit operating modes. Adjustment of these intervals may be made based on experience and the individual unit mode of operation and the fuels used.

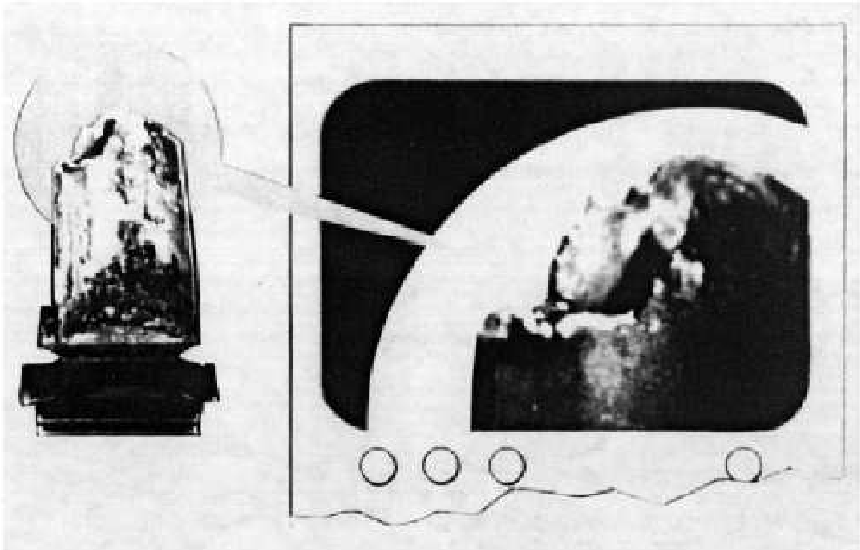
The borescope inspection program should include :

- •Baseline inspection and recording of conditions, both written and photographically, at the time of start-up.
- •Periodic inspection and recording of the results.

The application of a monitoring program, utilizing the borescope, will allow scheduling outage and pre-planning of parts requirements, resulting in lower maintenance costs, higher availability and reliability of the gas turbine.

Boroscope Typycal Equipment





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Maintenance and parts life affetting Factors

•Define a reference optimum gas turbine operating conditions, for which the life of hot gas path components is maximum.

•The following are the most common "standard" operating configuration considered and applied by the majority of them.

NATURAL GAS FUEL

CONTINUOUS OPERATION AT BASE LOAD

NO STEAM / WATER INJECTION

Under the above condition, the parts life is theoretically 100% of the design and the recommended intervals between maintenance inspection are maximum.

For different operating conditions, higher maintenance factors must be applied. Which correspond to reduced intervals between inspections and overhauling.

Standard Maintenance Schedule

Type of Inspection	Combustion System	Factored Hours / Factored Starts										
		MS3002K	MS5001PA/ MS5002C,D	MS6B	MS7E/EA	MS9E	MS6FA	MS7F/FA/FA+	MS7FA+e	MS9F/FA/FA+	MS9FA+e	MS7FB
Combustion	Non-DLN	24,000/400	12,000/800(1)(3)	12,000/1,200(2)(3)	8,000/900(3)	8,000/900(3)	–	–	–	–	–	–
	DLN	–	8,000/400	12,000/450	12,000/450	12,000/450	8,000/450	8,000/450	12,000/450	8,000/450	8,000/450	8,000/450
Hot Gas Path		24,000/1,200	Eliminated/1,200	24,000/1,200	24,000/1,200	24,000/900	24,000/900	24,000/900	24,000/900	24,000/900	24,000/900	24,000/900
Major		48,000/2,400	48,000/2,400	48,000/2,400	48,000/2,400	48,000/2,400	48,000/2,400	48,000/2,400	48,000/2,400	48,000/2,400	48,000/2,400	48,000/2,400

Factors That Can Reduce Maintenance Intervals

- Fuel
- Load Setting
- Steam/water injection
- Peak Load TF Operation
- Trips
- Start Cycle
- Hardware Design

(1) Units with Lean Head End liners have a 400 starts combustion inspection interval.
(2) Machines with 6581 and 6BeV combustion hardware have a 12,000/600 combustion inspection interval.
(3) Multiple Non-DLN configurations exist (Standard, MNQC, IGCC). The most limiting case is shown, however different quoting limits may exist on a machine and hardware basis. Contact a GE Energy representative for further information.

NOTE: Factored Hours/Starts intervals include an allowance for nominal trip maintenance factor effects. Hours/Starts intervals for Major Inspection are quoted in Actual Hours and Actual Starts.

Operating factors affecting maintenaince intervals

Causes of potential failures of gas path parts

Continuous duty	Cyclic duty
Rupture	Thermal/mechanical fatigue
Creep	LCF (Low Cycle Fatigue)
HCF (High Cycle Fatigue)	Wear
Corrosion	FOD(foreign objetcs damage)
Oxidation	
Erosion	
Wear/rubs	
FOD	

Hour's factors

- Fuel
- Steam injection
- Water injection
- Operating load

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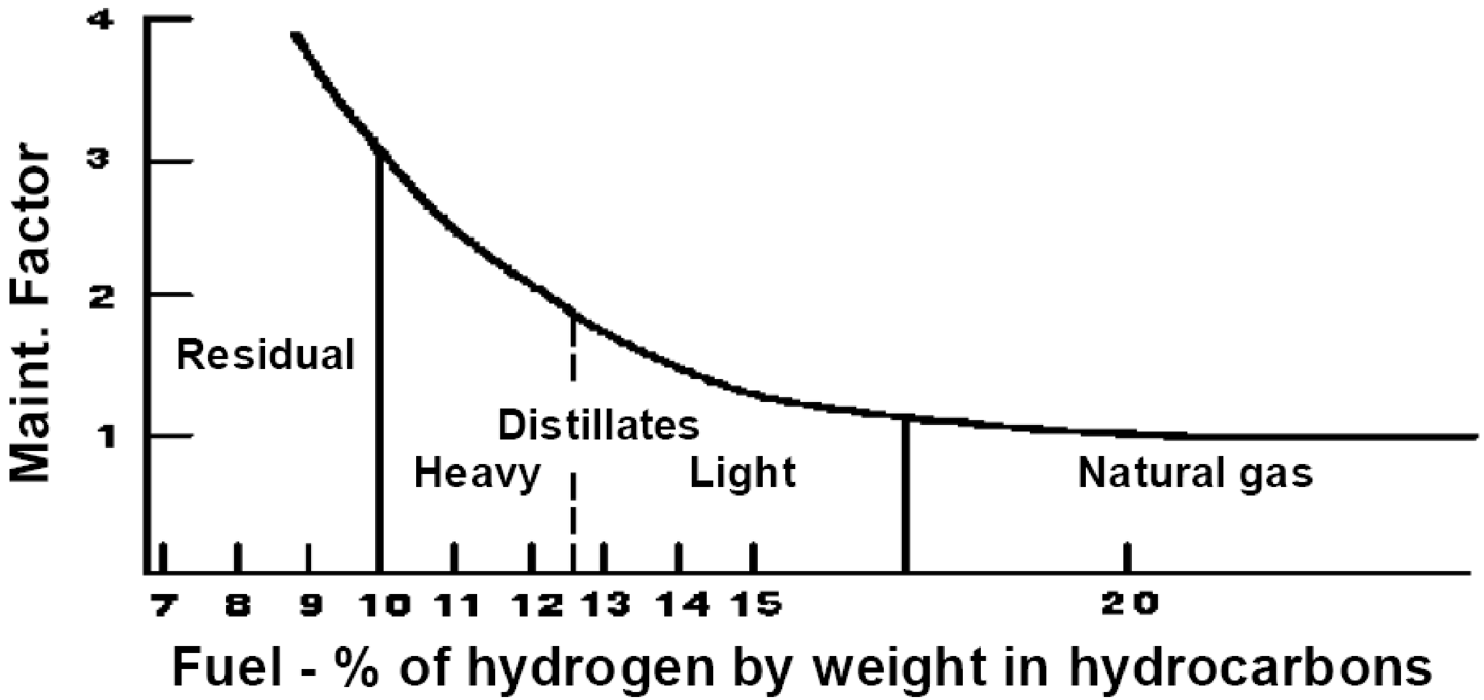
Fuel



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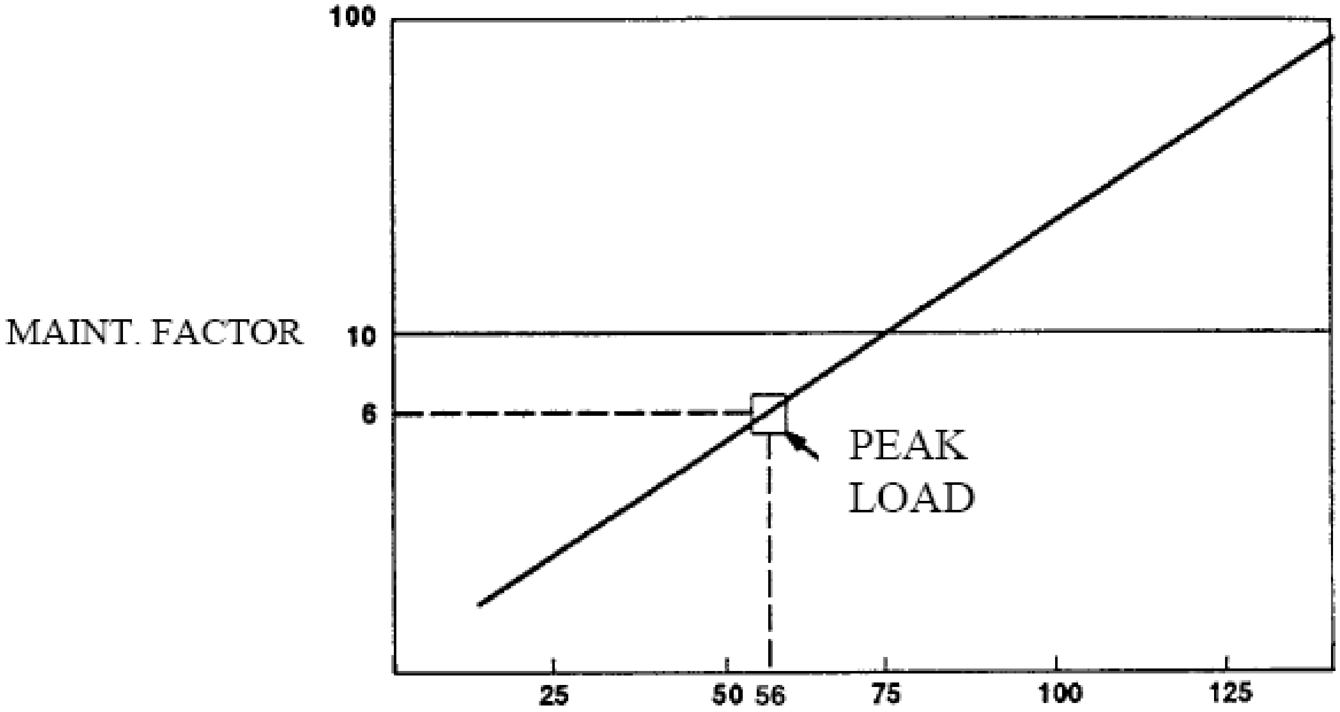
Operating load



FIRING TEMPERATURE VARIATION WITH INCREASING LOAD

Water and Steam injection

The maintenance factor may be calculated with the following procedure:

M.F. = K + M x I

Where:

I = Percent steam injection referenced to the inlet air flow

M = 0 **K** = 1 for dry control and I < 2,2%

M = 0,18 **K** = 0,6 for dry control and I > 2,2%

Start factors

- Start up with liquid fuel
- Start up sequence
- Sudden load changes
- Emergency shut downs

Liquid fuel

Start up with liquid fuel normally causes higher thermal effects if compared to natural gas fuel.

- Affected components: combustion and hot gas path parts.
- Maintenance factor for start up with No2 distillate = 1.5

Start up sequence

- Maintenance Factor for emergency start up = 20
- Maintenance Factor for fast-loading start up = 2

Where…

…emergency start-up the unit is brought from standstill to full load with a sequence faster than the standard.

…fast loading start-up where unit is brought from standstill to full speed no load with the normal sequence and then submitted to fast load.

Sudden load changes

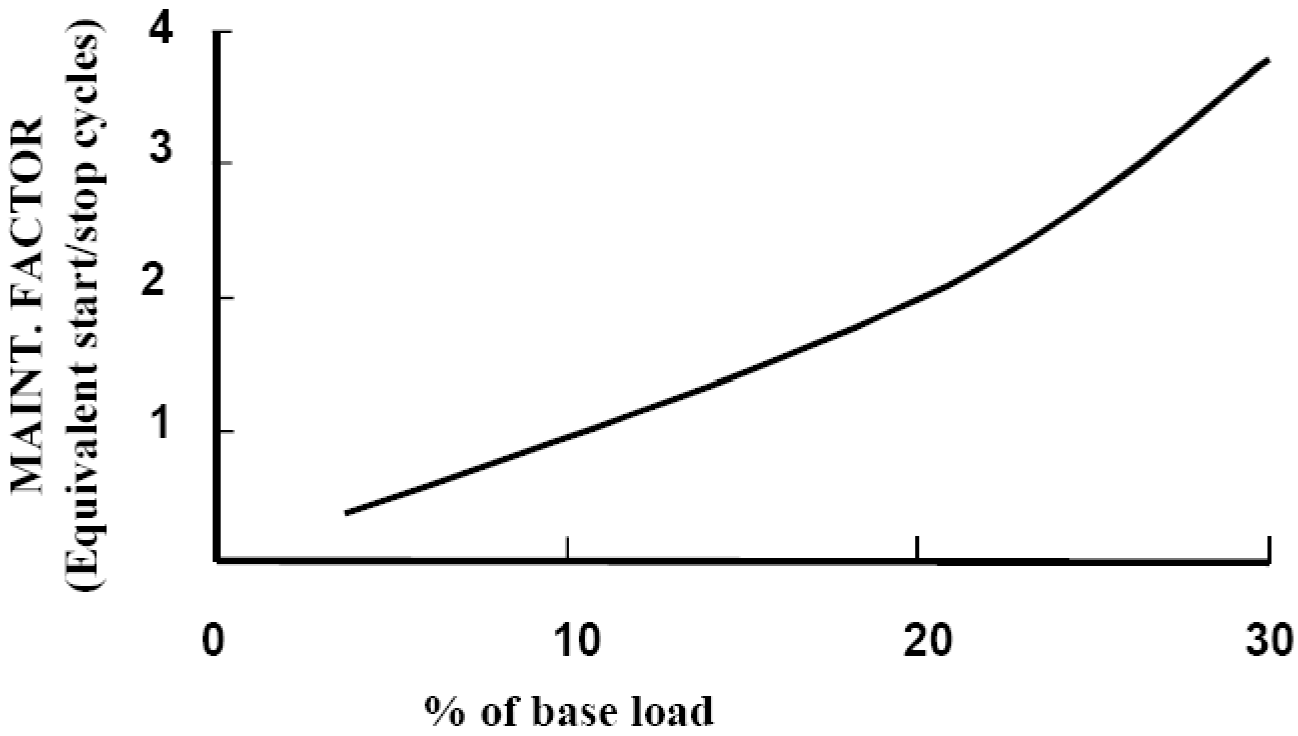


FIG. M.C.6 LOAD STEP

Sudden load changes

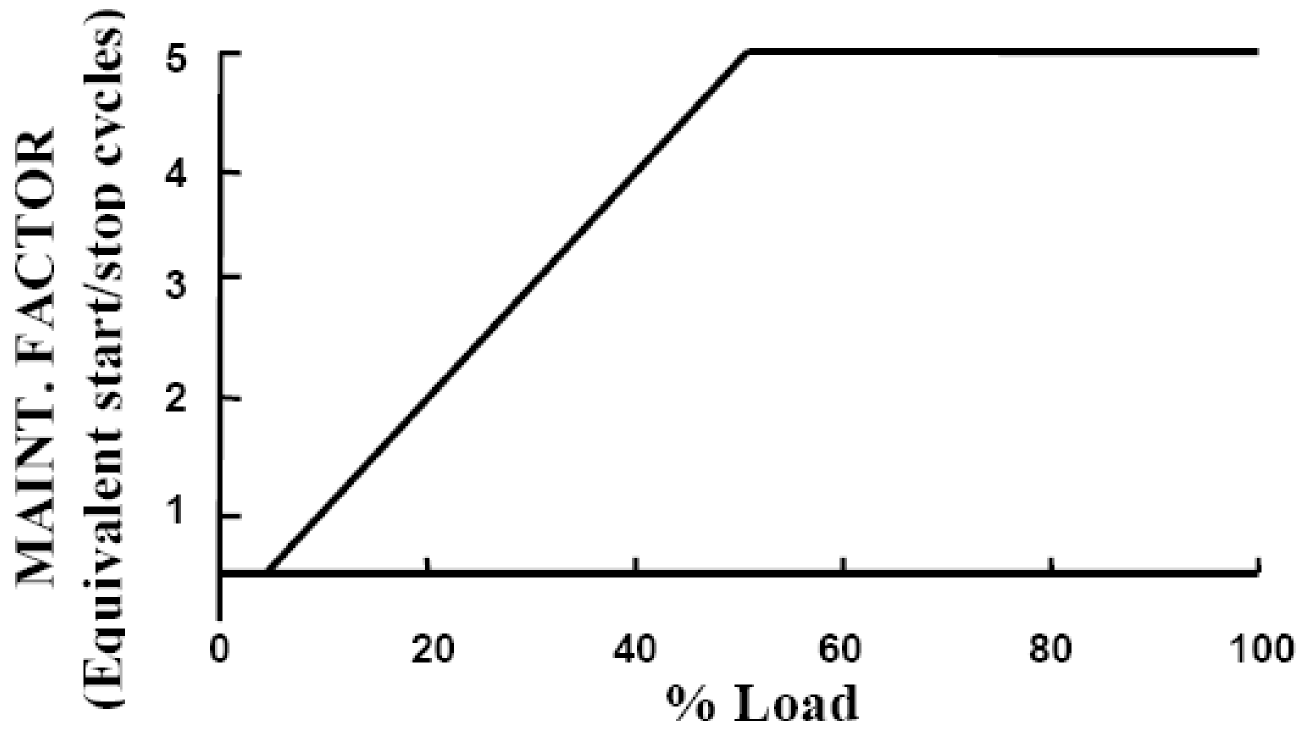


FIG. M.C.7 LOAD REJECTION

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Emergency shut downs

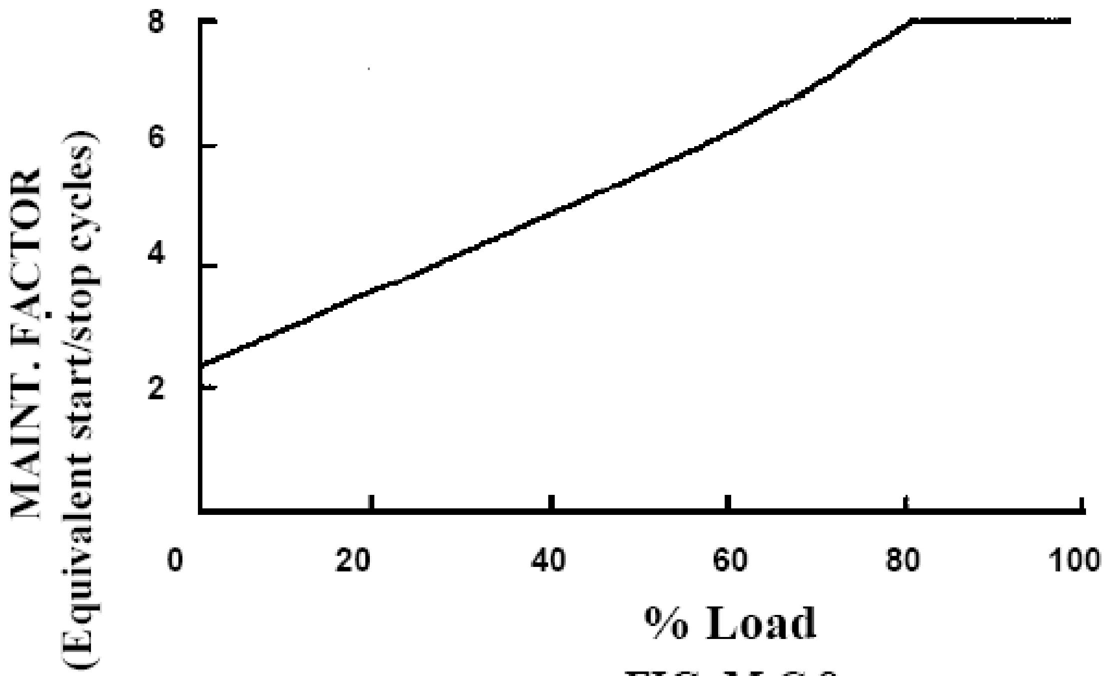

FIG. M.C.8

Note:
for trips during start- up
acceleration M.F.= 2

Maintenance Interval Equation

$$\text{Maintenance Interval (Hours)} = \frac{24000}{\text{Maintenance Factor}}$$

Where:

$$\text{Maintenance Factor} = \frac{\text{Factored Hours}}{\text{Actual Hours}}$$

Factored Hours = $(K + M \times I) \times (G + 1.5D + A_f H + 6P)$

Actual Hours = $(G + D + H + P)$

G = Annual Base Load Operating hours on Gas Fuel

D = Annual Base Load Operating hours on Distillate Fuel

H = Annual Operating Hours on Heavy Fuel

A_f = Heavy Fuel Severity Factor (Residual A_f = 3 to 4, Crude A_f = 2 to 3)

P = Annual Peak Load Operating Hours

I = Percent Water/Steam Injection Referenced to Inlet Air Flow

M&K = Water/Steam Injection Constants

M	K	Control	Steam Injection	N2/N3 Material
0	1	Dry	<2.2%	GTD-222/FSX-414
0	1	Dry	>2.2%	GTD-222
.18	.6	Dry	>2.2%	FSX-414
.18	1	Wet	>0%	GTD-222
.55	1	Wet	>0%	FSX-414

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Maintenance Interval Equation

$$\text{Maintenance Interval (Starts)} = \frac{S}{\text{Maintenance Factor}}$$

Where:

$$\text{Maintenance Factor} = \frac{\text{Factored Starts}}{\text{Actual Starts}}$$

$$\text{Factored Starts} = (0.5\ NA + NB + 1.3NP + 20E + 2F + \sum_{i-1}^{\eta} a_{Ti}\ T_i)$$

$$\text{Actual Starts} = (NA + NB + NP + E + F + T)$$

Actual Starts = (NA + NB + NP + E + F + T)

S	=	Maximum Starts-Based Maintenance Interval (Model Size Dependent)
NA	=	Annual Number of Part Load Start/Stop Cycles (<60% Load)
NB	=	Annual Number of Normal Base Load Start/Stop Cycles
NP	=	Annual Number of Peak Load Start/Stop Cycles
E	=	Annual Number of Emergency Starts
F	=	Annual Number of Fast Load Starts
T	=	Annual Number of Trips
a_T	=	Trip Severity Factor = f (Load) (See Figure 21)
η	=	Number of Trip Categories (i.e., Full Load, Part Load, etc.)

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Example – HGP Maintenance Interval Calculation

An MS7001 user has accumulated operating data since the last hot gas path inspection and would like to estimate when the next one should be scheduled. The user is aware from GE publications that the normal HGP interval is **24,000** hours if operating on natural gas, with no water or steam injection, and at base load.

It is also understood that the nominal starts interval is **1200**, based on normal startups, no trips, no emergency starts. The actual operation of the unit since the last hot gas path inspection is much different from the GE “baseline case.”

Annual hours on natural gas, base load

G = 3200 hr/yr

Annual hours on light distillate

D = 350 hr/yr

Annual hours on peak load

P = 120 hr/yr

Steam injection rate

I = 2.4%

Also, since the last hot gas path inspection,

140 Normal start-stop cycles:

40 Part load

100 Base load

0 Peak load

In addition,

E = 2 Emergency Starts with ramp to base load

F = 5 Fast loads ending in a normal shut down from base load

T = 20 Starts with trips from base load

Example – HGP Maintenance Interval Calculation

For this particular unit, the second and third-stage nozzles are FSX-414 material. The unit operates on "dry control curve."

At a steam injection rate of 2.4%, the value of "M" is 0.18, and "K" is 0.6.

From the hours-based criteria, the maintenance factor is determined from Figure 43.

$$MF = \frac{[K + M(I)] \times [G + 1.5(D) + Af(H) + 6(P)]}{(G + D + H + P)}$$

$$MF = \frac{[0.6 + 0.18(2.4)] \times [3200 + 1.5(350) + 0 + 6(120)]}{(3200 + 350 + 0 + 120)} = 1.25$$

The hours-based adjusted inspection interval is therefore,

H = 24,000/1.25

H = 19,200 hours

[Note, since total annual operating hours is 3670, the estimated time to reach 19,200 hours is 5.24 years (19,200/3670).]

Example – HGP Maintenance Interval Calculation

From the starts-based criteria, the maintenance factor is determined as:

The total number of part load starts/stop is NA = 40/yr

The total number of base load starts/stop is NB = 100 + 2 + 5 + 20 = 127/yr

The total number of peak load starts/stop is NP = 0/yr

$$MF = \frac{0.5\ (NA)+(NB)+1.3(NP)+20(E)+2(F) + \sum (a_n-1)T}{NA + NB + NP}$$

$$MF = \frac{0.5(40)+(127)+1.3(0)+20(2)+2(5)+(8-1)20}{40+127+0} = 2$$

The adjusted inspection interval based on starts is

S = 1200/2.0

S = 600 starts

[Note, since the total annual number of starts is 167, the estimated time to reach 600 starts is 600/167 = 3.6 years.]

In this case, the starts-based maintenance factor is greater than the hours maintenance factor and therefore the inspection interval is set by starts. The hot gas path inspection interval is 600 starts (or 3.6 years).

Maintenance Inspections

STAND-BY INSPECTIONS

RUNNING INSPECTIONS

DISMANTLING INSPECTIONS

STAND-BY INSPECTIONS

They are required when the engine is not in operation. During this period of time, the following items should be checked :

- LUBE OIL SYSTEM COMPONENTS
- FUEL SYSTEM COMPONENTS
- INTAKE SYSTEM AND FILTERS
- INSTRUMENTATION SETTINGS AND REPAIRS/SUBSTITUTIONS
- EMERGENCY BATTERIES STATUS
- FLUIDS LEVELS (OILS, WATER, ETC.)
- OTHER AUXILIARIES IN GENERAL
- BORESCOPE INSPECTION FOR ALL THE INTERNAL PARTS

RUNNING INSPECTIONS

They are required when the engine is in operation.

During this period of time, the records of the most important functional parameters must be done by the operation personnel, every one or two hours, in order to have a good operation trend of the system.

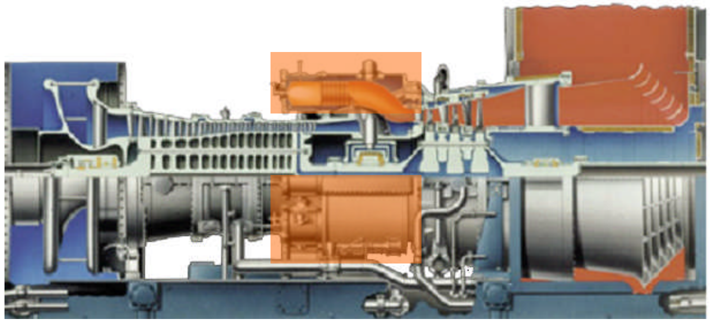
This will help find the root causes of gas turbine troubles.

TYPICAL PARAMETERS

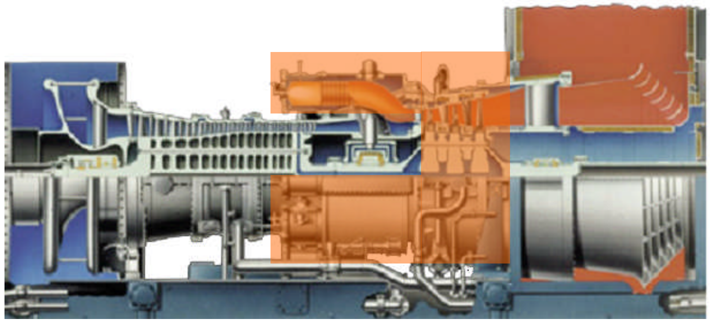
Parameter	Unit
Speed	RPM
Load	KW
N° of start-up	
N° of operating hours	
Ambient pressure	mbar
Temperatures	°C
Ambient	°C
Axial compressor discharge	°C
Turbine exhaust (average)	°C
Turbine exhaust (each thermocouple)	°C
Lube oil header	°C
Lube oil tank	°C
Lube oil discharge from bearings	°C
Bearings metal temperature	°C
Pressures	bar(g)
Axial compressor discharge	bar(g)
Lube oil pumps delivery	bar(g)
Control oil pumps delivery	bar(g)
Lube oil header	bar(g)
Cooling water	bar(g)
Fuel	bar(g)
Filters media	Δp (bar(g))
Vibrations	mm/sec. - µm.
Start-up time	Minutes
Coast down time	Minutes

DISMANTLING INSPECTIONS

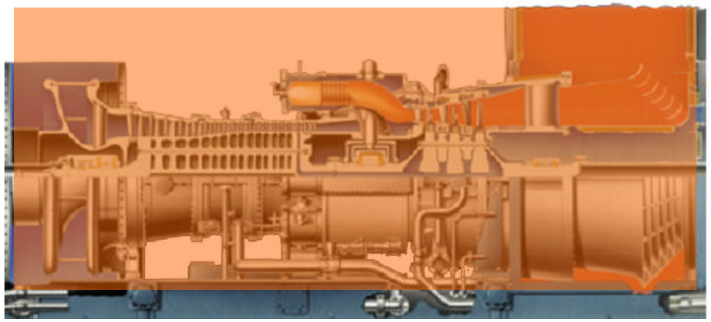
- **Combustion System inspection**



- **Hot Gas Path inspection**

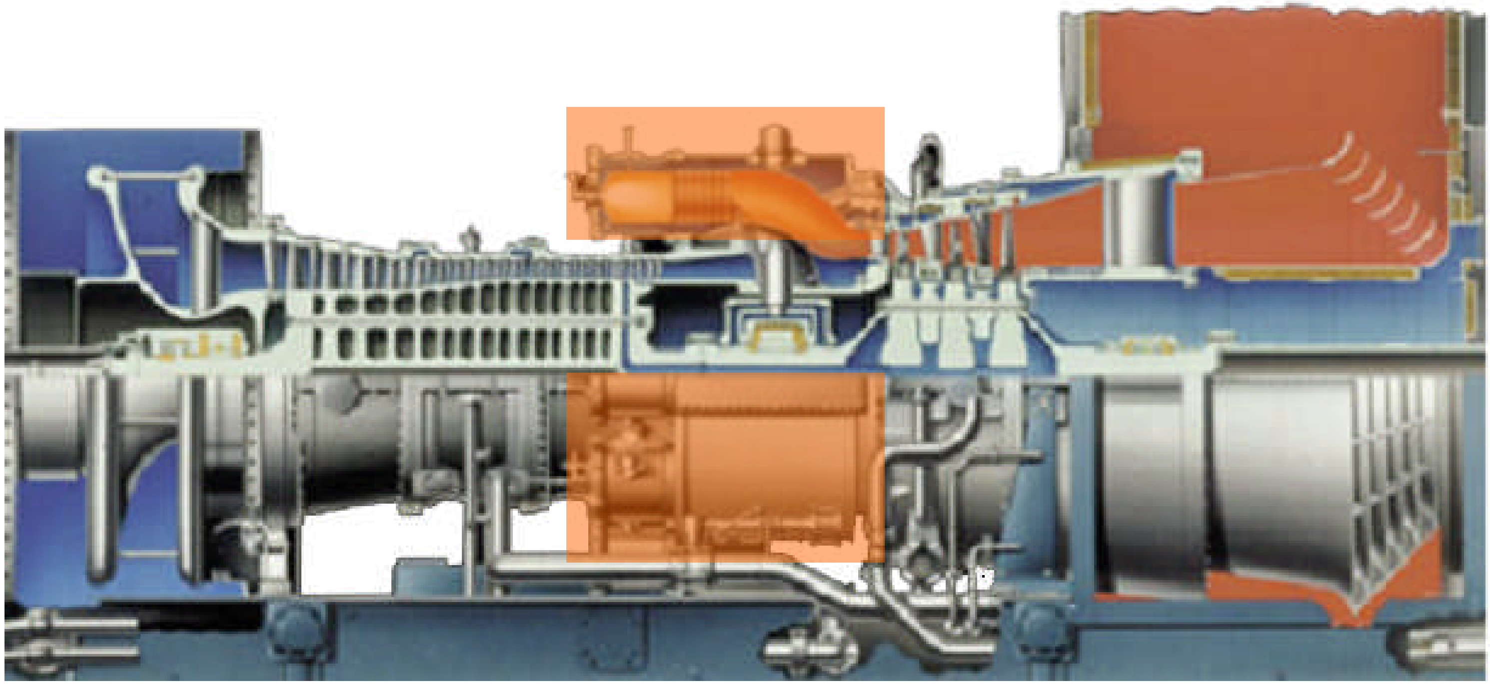


- **Major inspection**



Gas Turbine Maintenance

Combustion system inspections



Combustion inspection – Key elements

Combustion Inspection

Key Hardware:

- Combustion Liners
- Combustion End Covers
- Fuel Nozzles
- End Caps
- Transition Pieces
- Cross Fire Tubes
- Flow Sleeves
- Purge Valves
- Check Valves
- Spark Plugs
- Flame Detectors
- Flex Hoses

Inspect for:

- Foreign Objects
- Abnormal Wear
- Cracking
- Liner Cooling Hole Plugging
- TBC Coating Condition
- Oxidation/Corrosion/Erosion
- Hot Spots/Burning
- Missing Hardware
- Clearance Limits
- Borescope Compressor and Turbine

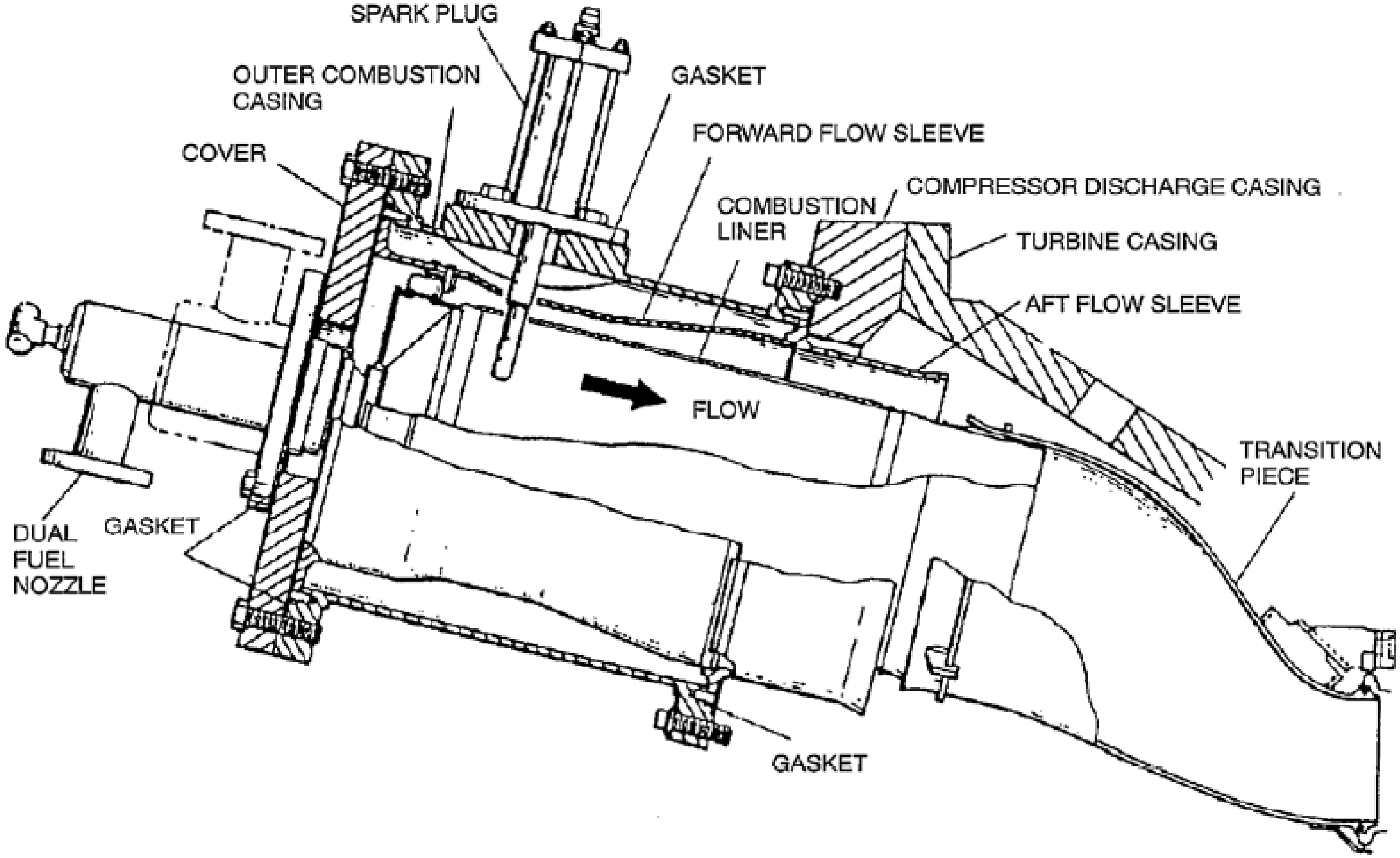
Potential Actions:

Criteria
- Op. & Instr. Manual
- TIL's
- GE Field Engineer

Inspection Methods
- Visual
- LP
- Borescope

Availability of On-Site Spares Is Key to Minimizing downtime

Combustion inspection



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Combustion inspection precedure

1. Prepare turbine compartment roof for removal
2. Remove turbine compartment roof and side panels.
3. Remove liquid fuel lines (if applicable).
4. Remove atomizing air lines (if applicable).
5. Remove gas fuel lines (if applicable).
6. Remove steam injection lines (if applicable).
7. Remove water injection lines (if applicable).
8. Remove liquid fuel check valves.
9. Remove false start drain tubing.
10. Remove fuel nozzles.

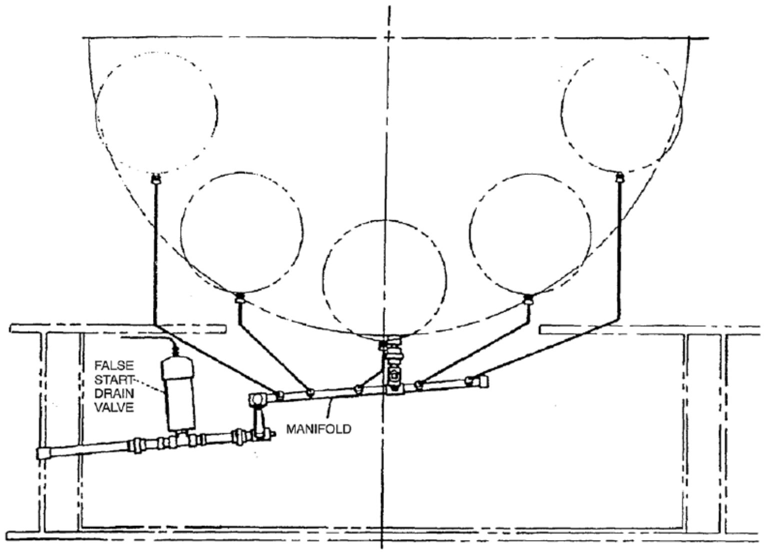
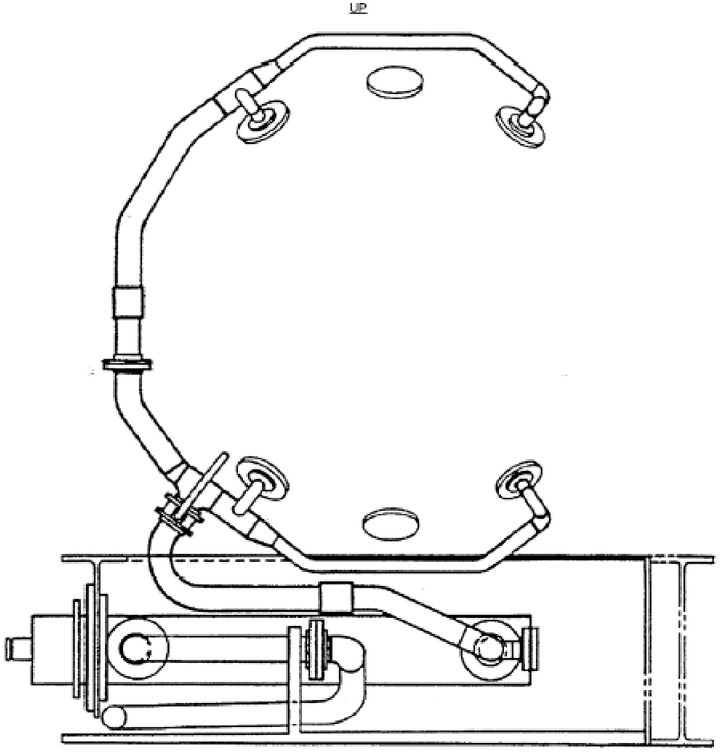


FIGURE CI-D9 : FALSE START DRAIN PIPING

Combustion inspection precedure



11 Remove flame detectors and spark plugs.

12 Remove 11th stage cooling and sealing air lines.

13 Unbolt and open up combustion outer casing covers.

14 Remove crossfire tube retainers, combustion liners, crossfire tubes and forward flow sleeves.

15 Remove access port blank flange from upper half turbine casing or the upper section of the atomizing air extraction manifold.

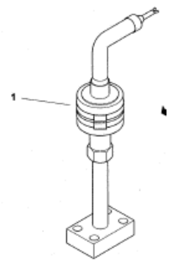
16 Remove outer combustion casings and aft flow sleeves.

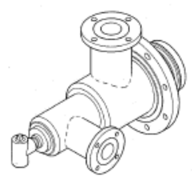
17 Remove transition pieces.

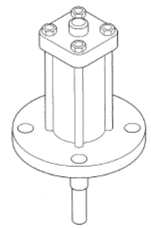
GT Combustion inspection

During this inspection the status of following components should be verified and all necessary repair/substitution is carried out:

- **Fuel nozzle (o burners)**
- **Combustion chamber components (liner, cap, flow sleeve)**
- **Transition piece**
- **Cross-fire tubes**
- **Spark plug**
- **Flame detectors**







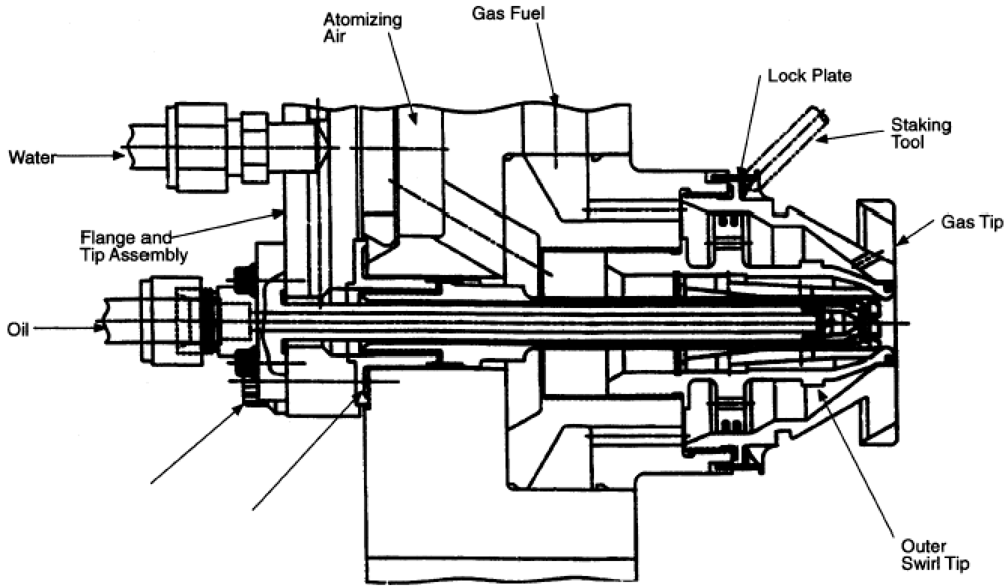
Note:

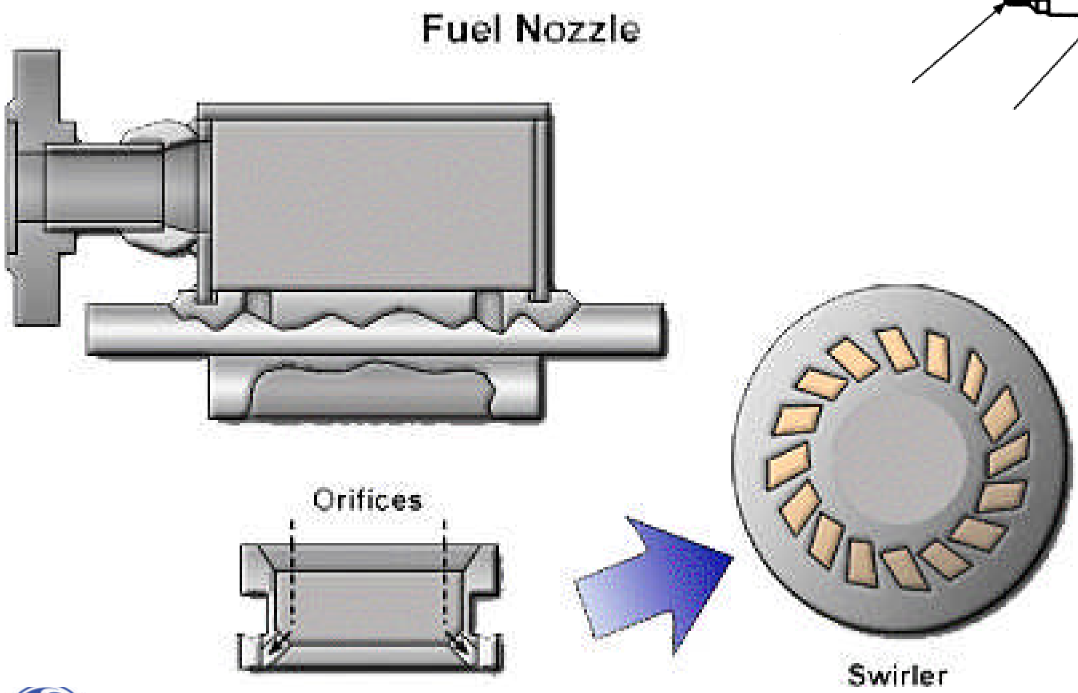
For the lifting of main components see drawing

“ Gravity centres and weights”

Fuel nozzle (o burners)

The inspection of fuel nozzle is necessary to clean up them from internal combustion residual carbon deposits and repair cracks, as well as for the combustion chamber.

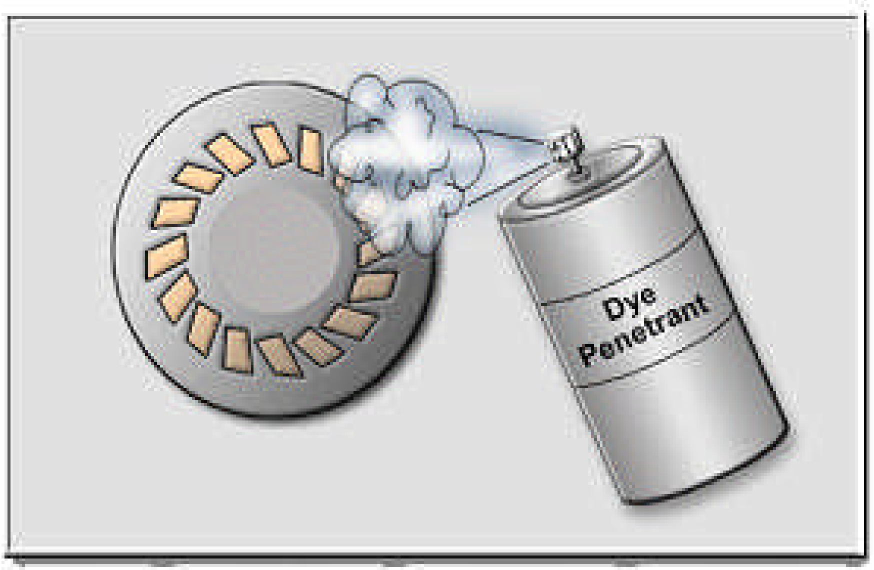




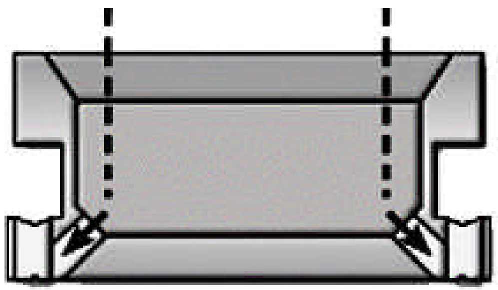
Fuel nozzle (o burners)

Normally, cracks inspections carried out using dye penetrating fluids sprayed on the components surface.

Dye Penetrant Check

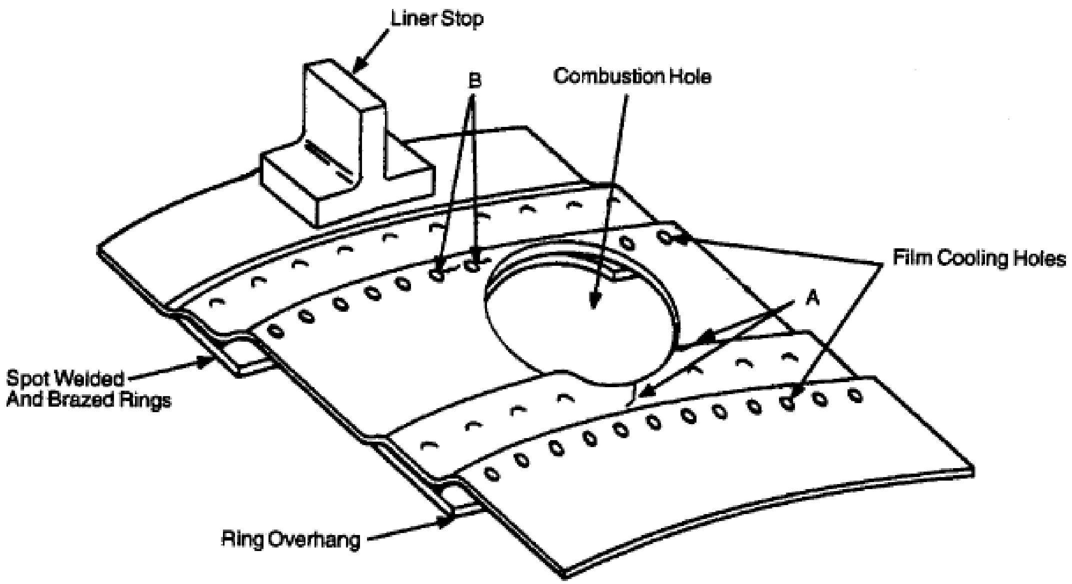


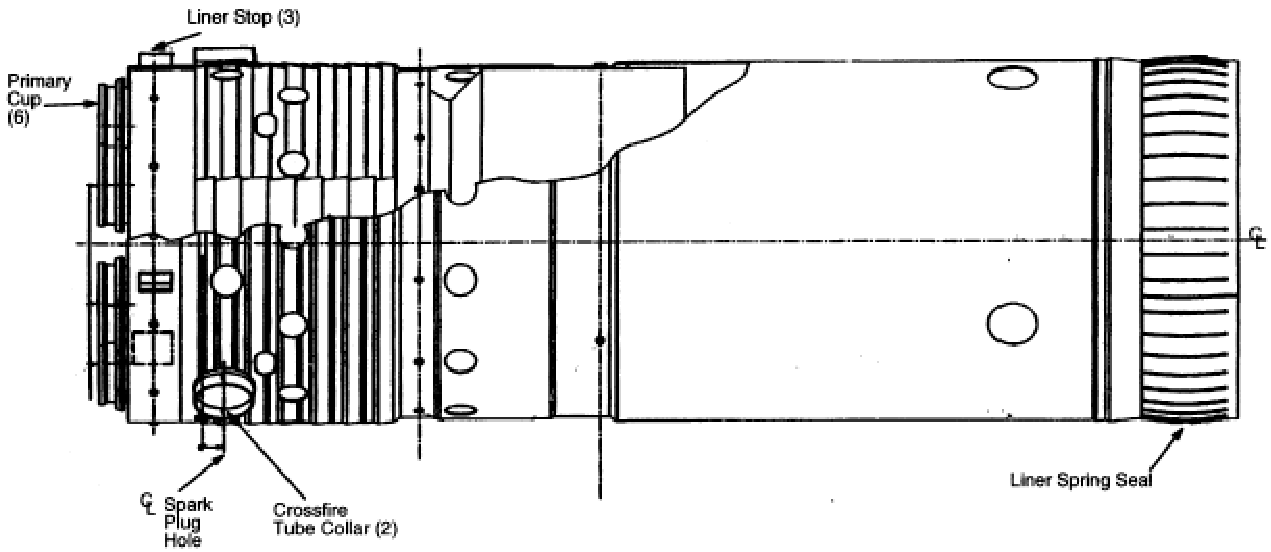
Check Orifices for:



- Proper size
- Wear
- Cracks

C. C. components (liner, cap, flow sleeve)





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C. C. components (liner, cap, flow sleeve)

INSPECTION CRITERIA

Table CI-2

Inspection Limits, MS-7000 DLN-1 Liners

CAUTION

The inspection criteria in this Table CI-2 applies to General Electric Company supplied combustion liners only.

Inspect	Maximum Acceptable Limits	Disposition (for Parts Beyond Max. Limits)
1. Liner Sleeve (Outer Shell)		
a. Cracks	None	Replace*
b. Burn through missing metal	None	Replace*
c. Out-of-roundness	1/4" (0.635 cm) from original contour	Replace*
d. Local distortion	1/8" (0.317 cm) from original contour with no cracks	Replace*
e. Liner wear beneath spring seals	40% material thickness beneath seal	Replace*
2. Liner Cooling Rings		
a. Ring slot height	0.065" (0.165 cm) min. gap	Replace*
b. Axial cracks	None	Replace*
c. Circular cracks	None	Replace*
d. Burn through (missing metal)	None	Replace*
e. Visual braze flow (overtemperature)	None	Replace*
f. Thermal barrier coating	Isolated Patches 1/2" x 1/2" (1.27 x 1.27 cm)	Reuse
	Larger than 1/2" x 1/2" (1.27 x 1.27 cm)	Replace*
3. Liner Venturi		
a. Cracks	None	Replace*
b. Burn through missing metal	None	Replace*
c. Out-of-roundness	1/4" (0.635 cm) from original contour	Replace*
d. Local distortion	1/8" (0.317 cm) from original contour with no cracks	Replace*
e. Thermal barrier coating	1/4" x 1/4" (0.635 x 0.635 cm)	Reuse
	Larger then 1/4" x 1/4" (0.635 x 0.635 cm)	Replace*

*"Replace" does not mean liner must be scrapped — this part can be repaired by qualified General Electric Company personnel.

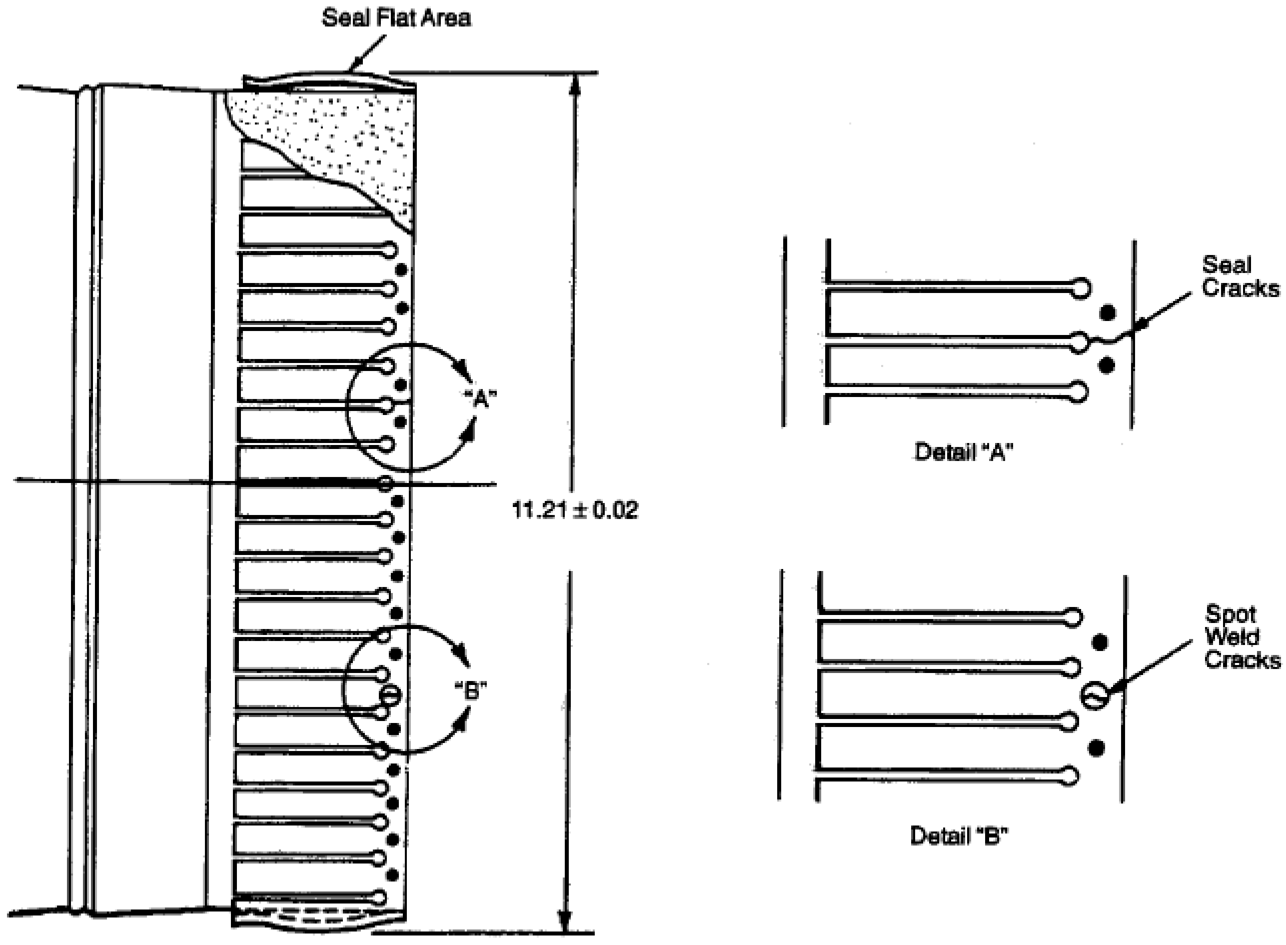
Table CI-2

Inspection Limits, MS-7000 DLN-1 Liners (Cont'd)

Inspect	Maximum Acceptable Limits	Disposition (for Parts Beyond Max. Limits)
4. Multi-Nozzle Cap		
a. Fuel nozzle collar wear	0.030 wear or less	Reuse
	0.030 wear or more	Replace
b. Fuel nozzle collars free to slide	Movable with light tapping	Reuse
	Not movable	Replace
c. Support frame weld cracks	None allowed	Replace
d. Impingement cooling plate cracks	None allowed	Replace
e. Loss of thermal barrier coating	Isolated Patches 1/4" x 1/4" (0.635 x 0.635 cm)	Reuse
	Larger then 1/4" x 1/4" (0.635 x 0.635 cm)	Replace
f. Warpage of plates around cups	Up to 0.06	Reuse
	More than 0.06	Replace
g. Burning or loss of material	None allowed	Replace
h. Cap-to-liner looseness	None allowed	Replace*
5. Liner Centerbody (Part of Cap Assembly)		
a. Ring slot height	0.065" (0.165 cm) min. gap	Replace*
b. Axial cracks	None	Replace*
c. Circular cracks	None	Replace*
d. Burn through (missing metal)	None	Replace*
e. Visual braze flow (overtemperature)	None	Replace*
f. Thermal barrier coating	Isolated Patches 1/2" x 1/2" (1.27 x 1.27 cm)	Reuse
	Larger than 1/2" x 1/2" (1.27 x 1.27 cm)	Replace*

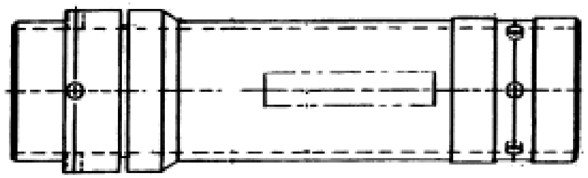
*"Replace" does not mean liner must be scrapped — this part can be repaired by qualified General Electric Company personnel.

C. C. components (liner, cap, flow sleeve)

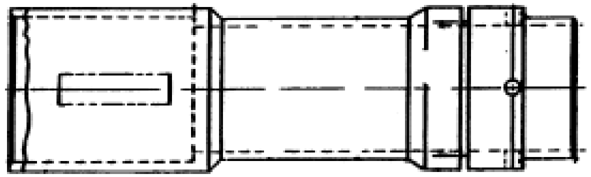


Liner Seal Inspection

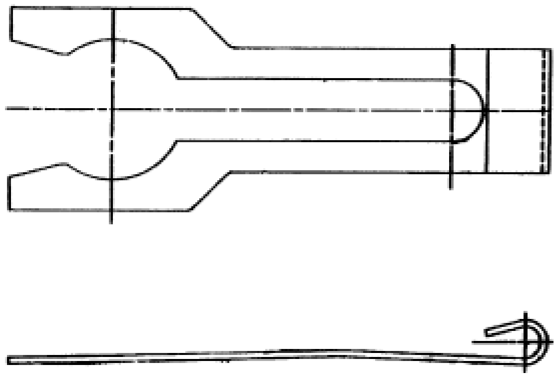
Crossfire Tube



Male Half Tube
169D3441



Female Half Tube
169D3442



Crossfire Tube Retainer
207C3558

Table CI-3
Inspection Limits, Crossfire Tubes and Retainers

CAUTION

The inspection criteria in this Table CI-3 applies to General Electric Company supplied crossfire tubes and retainers.

Inspect	Maximum Acceptable Limits	Disposition (For Parts Beyond Max. Limits)
1. Crossfire Tubes		
a. Burn through; missing metal	None	Replace
b. Distortion	None	Replace
c. Wear	50% of original material	Repair
2. Crossfire Tube Spring Retainers		
a. Wear	0.030" (0.076 cm) material	Replace
b. Evidence of distortion	None	Straighten*

*NOTE: Retainers are bowed 0.23" for spring locking tubes 5.25" from open end. *DO NOT* straighten this bend.

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Transition piece

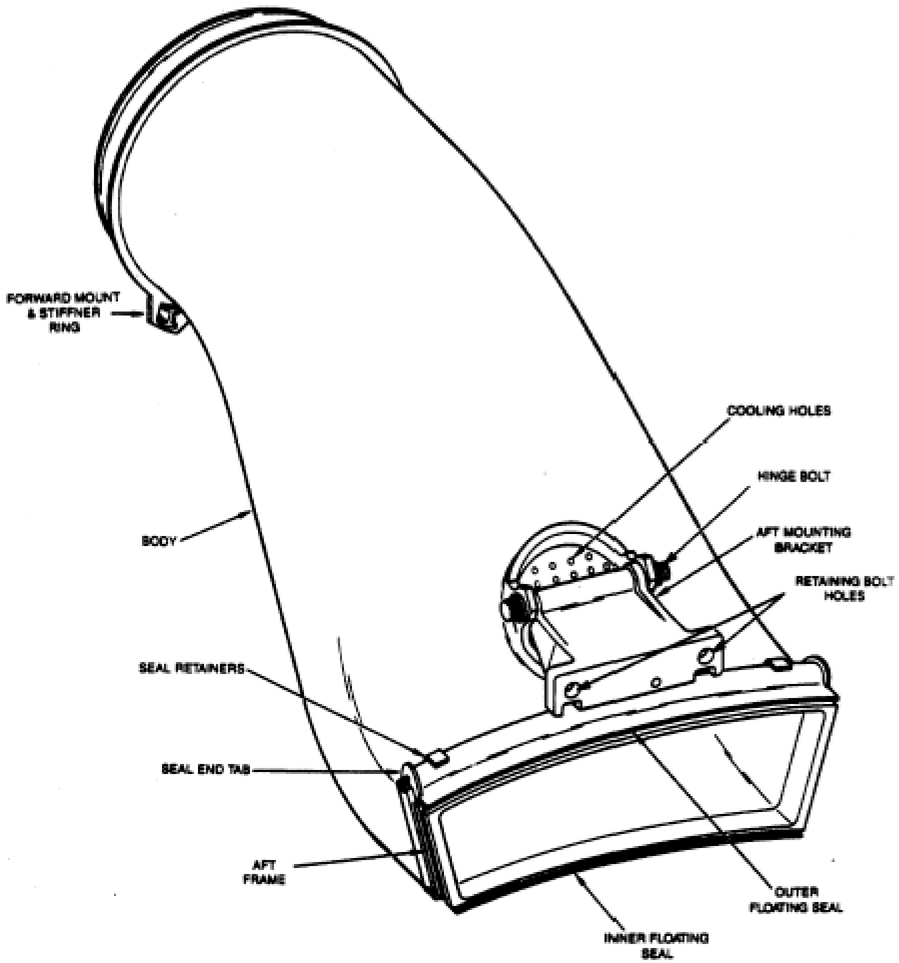


Table CI-5
MS-7001EA Transition Piece Inspection Limits

CAUTION

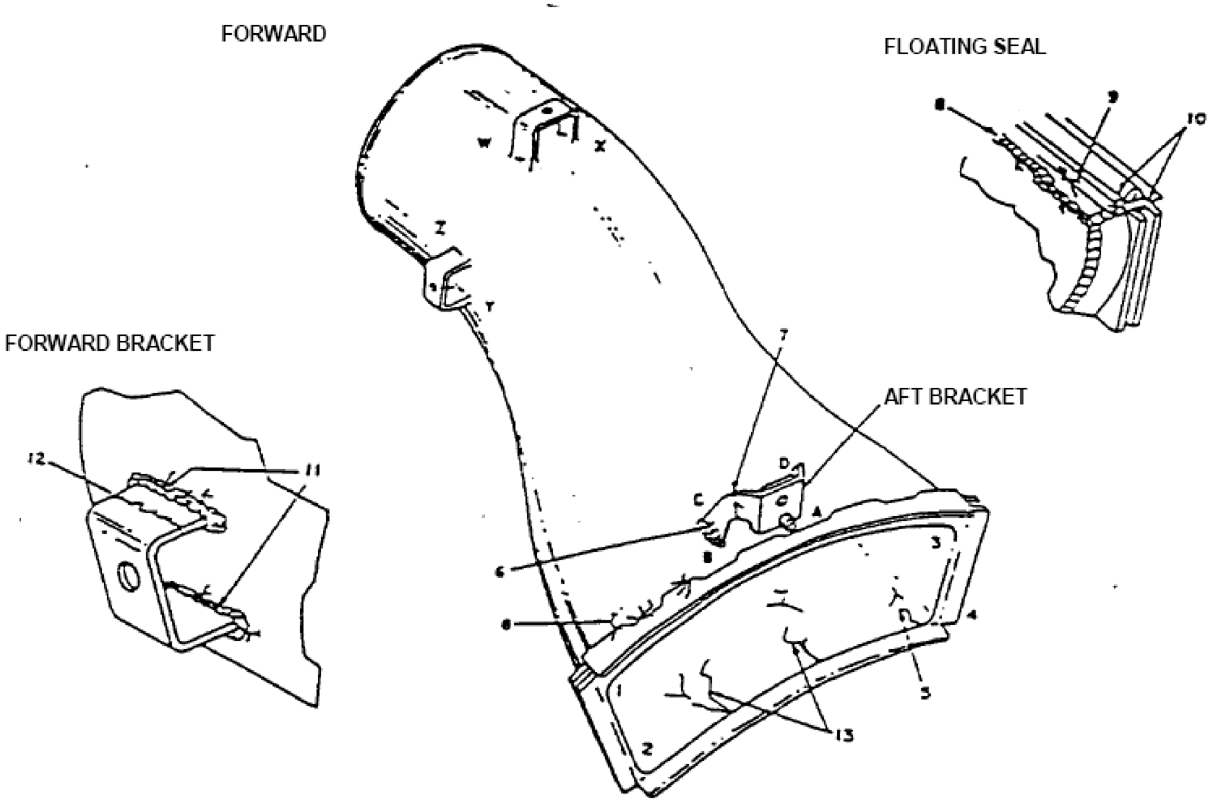
The inspection criteria in this Table CI-5 applies to General Electric Company supplied transition pieces.

Inspect	Maximum Acceptable Limits	Disposition (For Parts Beyond Max. Limits)
1. Aft Side Seal Slot Surface		
a. Wear	0.030″ (0.076 cm) deep	Replace*
b. Cracks	None	Replace*
2. Body		
a. Body or weld cracks	0.250″ (0.635 cm) long	Replace*
b. Out-of-roundness	0.080″ (0.020 cm) from original contour	Replace*
c. Corrosion	0.030″ (0.076 cm) reduction of original material thickness	Replace*
d. Deposits	0.030″ (0.076 cm) thick	Remove*
e. Loss of thermal barrier coating	0.5 × 0.5 in. (1.27 × 1.27 cm) isolated patches	Replace*
3. Forward Support (Bullhorn)		
a. Cracks	None	Replace*
b. Slot wear	0.060″ (0.152 cm) from original mat'l	Weld buildup*
4. Aft Bracket		
a. Weld or body cracks	0.250″ (0.64 cm) long on inside surface	Replace*
5. Aft Frame/Body Corners		
a. Weld or body cracks	None	Replace*
6. Forward Mount and Stiffener Ring		
a. Weld or body cracks	0.250″ (0.64 cm) long inside and outside surface	Replace*
b. Forward support engagement surface	0.060″ (0.152 cm) from original thickness	Replace*

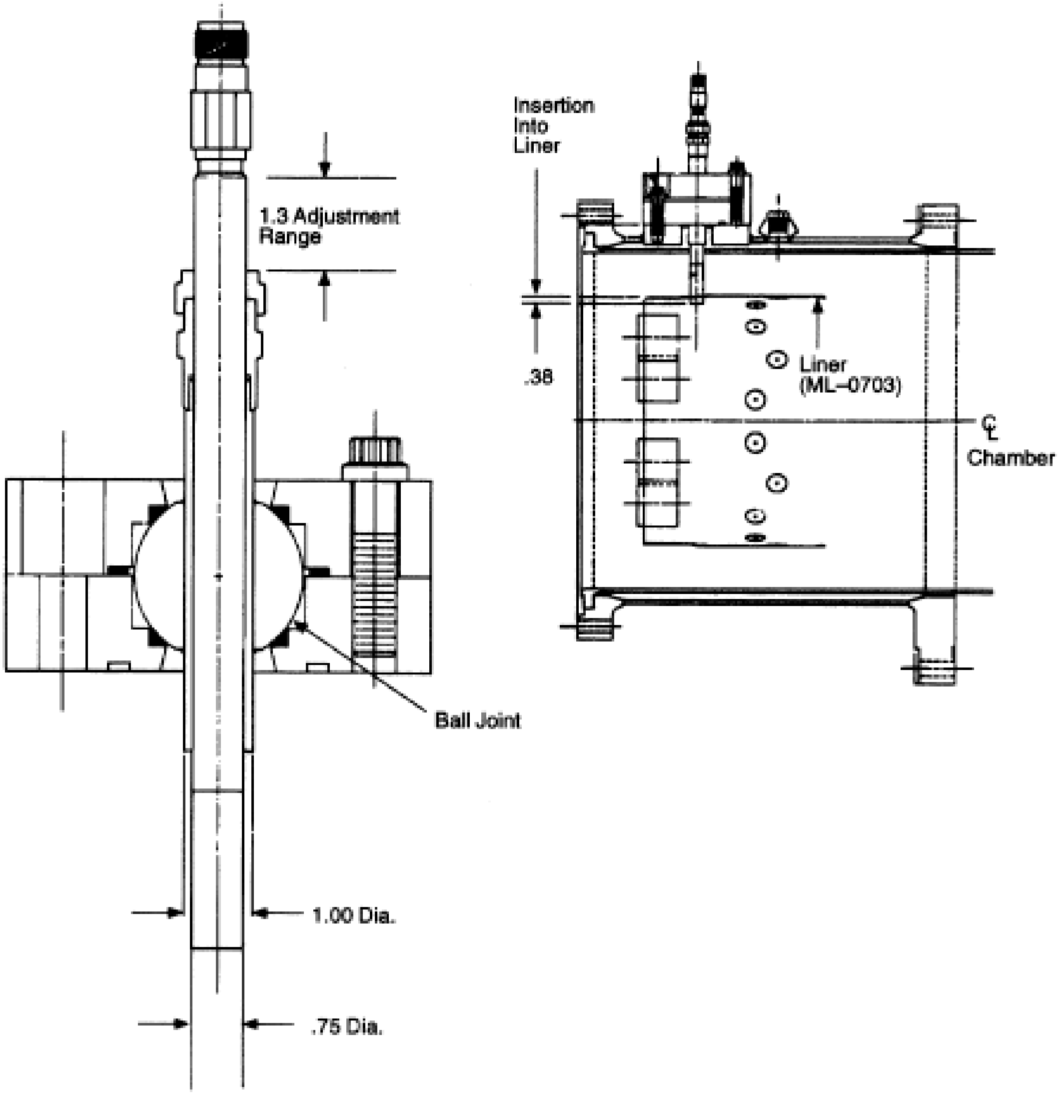
*"Replace" does not mean transition piece must be scrapped — this part can be repaired by qualified General Electric Company personnel.

imagination at work

Transition piece



Spark plug

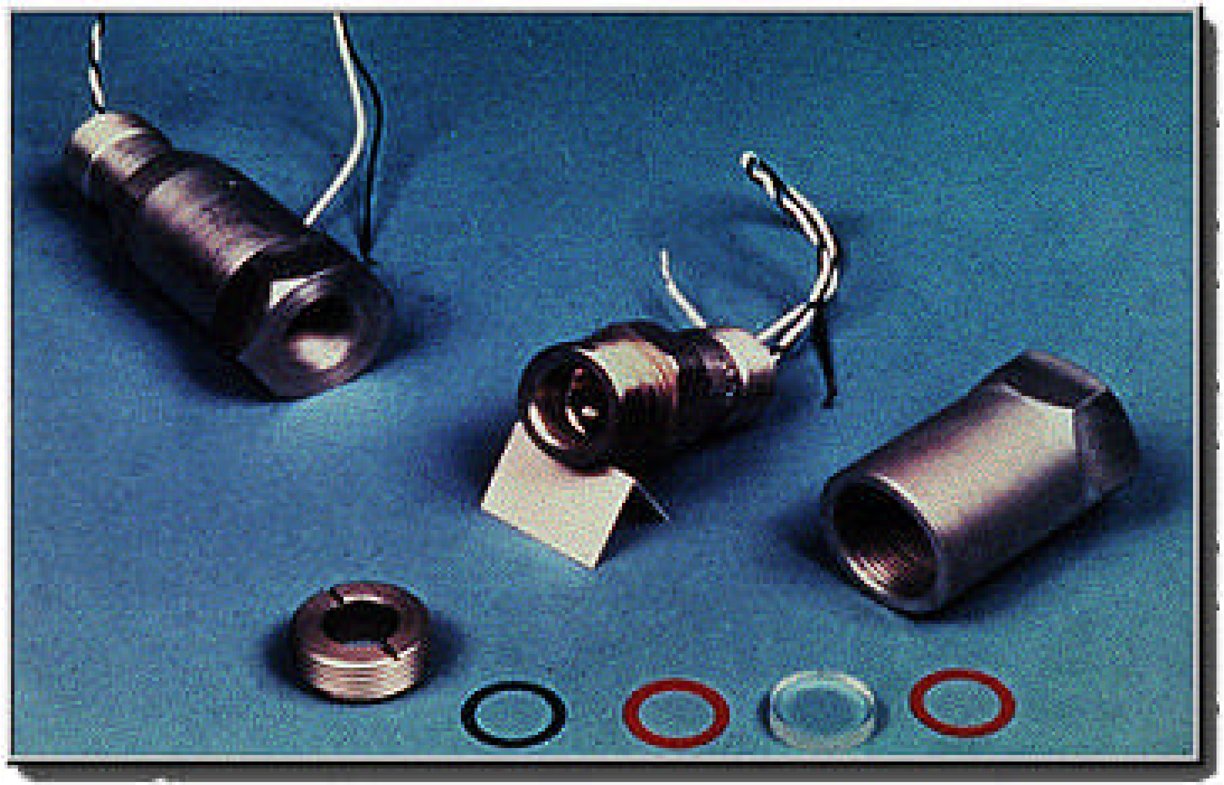


SPARK PLUG ASSEMBLY

Flame Detector

Flame detector are checked for eventual electrical damage and carbon deposits on the optical surface.

Flame Detector Sensor



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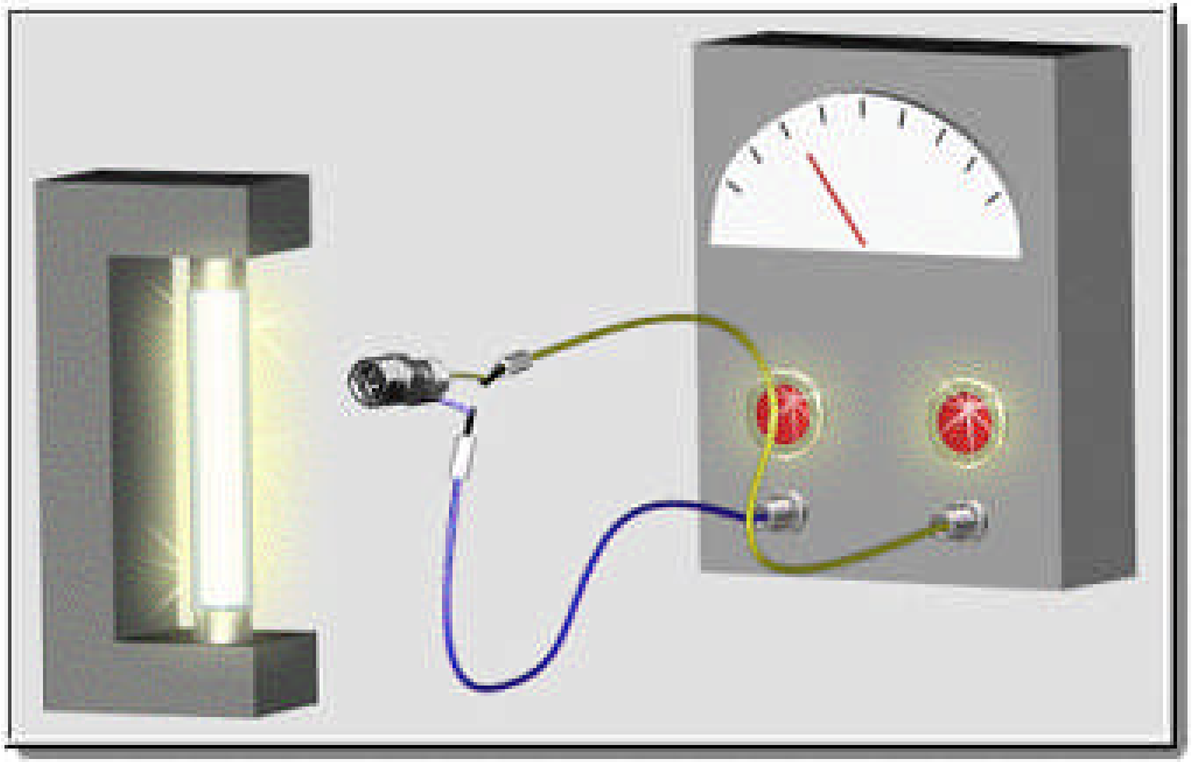
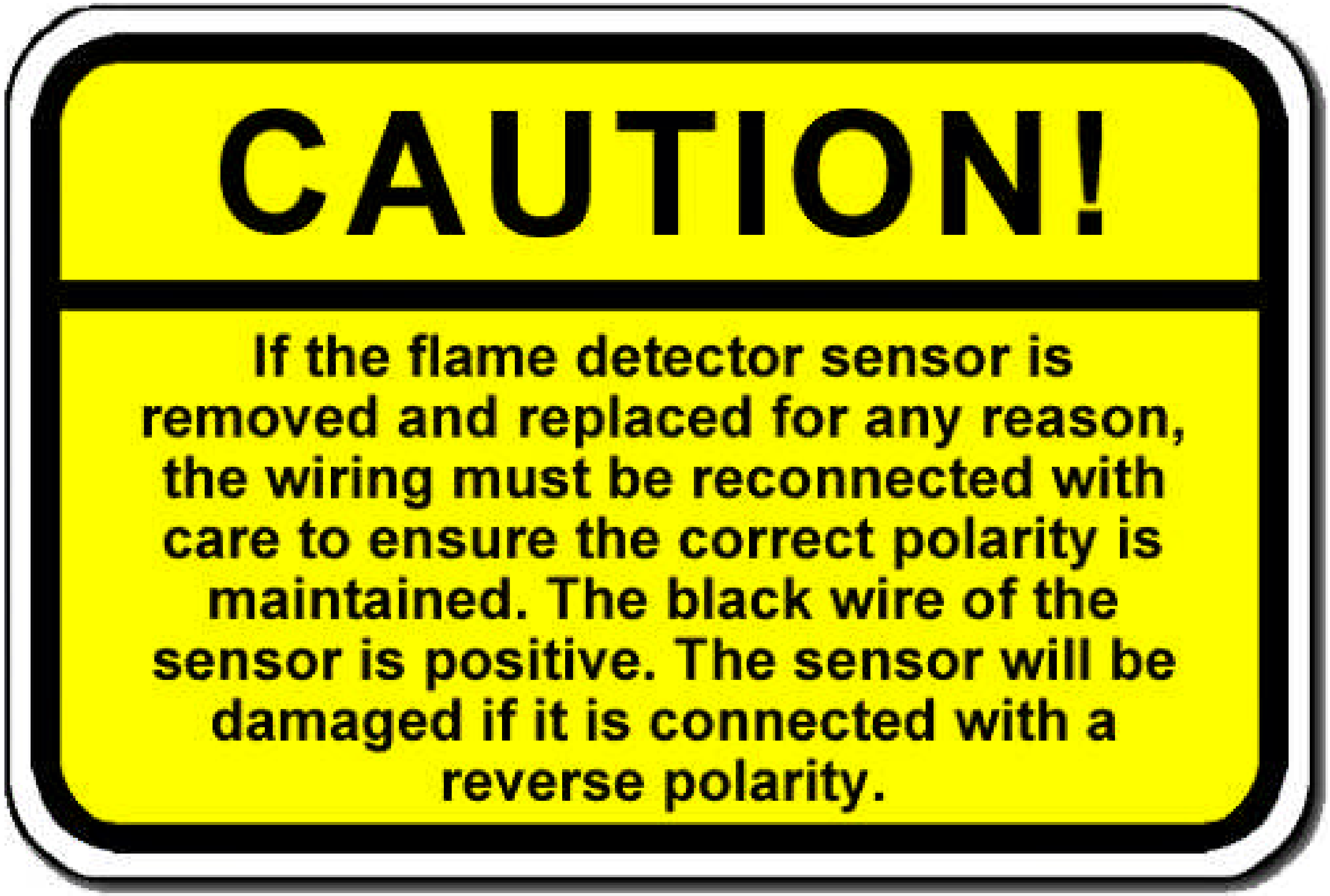
Flame Detector

Flame Detector Test

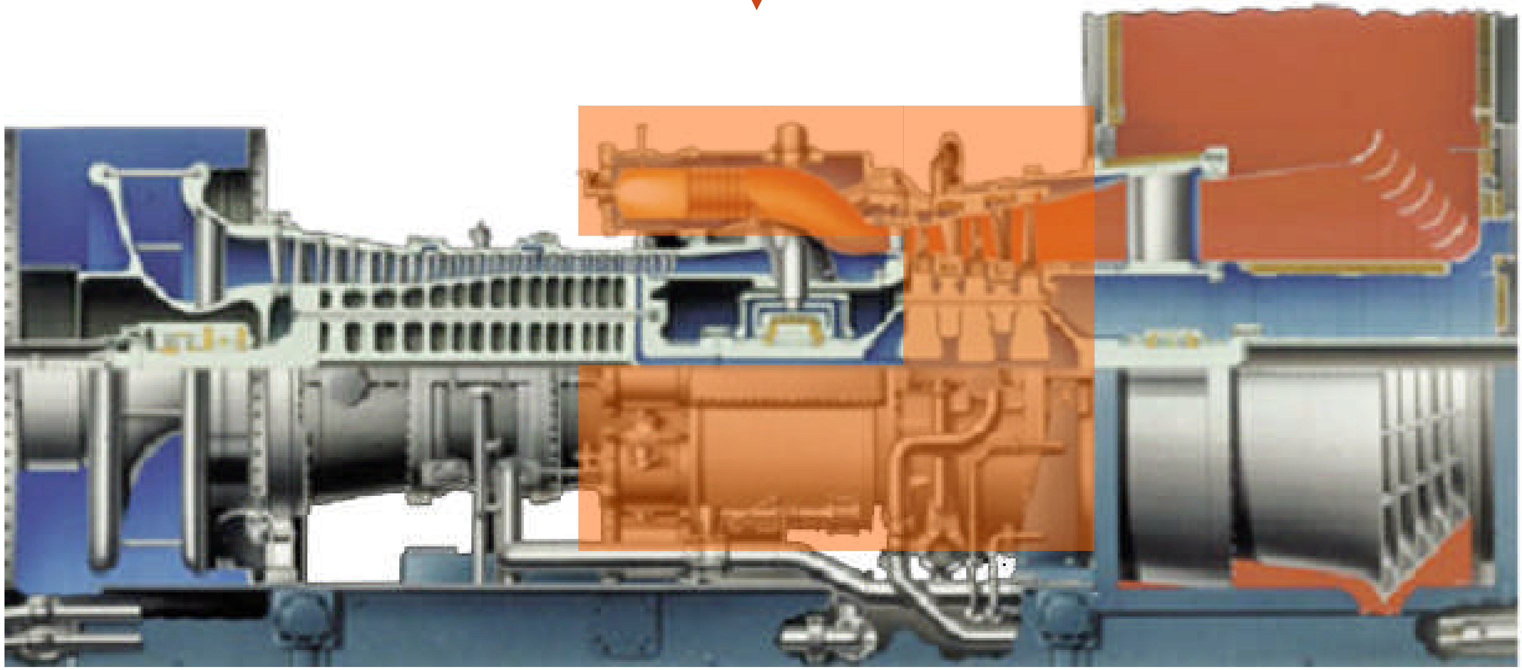


Flame Detector



Gas Turbine Maintenance

Hot gas path parts inspections



GT Hot Gas path inspection – Key elements

Hot Gas Path Inspection

Combustion Inspection Work Scope – Plus:

Key Hardware:

- Nozzles (1,2,3)
- Buckets (1,2,3)
- Stator Shrouds
- IGVs & Bushings
- Compressor Blading (Borescope)

Inspect for:

- Foreign Object Damage
- Oxidation/Corrosion/Erosion
- Cracking
- Cooling Hole Plugging
- Remaining Coating Life
- Nozzle Deflection/Distortion
- Abnormal Deflection/Distortion
- Abnormal Wear
- Missing Hardware
- Clearance Limits

Potential Actions:

Repair/Refurbishment/Replace

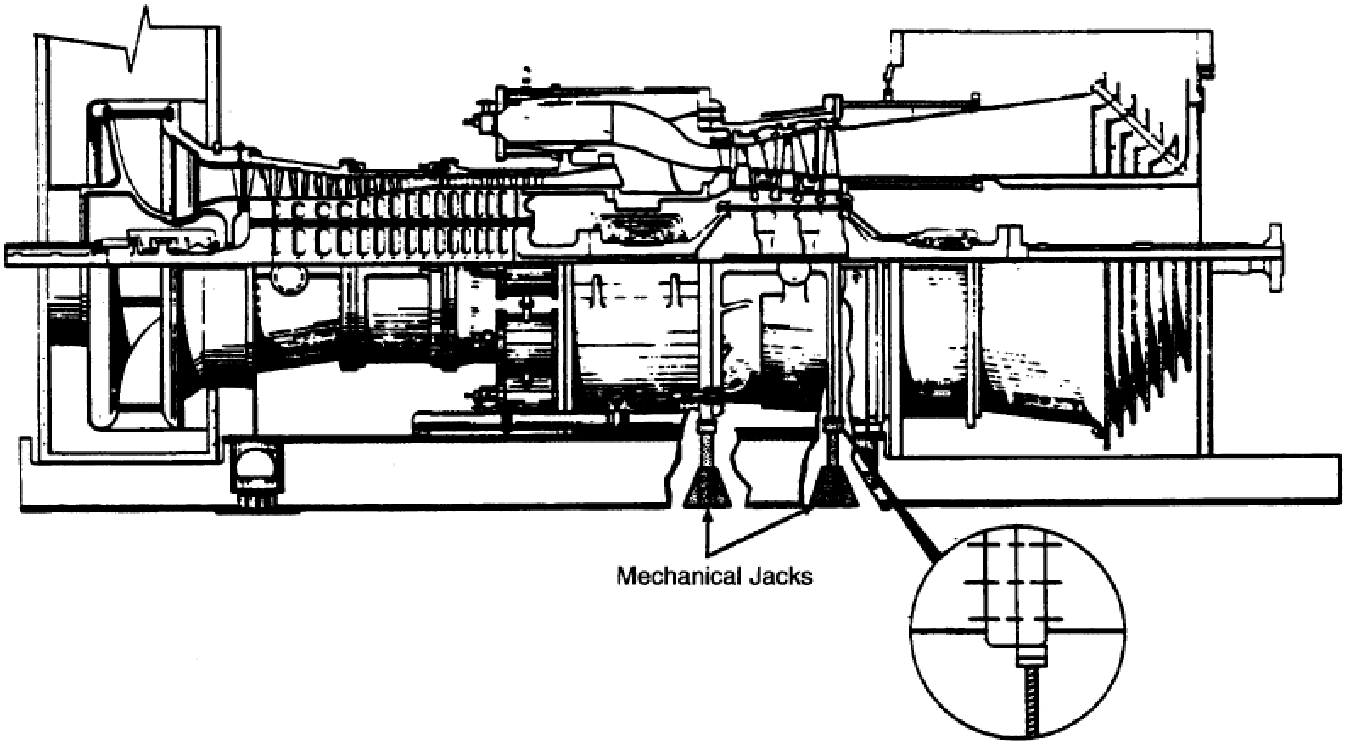
- Nozzles
  - Weld Repair
  - Reposition
  - Recoat
- Buckets
  - Strip & Recoat
  - Weld Repair
  - Blend
  - Creep Life Limit
  - Top Shroud Deflection

Availability of On-Site Spares Is Key to Minimizing downtime

Criteria	Inspection Methods
• Op. & Instr. Manual	• Visual
• TIL's	• LP
• GE Field Engineer	• Borescope

GT Hot Gas path inspection

To carry out an inspection on the hot gas path, it is necessary to remove the upper half casing of the turbine. Before proceding with disassembly, put jacks under the lower half casing, in order to help the upper half casing slide upward when beign opened avoiding subjecting the remaing parts of turbine casing to bending stress.



GT Hot Gas path inspection: Disassembly

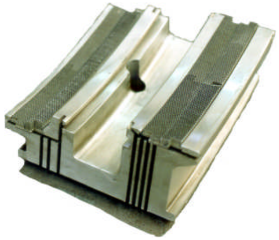
The disassembling procedure to access and remove the parts to be inspected is carried out in the following sequence:

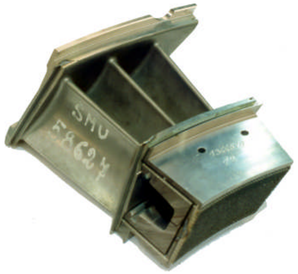
1. Remove turbine compartment side panels. (If applicable).
2. Remove roof attachments. (If applicable)
3. Lift off turbine compartment roof. (If applicable).
4. Remove upper half cooling and sealing air piping.
5. Remove turbine casing wheel-space thermocouple wiring and conduit.
6. Perform combustion inspection disassembly Operations.
7. Establish solid foundation and place mechanical screw jacks under unit casings.
8. Remove upper half turbine casing.
9. Remove upper half first-stage nozzle.
10. Take turbine clearance checks.
11. Remove lower half first-stage nozzle.
12. ……
13. ……

GT Hot Gas path inspection

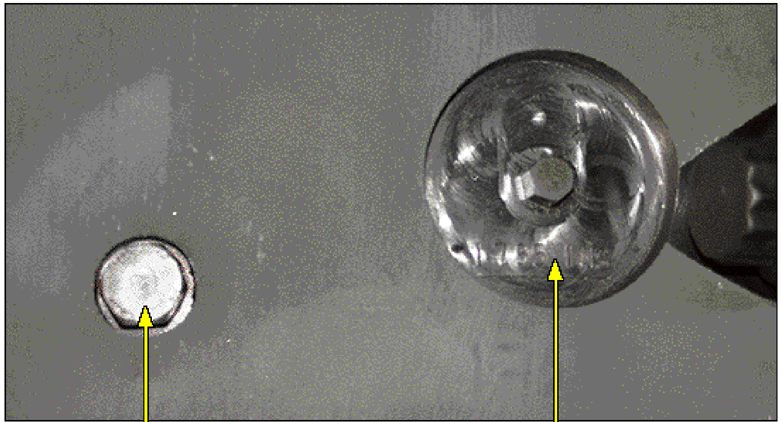
During this inspection the status of the following gas turbine section components should be verified and all necessary repair/substitution is carried out in case of natural gas or light distillate fuel operation:

- Combustion system .
- 1st stage Nozzle.
- 1st stage shrouds.
- 2nd stage Nozzle.
- 2nd stage shrouds.
- 1st and 2nd stage turbine buckets.
- Compressor Blade (Boroscope)



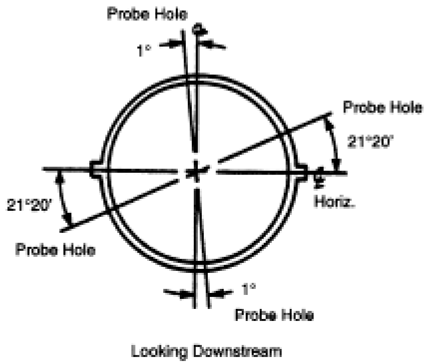


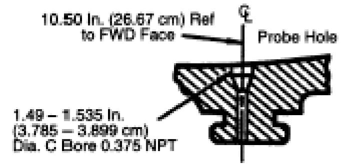
Opening Compressor and Turbine Rotor Position Checks

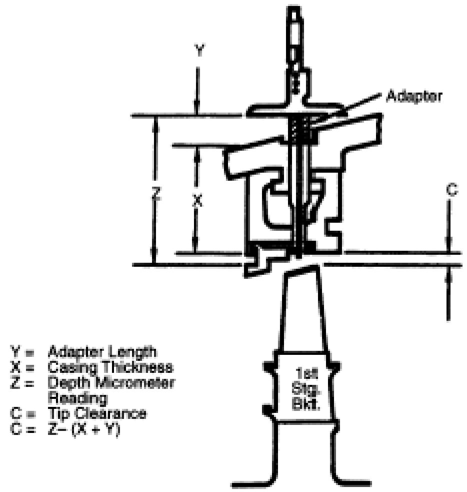


Borescope Hole   Probe Hole

Probe Holes Are Located 10.50 Inches (26.67 cm) From Turbine Casing Forward Flange Face and Are 1.50-Inch (3.81-cm) Counterbores With 0.375-Inch (0.95 cm) NPT Pipe Plugs Installed. The Shroud Probe Hole Is 0.250 Inch (0.635 cm)







Note: X is Approximately 7.40 Inches (18.80 cm)

GT Hot Gas path inspection

1. Inspect first, second and third stage turbine buckets.
2. Inspect first, second and third stage bucket cover-plates.
3. Inspect the Shroud Blocks.
4. Inspect second and third stage diaphragm segments.
5. Inspection the first stage nozzles ellipticity checks.
6. Inspect combustion system components

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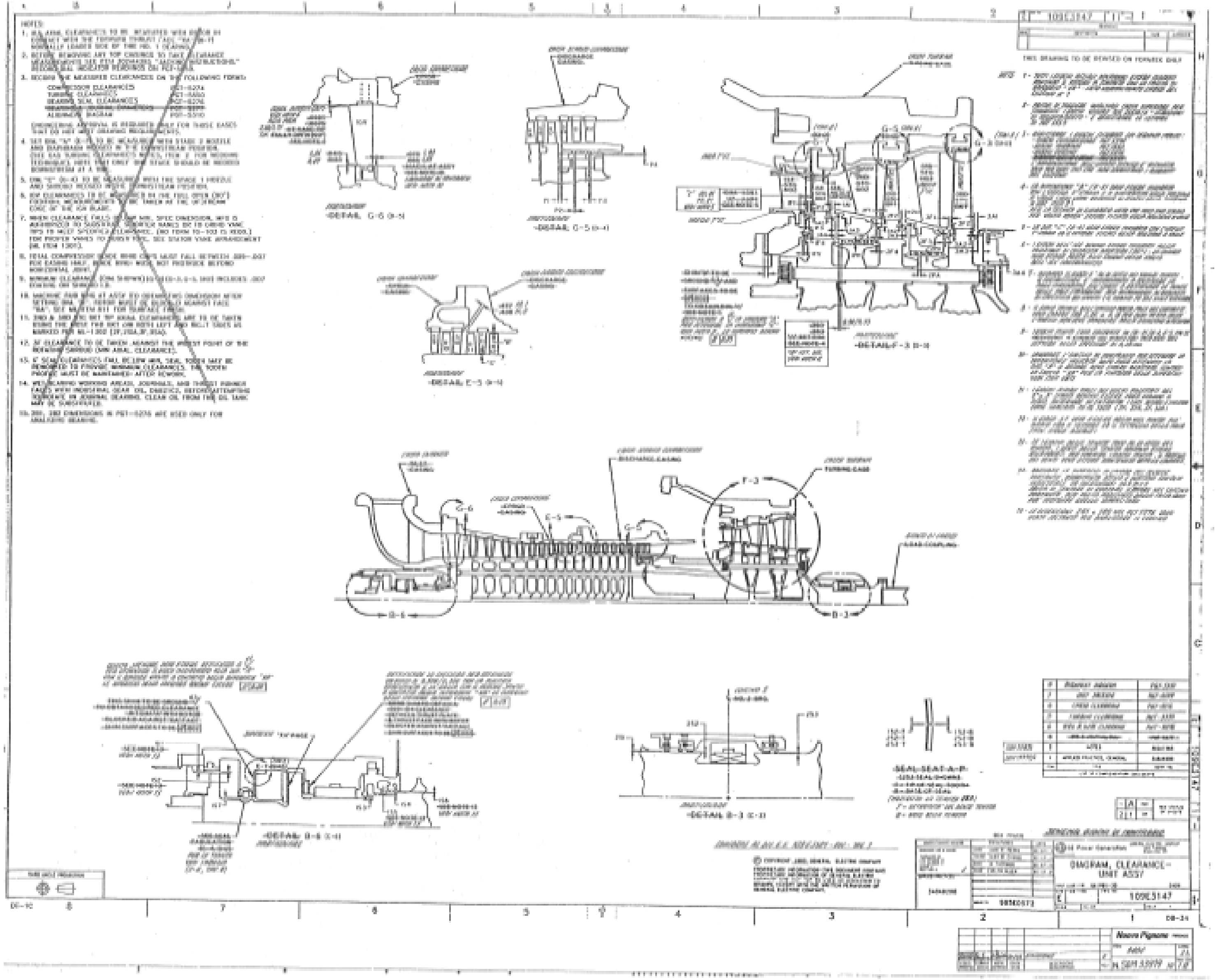
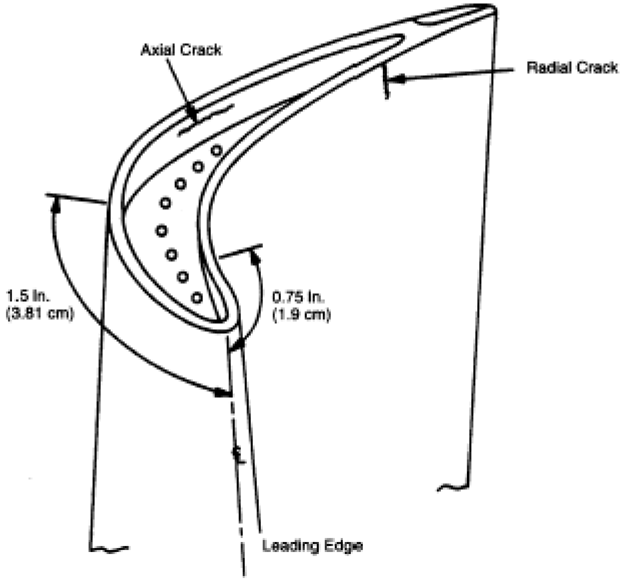
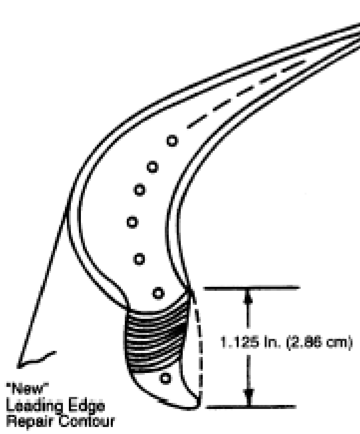
First Stage Nozzle Inspection

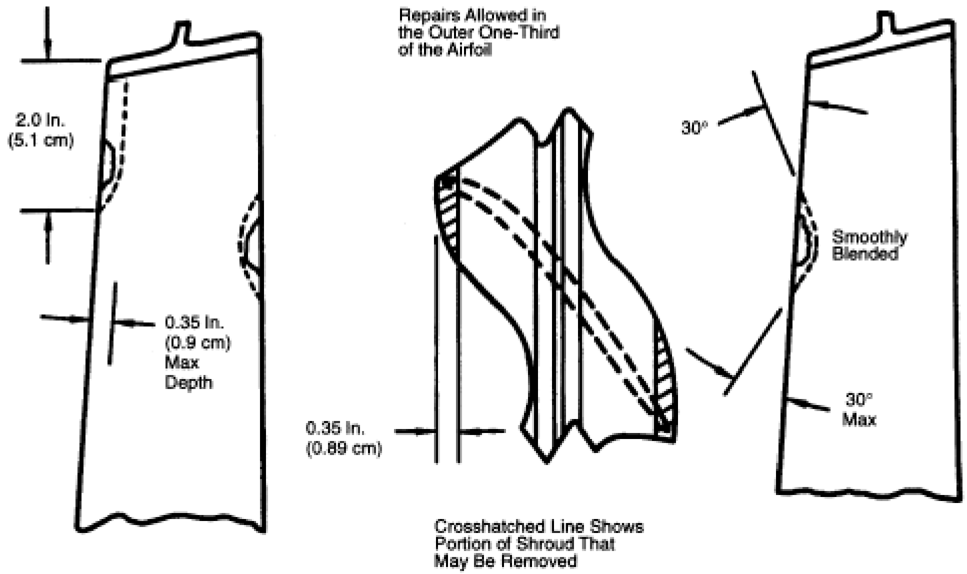
Turbine clearance checks



Turbine Buckets Inspection







Major material removals within 2.9 inches (5.1 cm) of the tip should be accompanied by removal of the tip shroud.

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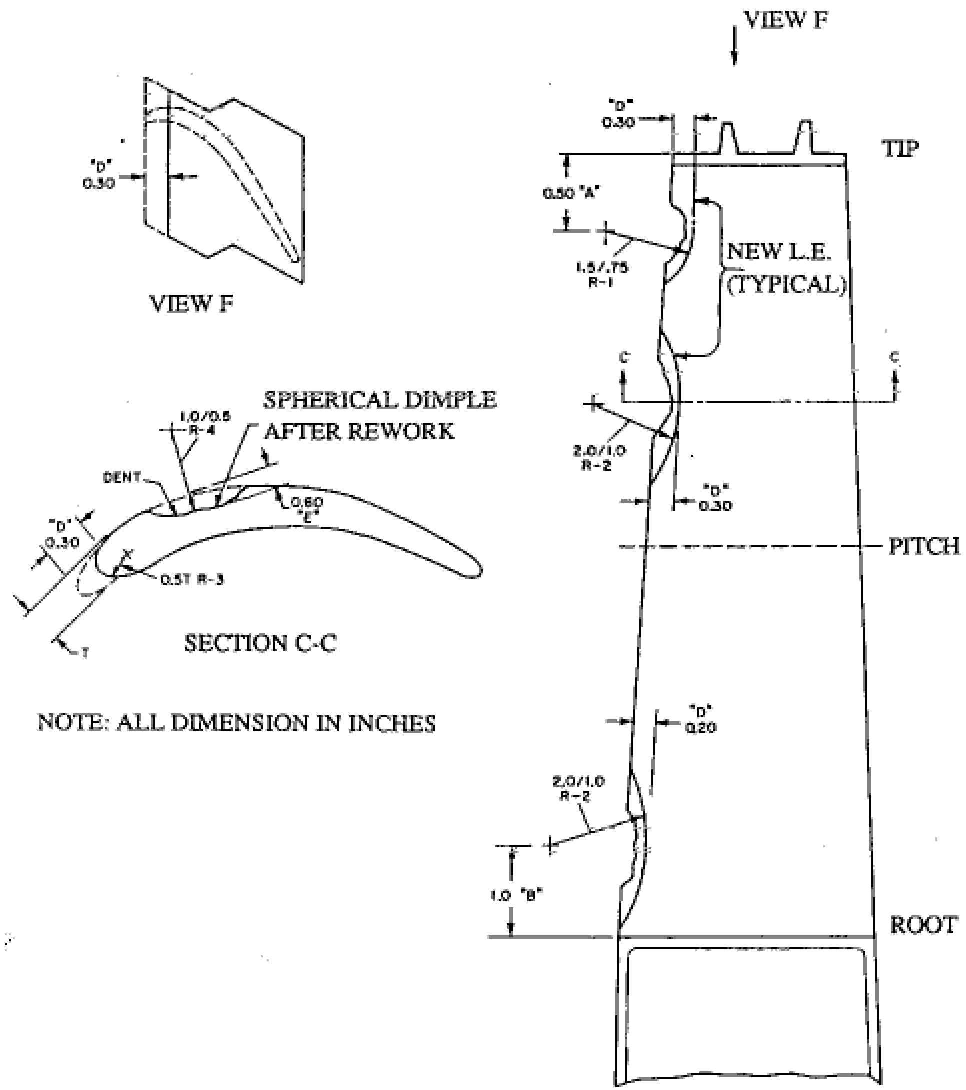
Turbine Buckets Inspection



REPAIR DIMENSIONS MATRIX

SECOND STAGE BUCKET

MS-5002

A	.5 Maximum
R1	1.5/0.75
R2	2.0/1.0
D	.3 Maximum*
R3	.5t
E	.06 Maximum
R4	1.0/0.5

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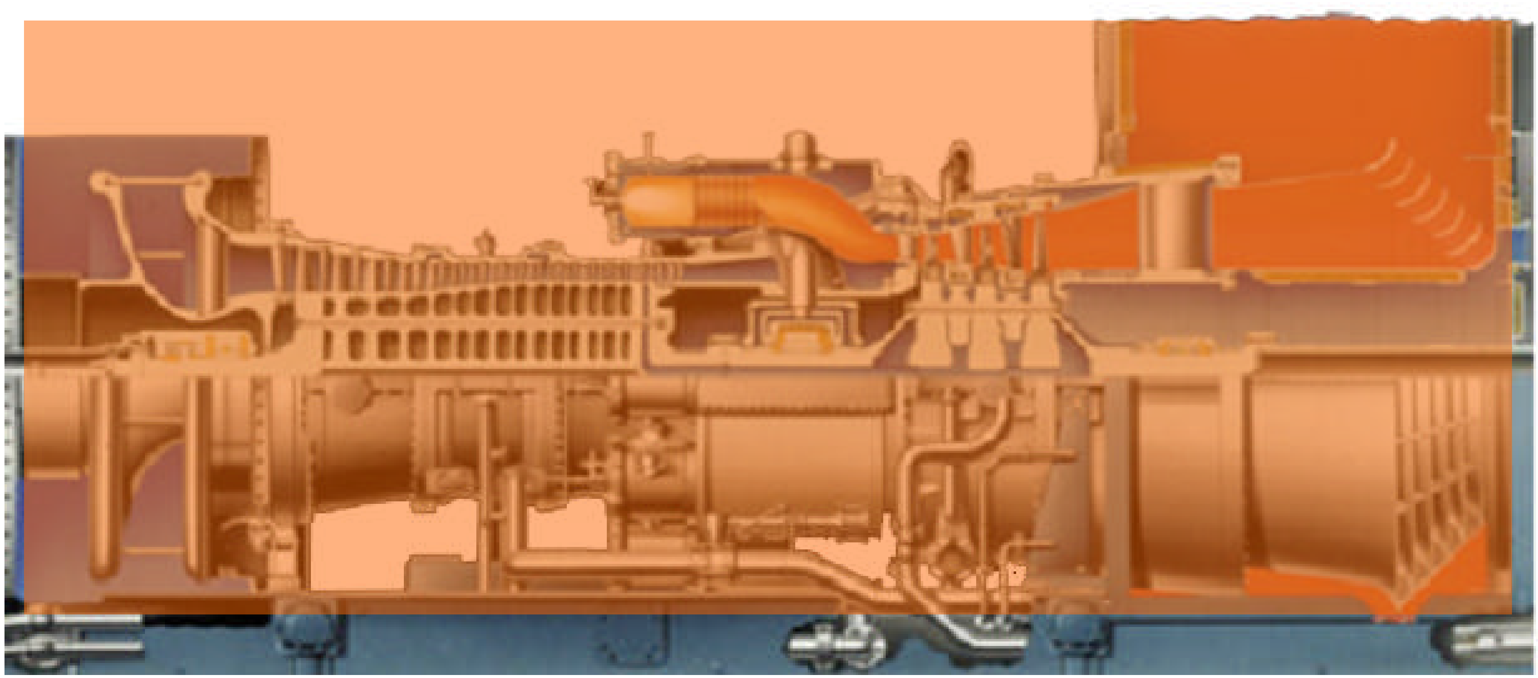
Gas Turbine Maintenance

Major inspection/overhaul



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GT Major inspection – Key elements

Major Inspection

Hot Gas Path Inspection Scope – Plus:

Key Hardware:

- Compressor Blading
- Compressor and Turbine Rotor Dovetails
- Journals and Seal Surfaces
- Bearing, Seals
- Exhaust System

Inspect for:

- Foreign Object Damage
- Oxidation/Corrosion/Erosion
- Cracking
- Leaks
- Abnormal Wear
- Missing Hardware
- Clearance Limits

Potential Actions:

- Repair/Refurbishment/Replace
- Stator Shrouds
  Cracking/Oxidation/Erosion
- Buckets
  Coating Deterioration
  FOD/Rubs/Cracking
  Tip Shroud Deflection
  Creep Life Limit
- Nozzles
  Severe Deterioration
- IGV Bushings
  Wear
- Bearings/Seals
  Scoring/Wear
- Compressor Blades
  Corrosion/Erosion
  Rubs/FOD
- Rotor Inspection

Criteria

- Op. & Instr. Manual
- TIL's
- GE Field Engineer

Inspection Methods

- Visual
- LP
- Ultrasonics
- Borescope

GT Major inspection

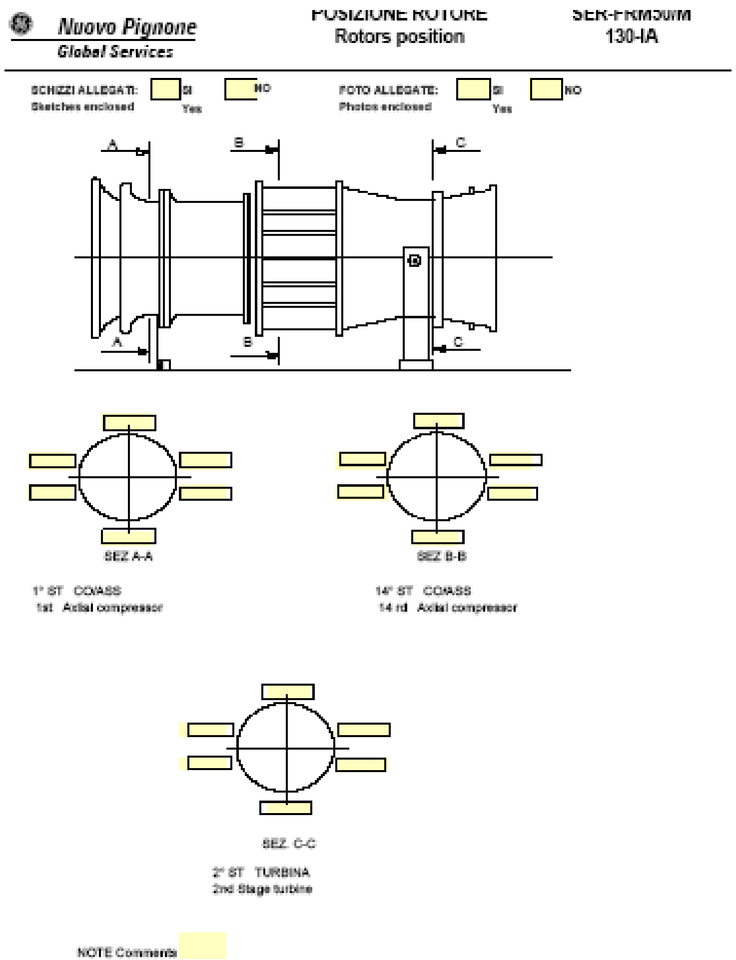
Major inspection/overhaul

The aim of a major inspection is to examine all rotor and stator inner parts, from the filter chamber inlet throughthe exaust system, including also the load gear and the driven machine.

A major inspection must be scheduled and organized in accordance with the recommendations in the maintenaince manual supplied along with the turbine, and with the results of the combustion and hot gas path inspections carried out beforehand.

In order to carry out a major inspection, all upper half casing must be removed,so as to beable to remove the rotors. Before proceeding with disassembly, jacks must be placed under the bottom half casings, so as to ease the upper half casing to be moved upward without subjecting the remain casings to bending stress.

Maintenance forms must be used for record clearances all rotor and stator parts.

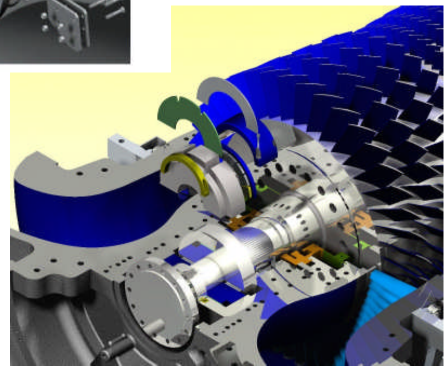


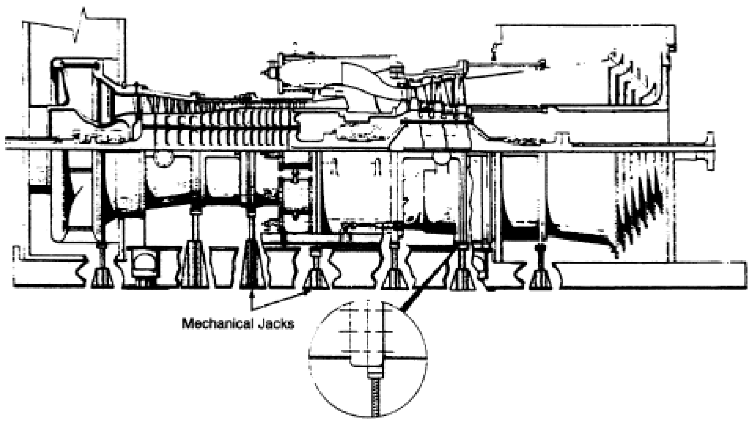
Typical maintenaince forms

GT Major inspection: Disassembly

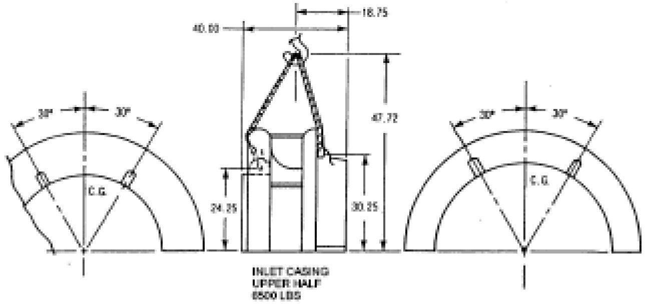
The disassembling procedure to access and remove the parts to be inspected is done in the following sequence:

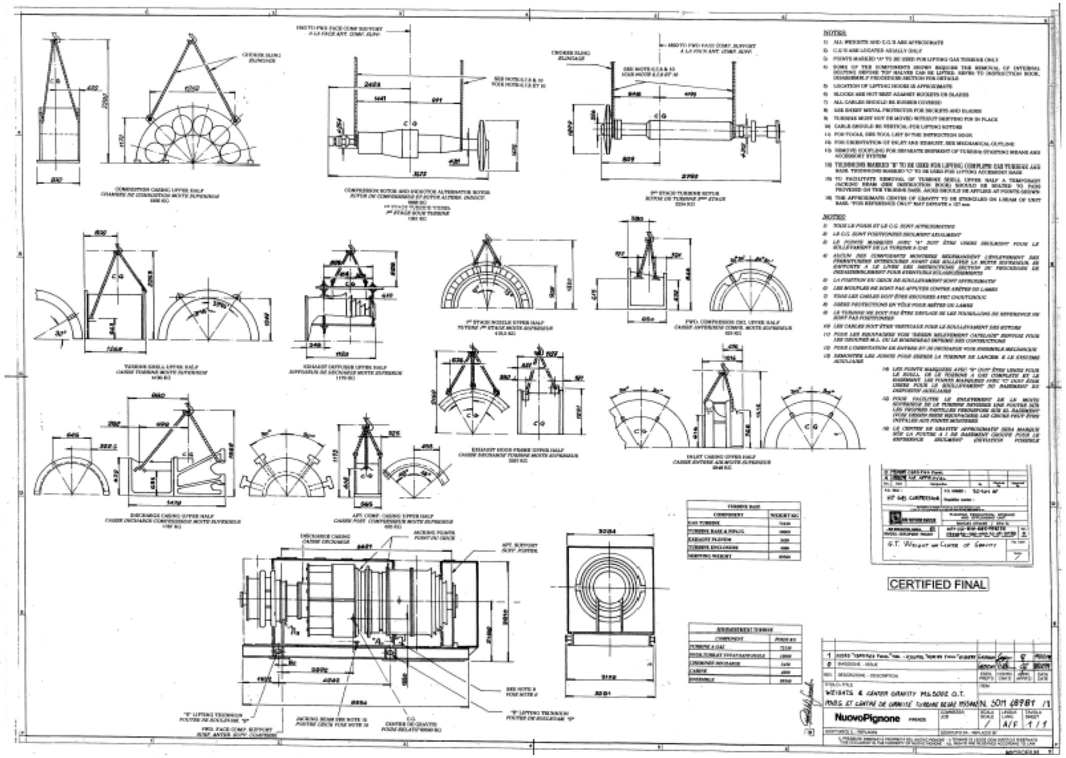
1. Remove accessory and load coupling guard.
2. Remove accessory and load coupling.
3. Check alignment rotor accessory side and load side and record on maintenaince form.
4. Check the rotor positioning after disassembly upper-half casing and record on maintenaince form.
5. Same sequence described for combustion and hot gas path inspection.
6. Remove the Inlet duct Elbow, Exhaust Duct section, Exhaust Insulation pannel, Upper half of Inlet plenum.
7. Fit additional jacks.
8. Disassamble the remaining upper half casingsand cover from bearing blocks.
9. Record clearance between all rotor and statoric parts.
10. Extract rotors.
11. Open the guard on the accessory and load gears.
12. Open casings on the driven machine.

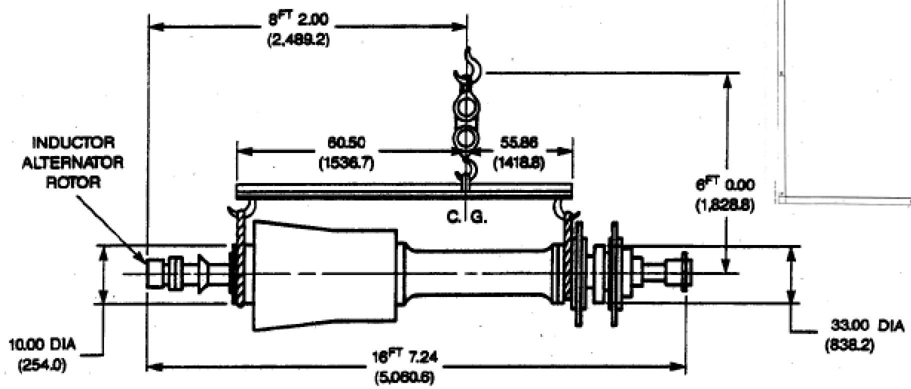




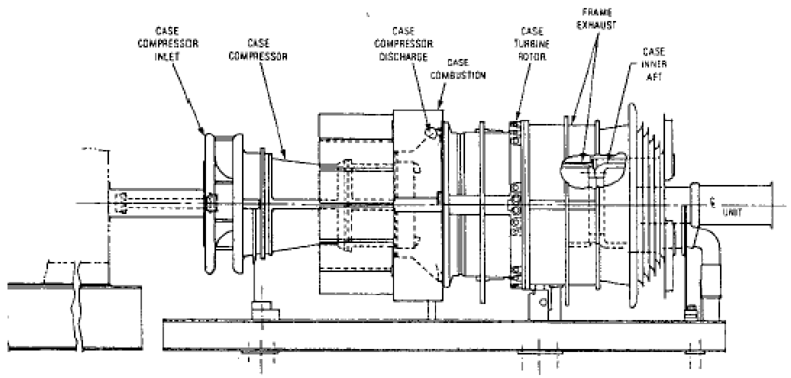
GT Major inspection



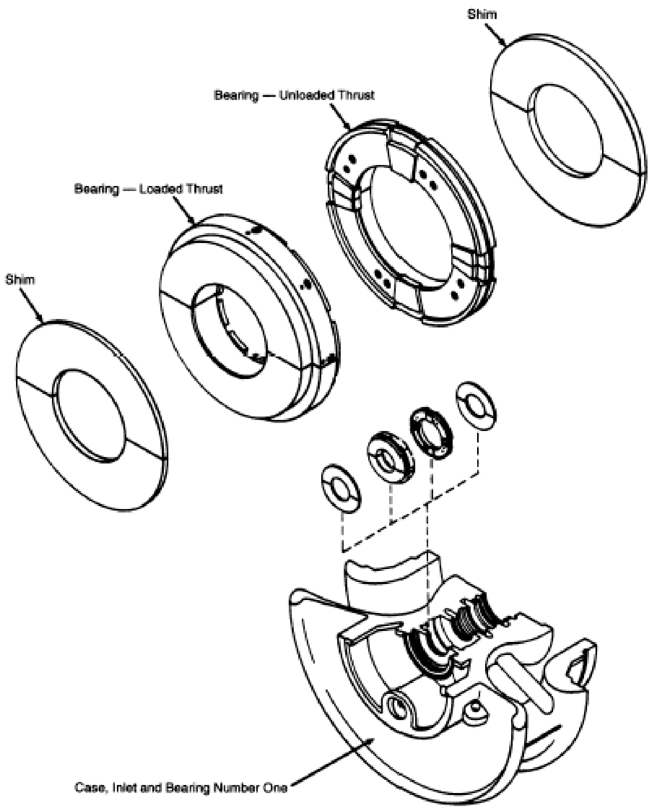


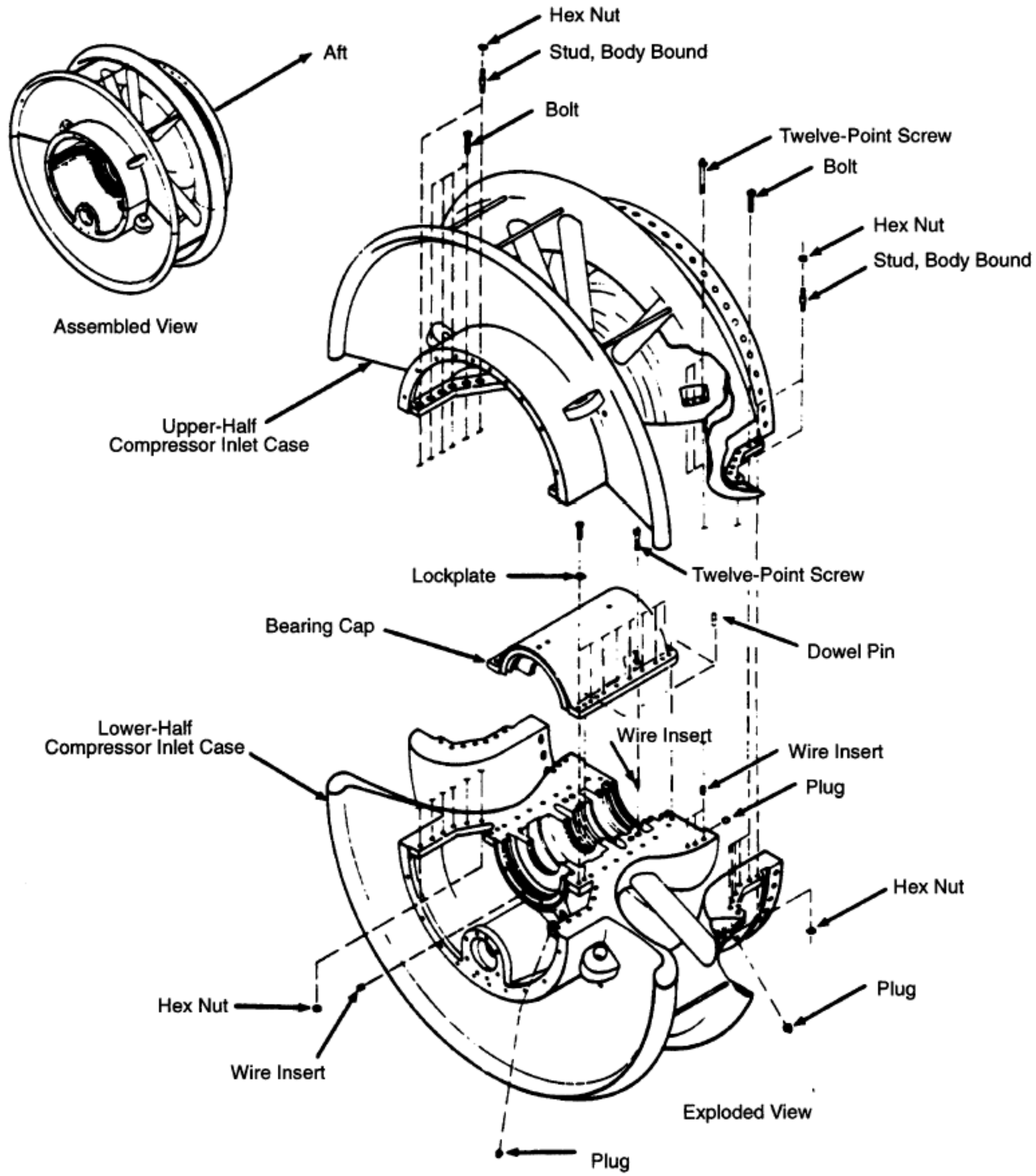


COMP. ROTOR & INDUCTOR ALTERNATOR ROTOR	9,730 LBS.	4413.5 kg
1ST STAGE TURBINE WHEEL	3,420 LBS.	1551.3 kg
2ND STAGE TURBINE WHEEL	4,500 LBS.	2041.2 kg
DISTANCE PIECE	2,150 LBS.	975.2 kg
TOTAL WEIGHT OF COMPLETE ROTOR	19,800 LBS.	8981.1 kg



Tubine Bearing Inspection





Tubine Bearing Inspection

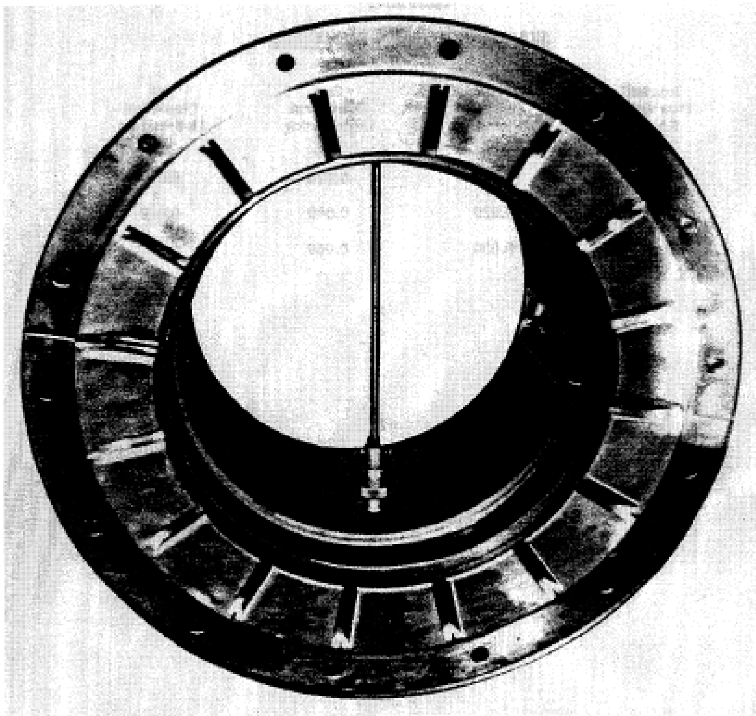
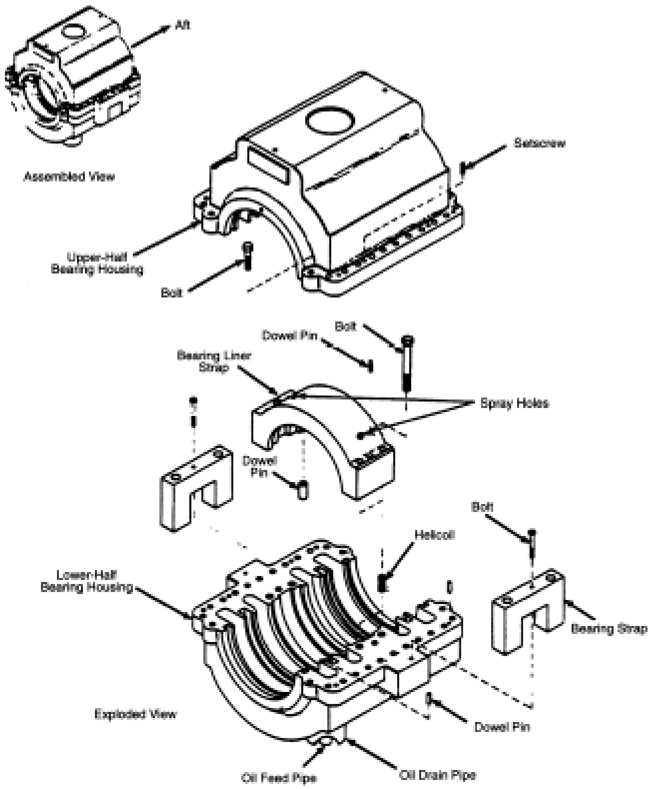


Fig. 7-31 - MEASURING DIAMETER OF No. 1 BEARING



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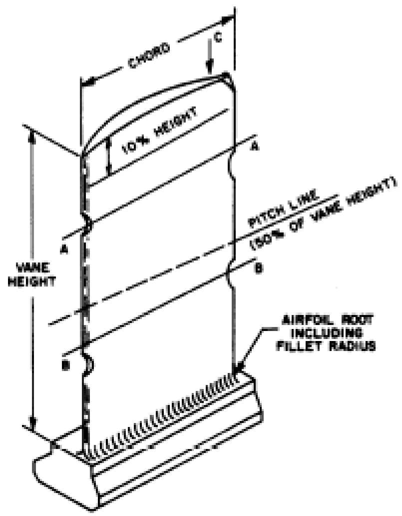
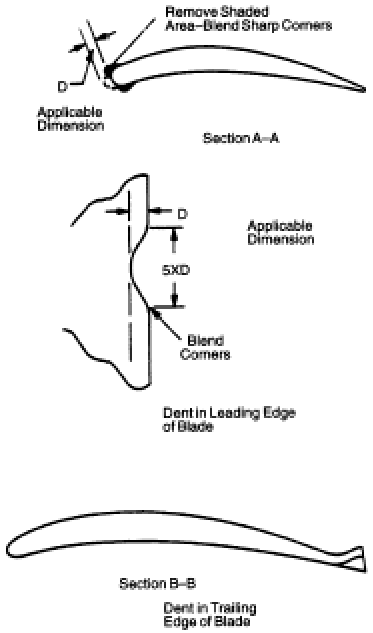
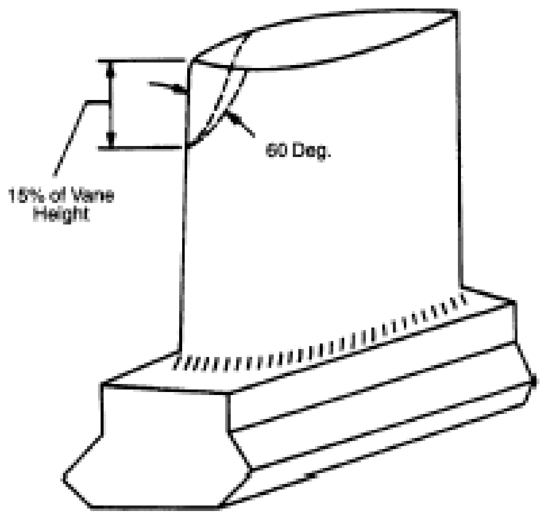
GT Major inspection: Inspection

1. Inspect No. 1, 2 journal bearings and seals.
2. Inspect No. 1 thrust bearings and seals.
3. Clean, inspect compressor rotor, stator blade, inlet guide vanes and compressor and turbine casings.
4. Inspect first, second and third-stage turbine buckets and wheel dovetails.
5. Inspect first, second and third-stage shrouds and diaphragm seals.
6. Perform Hot Gas Path Inspection

Components acceptability criteria



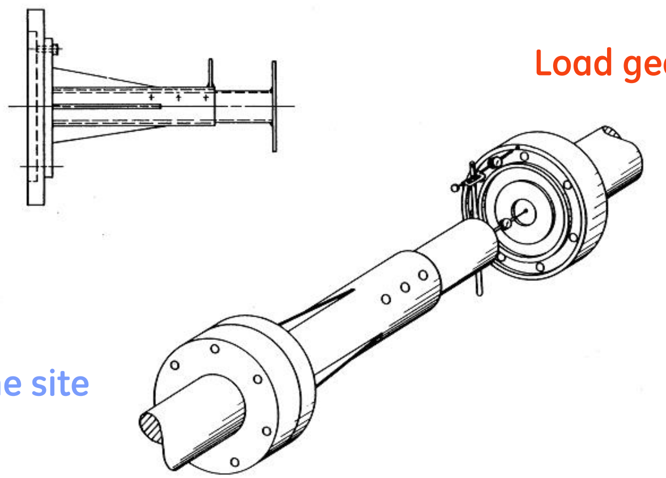




More example components acceptability criteria

Gas Turbine on-site Alignment

Attach the alignment fixture and dial indicators to the turbine shaft and check the turbine to load gear alignment. Refer to the Instructions and Data Alignment-Field, in the Reference Drawings Section of the service manual for alignment specifications.



Nuovo Pignone — Shaft Alignment Specification

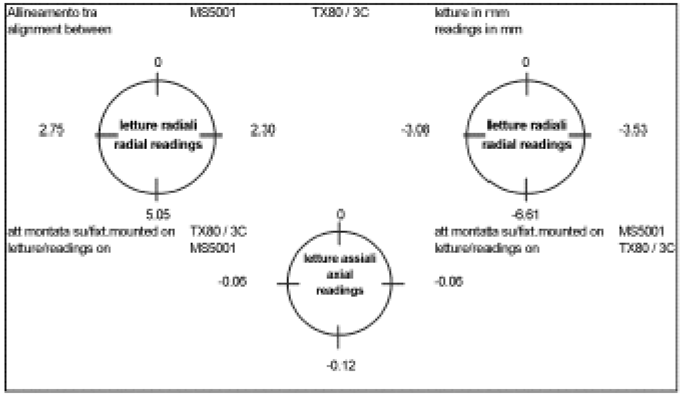
5. LETTURE DEI COMPARATORI- READINGS ON DIAL GAUGES

I valori riportati sono letti guardando il comparatore dal lato del suo fissaggio.

Tolleranze sulle letture: ±1/10 mm per le letture radiali; ± 5/100 mm per le letture assiali.

The reported values are read looking at the dial gauges from its fastening side.

Tolerances on dial gauges: ±1/10 mm on radial readings; ± 5/100 mm on axial readings.



		ITEM
1	REVISED for NEW ALIGNMENT TEMPERATURE	N. SOM6608078/4
0	ISSUED	LINGUA-LANG: I/A — PAGINA-SHEET: 6/7
REV	DESCRIZIONE - DESCRIPTION	

SOSTITUISCE IL - REPLACES

SOSTITUITO DA - REPLACED BY

CHECKS TO BE DONE BEFORE RESTARTING THE TURBINE

WARNING

TAKE CARE THAT NO FOREIGN OBJECTS (TOOLS OR OTHER HARDWARE) ARE FORGOTTEN INSIDE TURBINE.
OTHER CHECKS ARE LISTED IN THE SERVICE MANUAL SECT. 2

Manpower planning and type

The determination of the manpower and the relevant times required to carry out the three levels of inspections depend on the following assumptions :

- Intervention with or without the assistance of the OEM supervision
- Critical spares availability at the plant site
- Repair times in parallel to the substitution activities
- All the necessary standard and OEM's recommended special tooling available
- Skill of personnel
- Scheduled inspection

Spare Parts planning

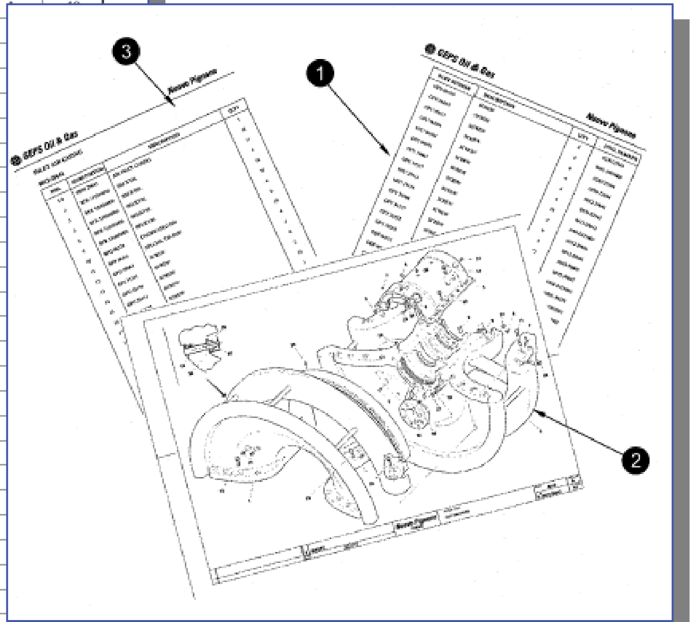
To obtain successful maintenance planning and operating economical results it is very important to consider the gas turbine system tear-down time required to accomplish all the maintenance actions.

Due to the above, a good spare parts planning will reduce the waiting time from disassembly to reassembly sequence period, during which the plant is out of operation.

Spare Parts planning

					SCHEDULED MAINTENANCES			
No. OF PARTS PER UNIT	TOTAL No. OF IDENTICAL PARTS INSTALLED	POS. No.	SECTION	DESCRIPTION	N° 1 Combustion Chamber Inspection	N° 1 Hot Gas Path Inspection	N°1 Major Inspection	Total Q.ty
A	B	C	D	E	L	M	N	P
1	1	**763**	1302	1ST STAGE BUCKETS SET			*	1
1	1	**762**	1302	1ST STAGE COVER PLATES KIT			*	1
1	1	**801**	1401	1ST STG. NOZZLE ASSY			*	1
1	1	**814**	1403	1ST STG.NOZZLE SUPPORT RING ASS.Y			*	1
1	1	**765**	1308	2ND STAGE BUCKETS			*	1
1	1	**822**	1405	2ND STAGE NOZZLE SET (PART.& LEVER)			*	1
1	1	**502**	0801	AIR SEAL			1	1
1	1	**834**	1503	AIR SEAL			1	1
1	1	**366**	0705	BEARING			1	1
2	2	**345**	0703	CAP & LINER	*	*	*	2
4	4	**346**	0703	CAP & LINER	*	*	*	4
6	6	**347**	0703	CAP & LINER	*	*	*	6
1	1	**536**	0805	COLLAR			1	1
12	12	**334**	0701	CROSS FIRE TUBE	*	*	*	
1	1	**759**	1301	IGV SET				
2	2	**743**	1214	INSULATOR	1	1		
1	1	**766**	1308	L.P. COVER PLATE ASS.Y				
1	1	**865**	1508	L.P. THRUST BEARING ASS.Y				
1	1	**823**	1502	LINER BEARING ASSEMBLY				
1	1	**863**	1507	N.P. THRUST BEARING ASS.Y				
1	1	**499**	0801	NO.1 JOURNAL BEARING				
1	1	**833**	1503	NO.3 BEARING				
1	1	**856**	1504	NO.4 BEARING				
6	6	**433**	0705	RADIAL PIN				
1	1	**496**	0797	SHROUD ASSEMBLY KIT, 1 STG., MS5002				
1	1	**497**	0798	SHROUD ASSEMBLY KIT, 2 STG., MS5002				
1	1	**434**	0705	SHROUD INNER SECOND STAGE NOZZLE				
1	1	**435**	0705	SHROUD OUTER SECOND STAGE NOZZLE				
2	2	**741**	1214	SPARK PLUG ASS.Y	1	1		
2	2	**750**	1214	SPARK PLUG CORE ASSY	1	1		
2	2	**337**	0701	SPARK PLUG TUBE	*	*		
4	4	**511**	0801	SPECIAL TIE ROD				
1	1	**758**	1301	STATOR BLADES KIT				
1	1	**872**	1509	STOP PLATE				
1	1	**486**	0717	STRIP PACKING		1		
2	2	**744**	1214	TERMINAL EXTENSION	1	1		
1	1	**394**	0705	THERMAL INSULATION				
4	4	**468**	0709	THERMOCOUPLE				
12	12	**188**	0513	TIP NOZZLE	*	*	*	
12	12	**343**	0702	TRANSITION PIECE	*	*	*	12

SPARE PARTS RECOMMENDED FOR INSPECTIONS



Spare Parts Availability Criteria

SPARE PARTS AVAILABILITY CAN BE OBTAINED IN TWO WAYS

By ordering the critical parts together to the main equipment purchase order

By issuing a mutual Customer -to- OEM After Sales Assistance contract which includes spare parts availability in the OEM's warehouse at any time during the turbine operating life. This type of contracts are variable case by case and have different levels of costs, in function of the required level of service.

THE CHOICE OF THE MOST CONVENIENT SOLUTION DEPENDS ON THE PLANT PROFITABILITY CALCULATION RESULTS, WHICH SHOULD INCLUDE THE FOLLOWING PARAMETERS :

- Daily loss of profit in case of turbounit out of operation
- Similar plants feedback experience
- Overall operating hours of the same gas turbine model club
- OEM's availability and reliability percent average data for the gas turbine model installed

MI Man-Hour Assumptions

Type of inspection	Ref. turbine rating (MW)	Average crew size	8 hour shifts
Combustion inspection	2	2	2
	5	2	2
	10	2	2
	20	4	5
	40	5	10
	>100	6	13
Hot gas path parts	2	2	7
	5	2	7
	10	2	7
	20	6	10
	40	9	15
	>100	10	30
Major inspection	2	4	10
	5	4	14
	10	4	15
	20	8	20
	40	10	35
	>100	11	50

NOTE
Average values. For specific job values refer to the operating and maintenance manuals.

Availability and Reliability Concepts

Availability and reliability data are very important for both gas turbine model selection and maintenance.

These two factors are used to quantify the ratio between not scheduled gas turbine "out of service" times and the potential operating time/year of the gas turbine.

There are many different (but similar) formulas to calculate the above percent values

Availability and Reliability Concepts

Availability is defined as "the probability of being available, independent of whether or not the unit is needed".

Availability = 100 x [PH - (FOH+POH)] / PH   [%]

Reliability is defined as "the probability of not being forced out of service when the unit is needed".

Reliability = 100 x [PH - FOH] / PH   [%]

PH = Sum of the annual operating hours, standby (ready to start) hours, not operating hours due to external causes.

FOH = Forced Outage Hours. Period of time during which the maintenance team is actually working during forced outage.

POH = Planned Outage Hours. Period of time during which the maintenance team is actually working during planned outage.

Estimated repair and replacement cycles

MS5001PA / MS5002C,D Parts

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	4 (CI)	3 (CI) / 4 (CI)(1)
Transition Pieces	CI, HGPI	4 (CI)(2)	2 (HGPI)
Stage 1 Nozzles	HGPI, MI	2 (MI)	2 (HGPI)
Stage 2 Nozzles	HGPI, MI	2 (MI)	2 (HGPI) / 2 (MI)(3)
Stage 1 Shrouds	MI	2 (MI)	2 (MI)
Stage 2 Shrouds	–	2 (MI)	2 (MI)
Stage 1 Bucket	–	1 (MI)(4)	3 (HGPI)
Stage 2 Bucket	–	1 (MI)	3 (HGPI)

Note: Repair/replace cycles reflect current production hardware, unless otherwise noted, and operation in accordance with manufacturer specifications.

CI = Combustion Inspection Interval

HGPI = Hot Gas Path Inspection Interval

MI = Major Inspection Interval

(1) 3 (CI) for non-DLN units, 4 (CI) for DLN units

(2) Repair interval is every 2 (CI)

(3) 2 (HGPI) for MS5001PA, 2 (MI) for MS5002C, D

(4) GE approved repair at 24,000 hours will extend life to 72,000 hours

Estimated repair and replacement cycles

PG6571-81 (6BU) / 6BeV Parts

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	4 (CI)	4 (CI) / 5 (CI)(1)
Caps	CI	4 (CI)	5 (CI)
Transition Pieces	CI	4 (CI)	4 (CI) / 5 (CI)(1)
Fuel Nozzles	CI	2 (CI)	2 (CI) / 3 (CI)(2)
Crossfire Tubes	CI	2 (CI)	2 (CI) / 3 (CI)(2)
Flow Divider (Distillate)	CI	3 (CI)	3 (CI)
Fuel Pump (Distillate)	CI	3 (CI)	3 (CI)
Stage 1 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Shrouds	HGPI	2 (HGPI)	2 (HGPI)
Stage 2 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 1 Bucket	HGPI	3 (HGPI)(3) / 2 (HGPI)(4)	3 (HGPI)
Stage 2 Bucket	HGPI	3 (HGPI)(5)	4 (HGPI)
Stage 3 Bucket	HGPI	3 (HGPI)	4 (HGPI)

Note: Repair/replace cycles reflect current production hardware, unless otherwise noted, and operation in accordance with manufacturer specifications.

CI = Combustion Inspection Interval

HGPI = Hot Gas Path Inspection Interval

(1) 4 (CI) for non-DLN / 5 (CI) for DLN

(2) 2 (CI) for non-DLN / 3 (CI) for DLN

(3) 3 (HGPI) for 6BU with strip & recoat at first HGPI

(4) 2 HGPI for 6BeV

(5) 3 (HGPI) for current design only. Consult your GE Energy representative for replace intervals by part number.

Estimated repair and replacement cycles

PG7001(EA) / PG9001(E) Parts

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	3 (CI) / 5 (CI)(1)	5 (CI)
Caps	CI	3 (CI)	5 (CI)
Transition Pieces	CI	4 (CI) / 6 (CI)(2)	6 (CI)
Fuel Nozzles	CI	2 (CI) / 3 (CI)(3)	3 (CI)
Crossfire Tubes	CI	2 (CI) / 3 (CI)(3)	3 (CI)
Flow Divider (Distillate)	CI	3 (CI)	3 (CI)
Fuel Pump (Distillate)	CI	3 (CI)	3 (CI)
Stage 1 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Shrouds	HGPI	2 (HGPI)	2 (HGPI)
Stage 2 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 1 Bucket	HGPI	3 (HGPI)(4)(5)	3 (HGPI)
Stage 2 Bucket	HGPI	3 (HGPI)(6)	4 (HGPI)
Stage 3 Bucket	HGPI	3 (HGPI)	4 (HGPI)

Note: Repair/replace cycles reflect current production hardware, unless otherwise noted, and operation in accordance with manufacturer specifications.

CI = Combustion Inspection Interval

HGPI = Hot Gas Path Inspection Interval

(1) 3 (CI) for DLN / 5 (CI) for non-DLN

(2) 4 (CI) for DLN / 6 (CI) for non-DLN

(3) 2 (CI) for DLN / 3 (CI) for non-DLN

(4) Strip and Recoat is required at first HGPI to achieve 3 HGPI replace interval for all E-Class.

(5) Uprated 7EA machines (2055 Tfire) require HIP rejuvenation at first HGPI to achieve 3 HGPI replace interval.

(6) 3 (HGPI) interval requires meeting tip shroud engagement criteria at prior HGP repair intervals. Consult your GE Energy representative for details.